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Программа Организации Объединенных Наций по окружающей среде برنامج الأمم المتحدة للبيئة
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GOVERNMENT OF THE

REPUBLIC OF SIERRA LEONE

THIRD NATIONAL COMMUNICATION OF SIERRA LEONE TO THE UNITED NATIONS FRAMEWORK CONVENTION ON CLIMATE CHANGE

Foreword

His Excellency Dr. Ernest Bai Koroma President of the Republic of Sierra Leone

On behalf of the Government and people of the Republic of Sierra Leone it is my great pleasure to present this Third National Communications (TNC) Report of Sierra Leone to the United Framework Convention of Climate Change (UNFCCC)

This report on the Third National Communications of Sierra Leone was prepared by Greenhouse Gas Inventory, Mitigation, Impact and Vulnerability and other Cross-Cutting Task Teams of the Climate Change Project which was implemented under the Meteorological Department(now Agency) of the Ministry of Transport and Aviation in collaboration with the Climate Change Secretariat of the Environment Protection Agency of Sierra Leone with financial support from the Global Environment Facility (GEF) and executed by the United Nations Environment Program (UNEP). The team comprised local experts drawn from the University, Government Departments, Agencies and Ministries as indicated in the Project Document.

As is evident in the report, Green House Gas emissions from key sectors such as Energy, Industries, Agriculture and Other Land Uses (AFOLU) and Waste have been reported on and climate change Mitigation and Adaptation strategies for Sierra Leone were also developed.

The Inventory groups were ably assisted by Mr. Julius Mattai (Inventory Component Consultant) of INTEGEMS CONSULTING Firm and the Local Consultant Professor Ogunlade R. Davidson of the University of Sierra Leone whose input were invaluable in the training of the team members on various components of the project.

This report is also a synthesis of the many country-wide sensitization workshops and training sessions organized by the climate change project office under the Meteorological Agency of the Ministry of Transport and Aviation in collaboration with the Climate Change Secretariat of the Environment Protection Agency of Sierra Leone. The draft report has been reviewed by imminent scientists both locally and internationally and the National Inventory Report (NIR) was reviewed by the Global Support Programme (GSP).

This report will serve as a partial fulfillment of the country's obligations to the United Nations Framework Convention on Climate Change (UNFCCC) as clearly stated in Article 4 and in accordance with Article 12 of the Convention. The Mitigation and Adaptation measures recommended in this report will require both local and international support for their implementation. With the preparation of this report, Sierra Leone will be in the position to further the implementation of it's Nationally Determined Contribution (NDC) and subsequently the Paris Agreement of 2015.

The report will also serve a useful purpose to the Government's decision policy-makers and universities and other relevant stakeholders working generally on climate change issues in the country.

His Excellency Dr. Ernest Bai Koroma

President of theRepublic of Sierra Leone

Preface

This report was compiled by the Climate Change Project of the Meteorological Agency (formerly Department) of the Ministry of Transport and Aviation and with the collaboration of the Climate Change Secretariat of the Environment Protection Agency (EPA) to meet Sierra Leone's obligation to prepare and submit it's Third National communications (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC) by the end of 2017.
The TNC has been prepared in accordance with the UNFCCC IPCC Report guidelines for Parties not included in Annex 1 to the Convention.
The final electronic version of this report will be made available to the general public on the website of EPA-SL (www.epa-sl.gov).
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Executive Summary

Sierra Leone acceded to the United Nations Framework Convention on Climate Change (UNFCCC) in 1995.
Signatories to the Convention are requested to report periodically on their inventory of anthropogenic emissions and removals of greenhouse gases (GHGs) not controlled by the Montreal Protocol as well as details of the activities the Party has undertaken to implement the Convention.
Sierra Leone, which is a non -Annex I Party to the Convention, submitted its Initial National Communication (INC) in November 2005. The INC included a GHG inventory for the reference year 1994 in compliance with Articles 4 and 12 of the UNFCCC and prepared in accordance with the Intergovernmental Panel on Climate Change (IPCC) 1996 *Revised Guidelines for Preparation of National GHG Inventories*. The INC also included vulnerability and adaptation assessments for the agriculture, water, and coastal zone sectors.

The Second National Communication (SNC) included GHG inventories for 2000 -05 (and reference year 2000), prepared using the same 1996 IPCC inventory guidelines. The SNC also assessed climate change impacts for the key sectors of health, human settlements, and tourism. Although not required as a non -Annex I Party, Sierra Leone's SNC also included an assessment of potential mitigation options to reduce GHG emissions without concrete targets that will, just as importantly, improve energy efficiency.

This Third National Communication (TNC) includes GHG inventories for 2005 -10 (and reference year 2005), prepared using the 2006 IPCC inventory guidelines. The TNC also assesses climate change impacts for the key sectors of agriculture, water, health, coastal areas, human settlements, and to some extent tourism. Sierra Leone's TNC also included an assessment of potential mitigation options to reduce GHG emissions again without concrete targets that will, just as importantly, improve energy efficiency. Finally, other activities in support of the Convention, such as awareness raising, a review of the national systematic observation systems, and a technology needs assessment, are also described.

The TNC was implemented by the Ministry of Transport and Aviation's Meteorological Department (now Agency) in collaboration with the Environment Protection Agency (EPA-SL) , which has the responsibility for the submission of the TNC.

National Circumstances

Sierra Leone is located in the Southern-Western part of the bulge of West Africa. It lies between latitudes 7° and 10° N of the equator and between longitude 10 and 13N of the Greenwich Meridian. The country has a surface area of about 71,700 square kilometers (28000 square miles) with a population of about 5 million growing at 2.5% per annum. Approximately 80-90% of the population is in the rural areas. The vast majority of the population subsists in poverty and most of it's people are malnourished as a result of the 10 years civil conflict, EVD outbreak and its' share of natural disasters (flooding and land(mud)) slides. Life expectancy at birth is extremely low (less than 40 years). Infant mortality is among the highest in the world.

Sierra Leone is the smallest Anglophone country in West Africa after Nigeria and Ghana. It is a unitary democratic republic guided by the 1991 Constitution which gives segregated power to the Executive, Legislature and the Judiciary.

Sierra Leone's Growth and Development Agenda, Agenda for Prosperity (A4P) is anchored on the transformation agenda for a green growth development pathway in the President's coordinated programme of economic and social development policy for 2012-2017 and the country's vision up to 2035. Sierra Leone government's climate change policy, National Climate Change Strategy And Action Plan (NCCSAP), Nationally Determined Contributions to the Paris Agreement and the Nationally Appropriate Mitigation Action(NAMA), complements this agenda in it's strive to implement the UNFCCCC.

The INDC of Sierra Leone has three components, one for Mitigation, one related to Adaptation and the third for Loss and Damage consistent with Sierra Leone □s green growth pathway to development.

Approximately 52 percent of the population lived in urban areas in 2001 – an increase of almost 12 percent since 1970. Most Sierra Leoneans (78 percent) live in separate/detached housing. As of 2006 approximately 48 percent of homes had piped water, 30 percent had flush toilets and 70 percent pit latrines, and 40 percent had electrical lighting.
Sierra Leone operates a mixed economic system; where there are state enterprises alongside a viable private sector. The major sectors of the economy are mining, fisheries, tourism, agriculture, and manufacturing, with fisheries mining and tourism, being the leading foreign exchange earners.

Climate

The local climate is tropical, with coastal areas having hot and humid weather and inland areas having a more temperate climate. Sierra Leone lies in the squall line which historically has been evidenced by strong thunder storms and intense rainfall during the rainy season. The more recent ones, September

15th 2016 and August 14th 2017, have created huge infrastructural damages and major loss of life.
Sierra Leone's freshwater resources come from surface sources (rivers and streams) and underground sources (wells and springs) and rainwater harvesting. Groundwater supplies most water demands (approximately 70 percent of production) and represents about 70 percent of the country's exploitable water.
The country's water sources are associated with major rock formations and their interrelationships.

Climate change Impacts

Sierra Leone faces multiple threats from climate change impacts. Level of climate change impacts is mainly defined by geographic span, incidence of poverty, gender and unique ecological zone conditions. The following summarizes the dominant climate change impacts in different sectors in the country.

Agriculture
Change in precipitation and temperature results in yield reduction.
Water
Variable precipitation increases water stress.
Health
Changes increase in risk of malnutrition, poor sanitation, diseases and natural disasters.
Energy
Droughts endanger hydro power supply (60-70% of power)
Cities and Infrastructure
Floods and heat impact, roads and buildings.
Coastal Areas
Rising sea levels increase danger of flooding and coastal erosion.

The National Greenhouse Gas (GHG) inventories

The National Greenhouse Gas (GHG) inventories of emissions by sources and removals by sinks have been carried out to meet Sierra Leone's obligation to the United Nations Framework Convention on Climate change (UNFCCC).

Emission estimates presented in the Inventory have been generated as part of the Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

The inventories were prepared in compliance with Articles 4 and 12 of the UNFCCC and in accordance with the Intergovernmental Panel on Climate Change (IPCC) 2006 Guidelines corresponding to the period 2005 – 2010 with 2005 selected as base year including for the selection of emission factors in all the sectors. The use of the Revised 2006 IPCC guidelines was to ensure that the GHG emission estimates were as much as practicable transparent, complete, consistent and accurate (TCCCA) through time and comparable with those inventories produced in other countries with similar national circumstances.

Gaps, data constraints, methodological problems and uncertainties in compiling the GHG emission estimates.

Not all emission categories of the 2006 Revised Guidelines (IPCC, OECD.IEA, 1997) are reported on in this chapter of the National Communications. This shortcoming is due to the following:

- Absence of activity data and nonoccurrence of categories and sub-categories in the country.
- HFCs have not been considered in this inventory again due to data unavailability.(Hydro fluorocarbons (HFCs),perfluorocarbons (PFCs) and sulphur hexafluoride (SF6), and the indirect GHGs) which contribute to Tropospheric ozone formation.
- Disruptions in the data collection exercise due to exogenous and health risks.

Major social and developmental setbacks

Due to the outbreak of the Ebola Virus Disease-2013-15 (EVD) in Sierra Leone which claimed 3,461 lives by February 2015 (WHO, 2015),the development gains made by Sierra Leone after the country's emergence from a ten-year civil war in 2000 were rudely reversed. However a major setback to the process was the EVD outbreak of which saw the collapse of many activities nationwide.

2.2.1 Emissions and removals of Greenhouse Gases in 2005

The total carbon dioxide emission (CO2) for the year 2005 per fuel type is 20340.20Gg CO_2 equ.
This overall emission from the country was calculated based on total fuel import figures from the Petroleum Agency in Sierra Leone per fuel type. The emissions cover all fuel combustion and electricity generation activities for all sectors countrywide. It is to be noted that the overall import figures are not disaggregated to the various sectors. Hence the difficulty of the sector approach.

The table below show 2005 emission levels for the most important greenhouse gases Sierra Leone.

Table 1.0 National Greenhouse Gas Inventories of Emissions by Sources and Removals by Sinks of all Greenhouse Gases, 2005 (Gg)

GHG Source and Sink Categories	CO_2 Emissions	CO_2 Removals	CH_4	N_20	HFCs	NO_x	CO	NMVOC	SO_2
Total (Net) GHG emissions by source and removal by sinks									
Main activity-Electricity Fuel Combustion Activities	20340.20	NO & NE							
Fuel Combustion Activities – Manufacturing Industries and Construction									
Mobile Combustion (Transport)	NE	NE	NE	NE	NE	NE	NE	NE	NE
Fuel Combustion Activities – Other Sectors	NE	NE	NE	NE	NE	NE	NE	NE	NE
Fugitve emissions	NO	NO	NO	NO	NO	NO	NO	NO	NO
Carbon dioxide transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO
Industrial Processes and Product Use	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Mineral Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cement Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lime Production	0.01014	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chemical Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO
Carbide Use	0.00941	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Industry									

Food Industry									
2D Non-energy Products from Fuels and Solvent Use									
Lubricant Use	NE	NE	NE	NE	NE	NE	NE	NE	NE
Paraffin Wax Use	NE	NE	NE	NE	NE	NE	NE	NE	NE
Solvent Use (Note 8)	NE	NE	NE	NE	NE	NE	NE	NE	NE
Other (Note 9)	NO								
Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO
2F Product Uses as Substitutes for Ozone Depleting substances	NO	NO	NO	NO	NO	NO	NO	NO	NO
2F1Refrigeration and air Conditioning	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F1a Refrigeration and Stationary Air Conditioning	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F1a Mobile air Conditioning	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F3 Fire Protection	NE	NE	NE	NE	NE	NE	NE	NE	NE
2G Other Product Manufacture and Use									
2H Other	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2H2 Food and Beverages Industry (Note 15)									
			0.00	0.00					
			0.00	0.00					
AFOLU									
Livestock	10.42								
Land									

Aggregate sources and non-CO2 Emission sources on land	NE	NE	NE	NE	NE	NE	NE	NE	
Waste									
6.1 Solid Waste Disposal Sites (SWDSs)	151.68		94.9						
6.2 Domestic & Commercial Waste Water	0.00	0.00	7.13	$167.23*10^{-5}$	0.00	0.00	0.00	0.00	
6.3 Industrial Waste Water handling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	
6.4 Human Waste (Indirect N_2O)	NE	NE	NE	NE	NE	NE	NE	NE	NE

Programmes Containing Measures to Facilitate Mitigation of the sources of Greenhouse Gases

Climate Change Mitigation is not a stand-alone problem. It will both affect and be affected by socio-economic policies and by choices involving development, sustainability and equity. Policies to limit net emissions can best promote sustainable development if they are consistent with broader societal objectives. Some mitigation options can even promote benefits far beyond immediate climate change concerns such as reducing health problems, increasing local employment, minimizing air pollution, protecting and enhancing forest and water sheds, minimizing certain subsidies and taxes and accelerating the development and diffusion of energy-efficient technologies.

Mitigation opportunities in the sectors

Many of Sierra Leone's actions which are being implemented have significant sustainable development contributions. These actions, which are mainly a combination of a variety of policies and measures cut across most sectors at different developmental levels. The opportunities in the various sectors are based on submissions made under the Copenhagen Accord of 2009 and Sierra Leone's Nationally Determined Contributions (NDC). The mitigation opportunities are related to the emissions from the economic sectors. The mitigation opportunities are with considerable sustainable development benefits that are existing in the, electricity, transport, AFOLU and the waste sectors. As a mitigation assessment approach for Sierra Leone, a scoping workshop was conducted which involved collecting data and information through stakeholder consultations. As a result, the following options were suggested:

i) Transport Sector

- Lead-Free petrol
- Mass transportation (road and water) for passengers and cargo.
- Creation of pay parking lots
- Enforcement of regular maintenance regulations for vehicles
- Improve the water transport system
- Regulate cost of duty to improve transport (tax incentives)
- Regulation/policies on fuel use and consumptions

ii) Energy/Industrial Sector

- Hydroelectric power
- Switching and promotion for renewable energy (solar energy and LPG)
- Use of other fuels such as ethanol, oxygen etc.
- Development of alternative energy sources such as Bio-fuels (from corn, sugarcanes, rice husk etc.)

iii) Agricultural Sector

- Climate Smart agriculture
- Water management in rice cultivation and maintenance of soils.
- Low amount of organic matter
- Use of rice-straw, compost, biogas residues
- Mineral fertilizers
- Fallow incorporation and mulching

iv) Forestry

- Forestry protection, conservation and increase
- Reforestation, afforestation and Agroforestry
- Urban and Community Forestry.

v) Waste Management Sector

- Waste incineration
- Composting
- Recycling.

Programmes Containing Measures to Facilitate Adaptation to Climate Change

Vulnerability and adaptation assessments were undertaken for four sectors: water resources, agriculture, human health, coastal zones.

Existing & Future Climate in the Sierra Leone

The annual average rainfall in Sierra Leone is 2746 mm based on data from the National Meteorological Office for1961 ‑1990.

Various models were used to assess future climate change scenarios for Sierra Leone, such as the GCM, HADCM, UKTR, ECHAM. The average for 1961-1990 is about 26.7°C. This average is expected to increase by about 7-9 percent by the year 2100.

Climate data for the period 1961 to 1990 were used to construct the climate change scenarios for Sierra Leone. Data were sourced from the following meteorological stations; Lungi, Bonthe, Kabala, Njala and Bo. The parameters used for the study were precipitation (Rainfall) temperature, solar radiation, evaporation etc. It was evident from the study that the coastal areas experienced the heaviest rainfall in the form of Torrential rains. The study period (1961-1990) shows an average annual rainfall of about 2746 mm which varied from 3659 mm at Bonthe in the south to 2618 mm at Kabala in the North

Projection from the 1961-2000 using the ECHAM4 and HDCM2 models for the rainfall values at 2100 are similar to the current climate rainfall amount, whiles the CSIRO-TR and UKTR models show a decrease in rainfall by about 3-10% below the current monthly and annual values. Based on the GCM outputs, solar radiation is expected to decrease by 12% under the HADCM2, by 9% under the UKTR model, and under the CSIRO-TR and ECHAM models by 5%. In Sierra Leone, based on the last reference MAGICC/SCENGEN models, $C0_2$ concentration of about 350 parts per million (PPM) was determined in 1990. Double $C0_2$ concentration levels of about 580ppm are likely to be achieved by 2025 and about 700ppm by 2100. Sea level rise (SLR) scenarios adopted in this study are 0.2m as baseline and 0.5m, 1.0m and 2.0m by 2100.

There is an indication of consistent temperature warming across all seasons and scenarios. The projected 1.5° -2.0° Celsius increase in temperature results in increased evaporation losses, decreased precipitation, and a continuation of rainfall decline.

Vulnerability and adaptation assessments for the Agriculture sector

Agriculture is the largest sector in the economy of Sierra Leone providing employment for over 65 percent of the labour force, and contributing about 35 to 47 percent of the Gross Domestic Product. Rice is the staple food crop in Sierra Leone, grown mainly by small-scale farmers under rain-fed conditions. The impact of climate change is already felt in the country, in changed rainfall patterns, strong winds, thunderstorms, landslides, heat waves, floods, and seasonal drought. Transporting agricultural produce continues to be a challenge in the country; most of the roads in remote areas are impassable during the rainy season.

The crop specific data required for the assessment of the impacts of climate change on agriculture was obtained from the Sierra Leone Agricultural Research Institute (SLARI).

Biophysical models with their scenarios show increasingly negative trends for net rice exports, but an increase toward 2050, with only a slight increase in the area under cultivation for cassava and other roots and tubers.

Groundnut production is shown to increase as a result of expansion in area under production; productivity is shown to decrease, probably due to climate change. Depending on the scenarios, net exports are shown to increase through 2020 and decline thereafter. With decreasing productivity, more area has to be brought under cultivation to meet the demand for groundnut as population increases, while increased land degradation forces farmers to use expensive inputs.

The following specific **adaptation measures** regarding agricultural policy measures are strongly urged to implement in order to mitigate the impact of current and future climate challenges:

- Support the establishment of adequate weather stations around the country in order to provide reliable and adequate weather data that will be useful to properly inform farmers.
- Provide adequate support to the Sierra Leone Agricultural Research Institute as well as Njala University to develop appropriate crop varieties and production practices that will enhance resilience to adverse weather conditions
- Develop and maintain seed banks to provide a variety of seed types that preserve biological diversity and enable farmers to make informed choices.
- Promote innovative and adaptive approaches such as irrigation and water harvesting, to protect farmers from variability in rainfall.
- Make provision for the construction of appropriate roads particularly feeder roads in the rural areas to be able to withstand increasing rainfall.
- Take appropriate by providing appropriate infrastructure, social services and mechanization of agriculture in the rural areas to slow down massive movements of youths into urban areas.
- Mainstream Climate Change into suceeding Agricultural Development Strategies.
- Develop modeling approaches and tools to allow assessment of impacts of climate change on export and domestic crops and meat production. Detailed crop/country/climate specific assessments are required to inform an adaptation programme and policy development.
- Develop regional links to fund and promote plant breeding programmes for common crops.
- Adaptation strategies include the development of crop varieties with increased temperature, drought and pest resistance.
- Review approaches to integrated pest management under climate change.

Vulnerability and adaptation assessments for the Water Resources sector
In Sierra Leone, groundwater supplies most water demands (approximately 80% of production) and represents 84 percent of the country's exploitable water. Existing stream flow data from the Sierra Leone Water Resources Authority indicate that several rivers are in deficit, which results in water lock offs and an overall limit in water supply. The Sewa River, Jong, and Mano areas are under stress. It is not clear whether Sierra Leone has enough storage to provide water supplies to adequately meet all demands during periods of

below average rainfall. The monitoring of wells need some improvements so that the real trends may be better identified. Additionally, more work need to be done with data collection to make it more relevant to user needs.

However, initial analysis of the Freetown Municipality, indicates that increase in population coupled with increased deforestation, after the war in 2000 increased abstraction from the Guma dam could be the main cause of lower water supplies and not so much as a direct result of less rainfall. Significant issues associated with water resources management and vulnerability and the impacts of climate change are likely to present some pressure.

Proposed Elements of a **Water Resources Adaptation Strategy** for Sierra Leone

1. The efficient management of water resources can be facilitated through use of less water, and recycling and reuse of water, facilitated education, voluntary compliance, pricing policies, rationing of water or the imposition of water conservation measures.
2. Improved planning and coordination of the use of the river basin, which may provide solutions to problems of water quality and supply.

3. Use of solar pumps for well water extraction
4. Effective monitoring and management of the watershed which is crucial to monitor the frequency of floods and droughts.
5. Increasing and maintaining investment in hydrological monitoring and water use through a national database.
5. Funding research into adopting a water resources and water supply planning method under climate Change.
6. Developing appropriate modelling tools to assist strategic planning of water resources.
7. Investigate shifting focus from ground water to surface water storage for water supply reducing the reliance on vulnerable coastal aquifers, in terms of quality and quantity with the increased use of surface water reservoirs to maintain supplies.

Vulnerability and adaptation assessments for the Health sector

Increased temperatures are also associated with increased episodes of diarrheal diseases, sea food poisoning, and increases in dangerous pollutants. Threats from higher temperatures may cause greater contact between food and pest species. Warmer seas contribute to toxic algae bloom and increased cases of human shell -fish and reef -fish poisoning. Such cases have been reported in Freetown in July-August 2011 and August 2012. Incidents of high temperature morbidity and mortality are projected to increase.

Due to water shortages, the impact expected on Sierra Leone would be loss of food production and the necessity to import and/or experience food shortages. This may lead to hunger and malnutrition.
The leading causes of death in Sierra Leone are non -communicable diseases – respiratory and lifestyle diseases. Cerebrovascular (stroke) that is susceptible to heat stress is among the leading causes of deaths. The problem could be exacerbated by the design and type of construction materials used in housing. Attention must be given to the design of buildings in order to reduce heat stress.

Pneumonia and Asthma are active among young children and this is an increasing cause for concern. The water and sanitation sectors of the population are dependent on water. Sources that are contaminated have implications in the spread of diseases. Typhoid was associated with and the destruction of pit latrines.

Epidemiological surveillance including entomological surveillance behaviours that promoted proliferation of rival habitats and the promotion of behavioural change are considered priorities. If the health system is efficient the country can adapt.

Proposed Elements of a Health Adaptation Strategy for Sierra Leone Climate change must also be mainstreamed into the health system to recognize the likely impact of vector -borne diseases. Under -financing is a major problem that can affected staff training and the ability to conduct surveillance.

Short -term adaptation strategies for addressing vector -borne diseases include:

- Public education aimed at encouraging individuals to identify and eliminate current breeding sites and the symptoms of malaria/dengue;
- Surveillance in outbreak communities for the purpose of environmental sanitisation;

Priority **Adaptation Projects** for the health sector include:

- Rehabilitation and building of new and modern health facilities at all levels;
- Retro fixing health facilities with solar panels to offset power outages;
- Improve on diagnostics and treatment of kidney stones, eye diseases
- (retina detachment, cataract, cancers e.g breast and lung etc);
- Mainstreaming of health adaptation strategies into the health system;
- Public education;
- Elimination of taxes on electric fans;

- Increased public education in the areas of sanitation and food poisoning;
- Public health inspections for mosquitoes, including pest and rodent eradication;
- Sustainable design standards for housing in areas subjected to high rainfall and strong winds, for example, roofs can reduce heat absorption by painting them white or silver; windows need cross ventilation; and more attention to be paid to the design of settlements;

Others include:

- Better water monitoring and management through improvements at the National Water Resources Authority;
- Improving the capabilities of DMD to warn of hazards;
- Improving data gathering ability and technical support staff of the Meteorological Agency for monitoring and warning of air-borne type diseases;
- More collaboration between research institutions involved in pollution control;
- Support should be given to research institutions involved in environmental related health risks to run as many regional and statistical downscaling models as possible for calibration and inter-comparison purposes;

Vulnerability and adaptation assessments for the Coastal Resources and Human Settlements and Tourism sectors

The most important measure for adapting to sea-level rise involves a development of setback guidelines. This could be related to the local risk of inundation from present and future storm events (i.e., site specific). Setbacks for structures on rocky coasts where there is storm-deposited debris should be determined by the position of the debris ridge formed by sandy and rocky debris accumulated over the past four millennia. Destroying this ridge for construction materials exposes communities and buildings behind the ridge to increased vulnerability from inundation and damage from moving debris.

The vulnerability of communities such as Kroobay, Moa wharf to extreme weather events and the susceptibility of escape routes to flooding require a major effort to re-engineer other arterial roads at low elevation as all-weather highways.

If the tourist industry is to survive through 2050, despite sea-level rise, increased ocean acidity and sea-surface temperatures, then identification of suitable offshore sand deposits should commence now to avoid the growth of unregulated sand replenishment schemes.

Continuing research is required on perfecting setback guidelines for Integrated Coastal Zone Management; identification of offshore carbonate sand deposits for beach nourishment; expansion of the programme of co -operative for fisher -folks; and a combination of conventional and satellite -based monitoring of changes in the health of coastal ecosystems.

Impacts of Climate Change induced Sea Level

The main limiting factor for making accurate assessment of the Vulnerability of the coastal sea level rise has been the lack of data of the topography of the coastal area to the desired accuracy (i.e. to allow the delineation of the appropriate contour line). Some sections of the coast, particularly the urban centres of the capital, Freetown and coastal towns of Kambia, Bonthe Sherbro Island do not have these data. As much as possible data was derived from limited information on the survey beach marks and surveys of roads within the coastal areas. The elimination of the area outside the risk zone was assisted by the availability of maps showing the 30m contour.

Shoreline Recession

Climate Change is expected to impact Sierra Leone's sandy beaches in two ways: -

(1) The rise in sea levels expected from Climate Change would accelerate the rate of recession of sandy shores.
(2) Increases in littoral transport capacity arising from increases in the intensity and duration of storms.

Also, sea level rise can affect coastal structures such as the jetties along the coastline.

Flooding and inundation affect some coastal segments of the Freetown peninsular (i.e. bays, estuaries and beaches). Sea level rise has the effect of augmenting a decrease in the quality and quantity of ground water resources otherwise caused by man's activities. The estimated population along the coastal areas at risk for 1m rise of sea level is about 2,315,860.

If no action is taken on sea level rise, a total of 26.4km square is estimated to be lost and areas such as the northern and southern areas are vulnerable. Potential adaptation measures to address management of the coastal zone in Sierra Leone are: -

- Re -engineer other arterial roads at low elevation as all -weather highways.
- Delineation of flood and erosion hazardous areas.
- Improvement of the quality of topographic data for the coastal zone.
- Education and Research

Although it is generally agreed that the incidence of severe weather, there is controversy over the likelihood of a general increase in storm frequency. Thus, it was assumed that there would be no increase in storm frequency or severity over the rest of the century.

The impacts of these processes on the various kinds of coastline of Sierra Leone were assessed. On beaches, short term erosion are largely governed by the incidence of storms. Over longer periods, sea level rise will cause progressive retreat. Hard engineered structures such as sea-walls will probably lead to eventual disappearance of any beaches in front of them. Offshore breakwaters will be more useful in retaining near-shore sand supplies. On cliffs and rocky coasts, sea-level rise will bring the cliff top closer to sea-level and increase the frequency of overtopping of the cliff by storm waves and rock debris, including large boulders. Recession will be greatest for soft-rock cliffs, whereas fractured hard rock cliffs will be more prone to sudden collapse, as indicated in the in the Sierra Leonean examples.

Wetlands present a particular problem due to their proximity to sea-level and the micro-tidal regime around Sierra Leone. Small changes in sea-level will prompt progressive retreat and migration of wetland eco-zones, unless vertical accumulation rates of wetland debris keep up with sea-level rise. Most of the wetlands of the coast of Sierra Leone are fronted by a narrow beach which will retreat over the wetland, driven by storms and sea level rise. No data on the vertical accumulation rate of wetland sediments is available for Sierra Leone.

These impacts are likely to be exacerbated, and even overshadowed, by non-climate change factors, such as deforestation, increasing riverine floods from destruction of forest, industrial farming and from poor farming practices, leading to increased near-shore sedimentation and turbidity, increased chemical pollutants from agriculture and industrial wastes, and from increasing coastal population growth.

Cross Cutting Sectors

Elements of a **Tourism Adaptation Strategy** for Sierra Leone

- Raise stakeholder awareness of the workings of both tourism and environment;
- Stakeholder identification of detailed programme and projects;
- Provide more varied visitor attractions to a) put less pressure on existing natural resources and b) Stimulate more visitors;
- Reflect social and environmental costs in the price of tourism products;
- Implement infrastructural changes to protect the coastal environment, e.g; groynes, and levees, reforestation, and coastal zone management;
- Implement education and sensitization programs;
- Intensify community tourism activities; and
- Increase urban tourism.

Impacts of Climate Change on Fisheries

In assessing the impacts of climate change on productivity in Sierra Leone, the effects of temperature on annual productivity of riverine fisheries resources are evaluated on the basis of the average stream width of 250 meters for the Rokel River, the biogenic capacity of the stream, the annual water temperature, the alkalinity/acidity of the water, and the type of fish population present in the river.

Productivity of the riverine fisheries of the Rokel River is projected to increase under all climate change model scenarios. The estimated productivity of the Rokel River under the current (1961-1990) climate is 228 tons per kilometer (tons/km) reach of the river.

All the climate change model scenarios projected an increase in the productivity of the river. The highest increase in productivity is projected by the HADLEY 2 model scenario and it ranges from 3% (i.e. 236 tons per Km) increase by 2025 to about 8% (i.e. 248 tons/km) increase by 2100. The projections based on CSIRA model is lowest of all the models considered for this study. The projected productivity under the CSIRA varies from about 2% (i.e. 234 ton/km) increase in 2025 to about 6% (i.e. 243 tons/km) increase in 2100. Commercial shrimp yield was estimated for current climate for the average period 1961 to 1990 and for simulated climate change to 2100 based on the model output for the GCM models (Hardly 2, UKMOTR, CSIRA and ECHAM 4). The stabilized commercial shrimp yield (SCSY) under current climate with annual temperature of about 26.7°c is 71.5kg/ha. Simulation based on the warming of the atmosphere by 2075 to about 28.7° C under the HADLEY2, 28.3°C under the UKMOTR, 28.1°C under CSIRA and 28.4°C under the ECHAM4 models shows increases from current climate.

The proposed **adaptation measures** for the fisheries sector are: -

- Promotion of effective formulation and implementation of the fisheries strategic management plan.
- Effective protection of spawning sites and fishing nursery areas.
- Promotion of research and development.
- Promotion of monitoring, control and surveillance of fishing grounds and fish stocks for sustainable exploitation.
- Promotion of climate change related education and awareness programs.
- Provision of financial resources and institutional capacity.

Impact of Climate change on Vegetation Cover

Under current climate, the land in Sierra Leone has the potential land cover of about 6% **tropical wet forest**, 49% **tropical moist forest**, 21% **sub-tropical wet forest**, and 23% **sub-tropical moist forest**. The overall indications from the Holdrige Life Zone classification analysis are that under an equilibrium climate, the potential land cover of Sierra Leone as projected by the GCM outputs used in this study predicted 66% (HADC), 55% (UKTR), 66% (CSIRO) and 81% (ECHAM) **tropical dry forest** and 30% (HADC), 55% (UKTR), 26% (CSIRO) and 13% (ECHAM) **tropical very dry forest** categories as a result of the projected decrease in precipitation ((figure 2) and associated increase in bio-temperature (Figure 3) by year 2100.
Basically, as a result of climate change, 60% of the country will be under **tropical dry forest**, 24% under **tropical very dry forest**, and 12% cover under **sub-tropical moist forest** particularly in the south and east of the Country. This is the reverse of the current situation and indicates a northward shift in the vegetation i.e. from **tropical rain forest** to **tropical dry forest.**

Potential adaptation measures will include silvicultural interventions such as appropriate management, for example, adjusting planting and harvesting dates, switching to more drought-resistant species, refining and liberation thinning.

Climate change research and systematic observation systems in Sierra Leone

Under the INC, SNC and NAPA projects, an initial assessment of Sierra Leone's systematic observation systems was conducted in conjunction with the national Meteorological Agency. This assessment comprised of interviews with key personnel, as well as visits to a number of locations where systematic observation systems are located.

The assessment focused on the needs and the requirements of the Meteorological Services, with a view to making recommendations for the improvement of the observation systems. More specifically, the following activities were carried out:

(i) A detailed assessment of the coastal, marine, and hydro meteorological systematic observation systems in Sierra Leone, describing: the types and locations of the equipment; the agencies responsible for the maintenance of the equipment; the scope of climate related data stored, including climate variables observed; the years for which data is available and frequency of data collection.
(ii) An assessment of the current coastal, marine, and hydro meteorological systematic observations systems in Sierra Leone.
(iii) An identification of the technological and capacity building requirements for the upgrade and improvements of the current systematic observation systems.

In order to achieve the goals and targets of the International Community on Research and systematic Observations, efforts should be made to address these issues of Research and Observations. Climate and Climate Change studies and assessments are highly dependent on reliable meteorological, hydrological and environmental data and information. Hence the need for representative network of systematic observations i.e. ground based data, satellite and communications networks. To achieve this, government as a priority should improve without delay the current conditions of service of its workers with a view to attracting qualified personnel into the service.

Priority activities/**project ideas** for the improvement of systematic observations of Sierra Leone include: -

- Strengthening of the climate data base of all institutions in the country, provide up to date computer facilities and train experts in the input and storage of climate related data.
- Providing automatic recording equipment and instruments for continuous recording of meteorological, hydrological and climatological elements and phenomena.
- Rehabilitation and expansion of meteorological stations for the collection and monitoring of all categories of data.
- Capacity building in human resource in the Meteorological Agency should be addressed in order to meet the present and future challenges.
- Education and sensitization of the public on climate change issues.
- Strengthening of the National Climate Change Secretariat and Committee (NCCC) to be able to advise the Government on climate change matters appropriately.
- Intensification of research on climate change in Sierra Leone.
- Collaboration with national and international institutions that are in the field of research in climate change.

Technology Needs Assessment

The technology needs assessment process consisted of a series of expert workshops with key sectoral experts present to discuss issues relating to technology in Sierra Leone. The first workshop focused on mitigation and energy issues, while the second workshop looked at adaptation issues as they relate to the coastal zone and water sectors in Sierra Leone. Both workshops used the SNC of Sierra Leone as the document of reference.

A number of issues were considered with regards to criteria for the transfer and development of technologies for mitigation for Sierra Leone. These included the overall integration with the current energy policy, and the linkage to development goals. In order for a technology to be suitable for Sierra Leone, it was agreed there a number of key criteria which have to be met. These are:

- Affordability and low cost,
- Environmental and economic impact,

- Social acceptability, and
- Job creation potential.

A number of mitigation technology **projects**/options were identified:
- Natural gas technology for electricity production, especially for the mining industries;
- Methane extraction from waste landfills for electricity production;
- Renewable energy technologies including wind, small -scale hydro, cogeneration and biomass, solar.

Adaptation technologies were considered for the coastal zone and water resources sectors. A number of issues were considered when criteria for the transfer and development of technologies for adaptation were considered. Stakeholder consultations and expert judgment were used to determine the criteria. It was noted that technologies for adaptation should be: cost effective, proven, flexible, aid in vulnerability reduction, and easy to use. Technologies for adaptation should also look at technologies in the broadest sense.

For improving coastal zone management, the following technologies were identified:

- Beach protection measures such as groynes and revetments;
- Reinstatement of the tidal gauge network (for obtaining data to feed into the Geographic Information System (GIS) and aid in planning and project designs, thus ensuring vulnerability reduction occurs;
- Beach profiling (to aid improved data collection); and
- Regeneration of mangroves.

In the water sector, the following needs were noted:

- Improvement and rationalization of the hydrometric network;
- Additional river gauges and more automatic weather stations to aid in data collection and planning to reduce vulnerability;
- Additional flood warning systems; and
- Additional software such as water ware, river ware, and mike basin to aid in improvement of water management.

The main barrier to the transfer of technology to Sierra Leone is the high initial capital cost of technologies and the capacity to absorb and manage the technologies. There is a need for flexible financial measures in order for new technologies to be adopted. Attitudes, perceptions, and lack of information were also highlighted as a key barrier. In particular, lack of understanding about specific technologies and lack of political will prevent the transfer and adoption of potential technologies. Lack of data is a constraint, particularly with regards to vulnerability issues which prevents adoption and applications of technologies for adaptation. The lack of a central decision making entity to handle issues with regards to technology was also noted as a barrier.

Education, Training and Public Awareness

A number of baseline studies were conducted to obtain a better understanding of the level of education and understanding about climate change in Sierra Leone amongst which is " Report submitted to UNDP- Energy, Environment and Natural Resource Management Cluster" on The State of Climate Information, Early Warning Systems and Adaptation to Climate Change in Sierra Leone,2016.
A number of activities were undertaken by the project and EPA-SL as the contracted partner, including:

(i) A project launch workshop. The objectives of this workshop were to: 1) aid in reconvening the National Implementation Coordinating Unit for climate change in Sierra Leone and 2) launch phase two by informing participants about climate change, regional concerns, climate change scenarios, and alternative energy options for Sierra Leone.
(ii) At Climate Change Workshops. Participants were sensitised on international issues related to climate change, particularly the Conference of Parties of the UNFCCC and the effect that climate change could have on energy, water resources, coastal resources and biodiversity.

Overall, the activities aided in facilitating national networks on climate change and promoting the integration of climate change concerns into the national development planning dialogue.

It is pertinent to note that during the implementation of the various studies incorporated in the National Communication, sensitization and public awareness campaigns targeting grassroots people, high level government officials, Ministers, NGO's, CBS's, farmers, teachers, students etc were carried out by the project throughout the country.

In the Education Sector, the following needs were noted:

- Improvement in the level and extent of educational activities on climate change;
- Collaboration between tertiary educational institutions in relation to teaching and research;
- Collaboration of between technical department/agencies of government and universities to enhance development agendas in climate change issues

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ACKNOWLEGEMENTS

In compliance with Article 4.1, 4.2 and in accordance with Article 12 of the United Nations Framework Convention on Climate Change (UNFCCC), the Project GOSL/GEF/UNEP-00055945 entitled "Third National Communications to the United Nations Framework Convention on Climate Change (UNFCCC)", was established in January 2014 with the objective of building Institutional and Technical capacities in the country and to prepare the Third National Communications for the country.

The Meteorological Department is Sierra Leone's national focal point to the United Nations Framework Convention on Climate Change (UNFCCC) and was responsible for the preparation and submission of this Third National Communication. The process was undertaken by the Climate Change Project Office established for this purpose by the project. A full time project coordinator and a Financial manager was hired for the duration of the project. The skills of international and local consultants and several national experts were fully utilized to prepare this National Communication.

May I through this medium on behalf of the Climate Change Project Office in the Meteorological Department, Ministry of Transport and Aviation congratulate the leaders and members of the GHG Inventory, Mitigation Analysis Study and Vulnerability and Adaptation teams, the Local and International Consultants for the production of this report.

My sincere gratitude also goes to the Global Support Programme of GEF/UNDP /UNEP in Istanbul, Turkey for reviewing the NIR chapter of this Third National Communications.

I wish to register my sincere gratitude and that of the Secretariat of the Climate Change Project to the UNFCCC/GEF/UNEP for the successful completion of this report. Not to mention names would be very unfair to all those who have contributed significantly to the preparation of the report. Credit must go to the following individuals, Susanne Lekoyet, Patricia Mwenya, Stanford Mwakasomba, Leena Darlington of the UNEP, Dr. Raymond Johnson leader of the GHG team, Dr. Sahr A. Aruna (Deceased), compiler of the Energy sector report and Leader of the Mitigation Analysis Study team, Mr. Momodu Alrashid Bah leader of the Vulnerability and Adaptation team, Mr. Julius Matai, Professor Ogunlade Robert Davidson Local Consultants and Chairman of the writing team which prepared the TNC report, the reviewers (local and international) of the various sectors of the report, and all members of the Climate Change Project Office (CCPO)

Prepared by Reynold G. Johnson
Project Coordinator and Compiler

ACRONYMS AND ABBREVIATIONS USED IN SNC REPORT

A4P	-	Agenda for Prosperity
AFOLU	-	Agriculture, Forestry and Other Land Uses
CCP	-	Climate Change Project
CO_2	-	Carbon Dioxide
CEF	-	Carbon Emission Factors
CFC	-	Chloro Fluorocarbon
CH_4	-	Methane
CMB	-	Coastal Management Board
CO	-	Carbon Monoxide
COP	-	Conference of Parties
EF	-	Emission Factor
EI	-	Energy Industries
EJ	-	Exajoule
EPA-SL	-	Environment Protection Agency – Sierra Leone
FAO	-	Food and Agricultural Organization
FBC	-	Fourah Bay College
GDP	-	Gross Domestic Product
GEF	-	Global Environmental Facility
Gg	-	Gigagrams
GHG	-	Greenhouse Gas
HCFC	-	Hydro-Chlorofluorocarbon
HFO	-	Heavy Energy Oil
IPCC	-	Intergovernmental Panel on Climate Change
ICZM		Integrated Coastal Zone Management
IMBO	-	Institute of Marine Biology and Oceanography
INC		Initial National Communication
IPCC		Inter -governmental Panel on Climate Change
ISIC		International Standard Industrial Classification
MAFFS	-	Ministry of Agriculture, Forestry and Food Security
MCI	-	Manufacturing and Construction Industries
MTA	-	Ministry of Transport and Aviation
MT	-	Million Tonnes
MP	-	Metal Production
NO_x	-	Nitrogen Oxide
N_2O	-	Nitrous Oxide
NDC	-	Nationally Determined Contribution
NGO	-	Non-Governmental Organization
NMVOC	-	Non-Methane Volatile Organic Compound
NCSP	-	National Communications Support Programme
PRSP	-	Poverty Reduction Strategy Paper
SNC	-	Second National Communications
SSL	-	Statistics Sierra Leone
SO_2	-	Sulphur Dioxide
SF_6	-	Sulphur Hflexafloride
SWDS		Solid Wastes Disposal Sites

TNC	-	Third National Communications
UNDP	-	United Nations Development Programme
UNEP	-	United Nations Environmental Programme
UNFCCC		United Nations Framework Convention on Climate Change
UNITAR		United Nations Institute for Training and Research
USL		University of Sierra Leone
VMT	-	Vehicle Miles Traveled

CHAPTER 1: Introduction

1.1The UNFCCC Context

The United Nations Framework Convention on Climate Change (UNFCCC) entered into force on 21 March 1994 and sets an overall framework for intergovernmental efforts to tackle the challenge posed by climate change. All Parties must report on the steps they are taking or envisage undertaking to implement the UNFCCC (Articles 4.1 and 12.1) by: "reporting to the Conference of the Parties (COP) on emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol (greenhouse gas inventories); national or, where appropriate, regional programs containing measures to mitigate, and to facilitate adequate adaptation to climate change (general description of steps taken or envisaged by the Party to implement the Convention); and any other information that the Party considers relevant to the achievement of the objective of the Convention." (UNFCCC, 2003)
This national report is referred to as the Third National Communication.

1.2 The Sierra Leone Context

Nationally, Sierra Leone ratified UNFCCC on the 22 of April, 1995 the Kyoto protocol in June, 2005 and the Paris Agreement on the 20th of November, 2016. The Meteorological Department (now agency) is the UNFCCC national focal point, whilst the EPA-SL which houses the Climate Change Secretariat is the national GEF focal point and is responsible for submission of Sierra Leone's national communications. Sierra Leone submitted its Initial National Communication to the UNFCCC on 21 November 2006 and it's Second in December 2012. In addition Sierra Leone has a National Adaptation Programme of Action (NAPA) and recently developed a Nationally Appropriate Mitigation Action (NAMA) and has submitted it's INDC in 2015 to the UNFCCC ahead of the Paris COP.

A stakeholders' self-assessment process preceding the initiation of the Third National Communication (TNC) took place in June-Nov 2013, and it was finalized before the end of the year. Currently the TNC is being developed in partnership with UNEP (UN Environment).

1.3 Financial and Technical Assistance for Preparing the Third National Communications

The Global Environment Facility

The Global Environment Facility (GEF) provides financial assistance to non -Annex I Parties to prepare their national communications under guidance from the COP. This financing is made available under projects called "enabling activities", which are implemented through the United Nations Development Programme (UNDP), the United Nations Environment Programme (UNEP), and World Bank.

Key differences between funding for the Second and Third National Communications

Countries that chose expedited funding for their second National Communications received up to $350,000 from the GEF. For the Third National Communications, this sum rose to $420,000, which includes $15,000 for an initial stocktaking exercise, stakeholder consultations and the preparation of the project proposal. This preliminary exercise is a critical step so that Third National Communications build on the results, experiences and lessons learned from the second National Communications, thus ensuring improvements are carried out in a more cost -effective manner and are not duplicative.

The Secretariat of the United Nations Framework Convention on Climate Change

One function of the UNFCCC Secretariat is to facilitate the provision of financial and technical assistance to non -Annex I Parties as they prepare national communications. One mechanism for providing assistance is through the Consultative Group of Experts(CGE) on non -Annex I National Communications.

In the region, the CGE conducted hands -on training workshops on greenhouse gas (GHG) inventories and vulnerability and adaptation (V&A) assessments, as well as a global one on mitigation analysis in the context of the preparation of national communications. The thematic training materials presented to participants at these training workshops have been used by the national experts during the preparation of this national communication.

The UNDP/UNEP Global Support Programme (GSP)

The Global Support Programme (GSP) is a UNDP/UNEP project, funded by the GEF, which provides technical and policy support to non -Annex I Parties for the preparation of national communications. The GSP is sustaining capacity -building efforts through technical and policy support, knowledge management, and communications and outreach. The GSP offers an integrated package of technical and policy support to enhance capacity in non -Annex I countries and to better meet the needs of countries, such as targeted, in -depth and issue -specific workshops and technical backstopping. The GSP also promotes the quality and comprehensiveness of national communications and the timeliness of their submission, and assists non -Annex I Parties to better incorporate climate change into national development policies.

1.4 Other Resources

Mainstreaming Adaptation to Climate Change into National Development Planning

In Sierra Leone, the European Union has implemented a four -year (2004 -2007), GEF -funded project, *Mainstreaming Adaptation to Climate Change into National Development Planning (MACC)*, which aimed to integrate climate change and variability into the agendas of the tourism, agriculture, fisheries and infrastructure sectors.

The project was implemented through the EPA-SL climate change secretariat together with the meteorological agency which supports the people of Sierra Leone as they address the impact of climate variability and change on all aspects of economic development through the provision of timely forecasts and analyses of potentially hazardous impacts of both natural and man -induced climatic changes on the environment, and the development of special programs which create opportunities for sustainable development".

1.5 The TNC preparation Process/Institutional Arrangements

At the national level, project sponsorship and coordination involve institutional arrangement ensuring the integration of the project at policy level and an operational structure to implement specific project activities.

Description of institutional arrangement

The project's institutional arrangements involved experts from different public and private institutions. The roles and responsibilities of each institution and their reporting lines are arranged to reflect the levels of interlink ages contained in the respective memorandum of understanding.
The inventory compilers also serving in the capacity as the generalist, the uncertainty management lead, QA/QC lead and the documentation and archiving lead are responsible for cross-cutting issues both at national and sector levels. The four working groups were responsible for completing the inventory for the four sectors, namely; Energy, IPPU, AFOLU and Waste. Each working group had a lead and membership drawn from the University of Sierra Leone, public and non-governmental organizations. In addition, there are a number of institutions that supply data to the inventory compilers. In order to ensure that there is no double counting, the inventory group leader ensured that there is enough coordination among the working groups.

The National Implementing Organization

The project was executed through national Execution (NEX) modality with the different roles undertaken by the following institutions:

- Overall supervision on financial management – UNEP, Nairobi Office
- Guidance and Oversight – Project Steering Committee
- Project Implementation – Meteorological Department (Agency), Ministry of Transport and Aviation (MTA)

Sponsorship/ Coordination and integration of the project at policy level

At policy level, the Institutional Framework offered by the following three sponsorship/Coordination entities will endeavor to facilitate the integration of the TNC in to national development policies:

- The United Nations Environment Programme (UNEP)
- The Office of the President/Environnent Protection Agency- Sierra Leone (EPA-SL), Climate Change Secrétariat
- The Meteorological Department, Ministry of Transport and Aviation (MTA).

The Meteorological Department (Agency), Ministry of Transport and Aviation (MTA).

Currently within the Meteorological Department (recently upscaled to an Agency)**,** the UNFCCC Focal Point is the national inventory entity directing the TNC project implementation and is directly responsible for the management of the entire inventory process. The unit ensures that the delivery of the inventory is timely, of fairly good quality and above all meets international standards as far as feasible.

The Office of the President EPA-SL

The Office of the President under which the EPA was established is responsible for the official approval and endorsement of the TNC and onward submission to UNFCCC.

The Climate Change Secretariat of EPA-SL, coordinates the country's response to climate change and is the key node for information on climate change issues and on the country's response to managing and adapting to climate change. It is the official repository and clearing house for regional climate change data, providing climate change -related policy advice and guidelines to Sierra Leone. In this role, the EPA-SL is recognized by the UNFCCC, UNEP, UNDP, and other international agencies as the hub for climate change issues in Sierra Leone.

As the “single national entity” the EPA collaborates with the inventory stakeholders of the Meteorological Agency to undertake management of activity data and emissions factors, compilation of emission estimates from the sectors, quality control/quality assurance, improvement planning, and preparation of the reports.

EPA-SL will accomplish general coordination and will ensure proper linkages and collaboration among the various public and private institution involved in the TNC preparation. As the Agency is the GEF operational focal point and recipient of all reports and project conclusions, EPA-SL will be in a position to effectively integrate the TNC into national development priorities as well as facilitate access of TNC technical teams to data-holding national institutions.

The Basic Country Driven TNC Preparatory steps

The conceptual framework of TNC project design is dominated by national stakeholder/participants at all levels. The various levels of the national institutional framework, used to conceptualize the process are as follows:

TNC Task Force (TF):

The TNC local consultants comprised of professionals from academia, research institutions the public, private and NGOs in Sierra Leone. The TF serves as the technical arm of the TNC process. For example, the TF carried out criteria development, and scoring and ranking of options for the TNC priority activities.

National Stakeholders:

The stakeholders in the TNC included key institutions from the whole country including those at the local level.

1.6 Results of Nation-wide Consultations

The Third national communications (TNC) was informed by a series of nation-wide consultations in which all MDAs, CSOs parliamentarians; CBOs & NGOs, civil society and media were given the opportunity to make inputs. It was also supported by site based impact, vulnerability and adaptation studies result of which were incorporated into the TNC. The approach used in developing the TNC was through studies by various taskforces (a mix of individual consultants and MOUs between the project and data holding institutions like the Meteorological Department, EPA-SL, SLARI and IMBO and the University for the Various Sectors identified in the Self Assessment Exercise (SAE). The results of the task forces and stakeholders consultation for the various components of the study are summarized below.

Energy

In the energy sector the need for a fair, equitable, sustainable supply and distribution of electricity for development was emphasized. However there was the overriding view that a shift from thermal power generation to cleaner modes would be welcomed, for example solar, hydro, ion-diesel, biogas, LPGs etc.

Transportation

Apart from electricity generation in the energy sector, transportation was considered to be the sector where energy products were mostly consumed. It was noted though transportation is a major challenge to the development of all sectors, yet still, emission control mechanisms should be put in place for vehicles of all types. It was thought that the emissions related to the improvement of road networks were temporal and diminished with time. The improvement of bulk public transport system (buses, rail) etc. were highlighted as mitigation measures.

Agriculture

In all agriculture was identified as the number one livelihood of the bulk of Sierra Leoneans. It was therefore suggested that a balance should be struck between agricultural development and emissions control from this sector through climate friendly agricultural practices such as climate smart agriculture. This sector was also identified to be most vulnerable to climate change, therefore government should endeavor to ensure proper early warning system for farmers and timely input of agricultural materials to farmers to in order to increase the adaptive capacity to climate change

Land Use and Land Cover Change

Rapid urbanization, agriculture, developments of the mining sector and timber production were considered to be the major drivers of deforestation. The need for conservation practices to maintain carbon sinks therefore were underscored.

Report Structure

This TNC document comprises of eleven chapters as follows:

- Chapter 1 Introduction
- Chapter 2 National Circumstances
- Chapter 3 GHG Inventory
- Chapter 4 Greenhouse Gas Mitigation Assessment
- Chapter 5 Vulnerability and Adaptation Assessment
- Chapter 6 Technology Transfer and Development
- Chapter 7 Research and Systematic Observation
- Chapter 8 Education, Training and Public Awareness
- Chapter 9 Capacity Building

- Chapter 10 Networking and Information Sharing
- Chapter 11 Constraints and Gaps, and Related Financial, Technical and Capacity Needs

CHAPTER 2: NATIONAL CIRCUMSTANCES

2.1 GEOGRAPHY, CLIMATE AND DEMOGRAPHY

2.1.1 Location of Sierra Leone:

Sierra Leone is located in the southern in the south-western part of the bulge of West Africa, between 7 and 10°N and 10 and 13°E bordering the North Atlantic Ocean, between Liberia and Guinea. , The country covers a total area of 71,325 km^2 and is divided into four geographical or administrative regions: the Northern Province, Eastern Province, Southern Province and the Western Area. These regions are further subdivided into fourteen districts that directly elect local governments known as local councils. There are 19 local councils. Freetown, located in the Western Area of the country, is the capital.

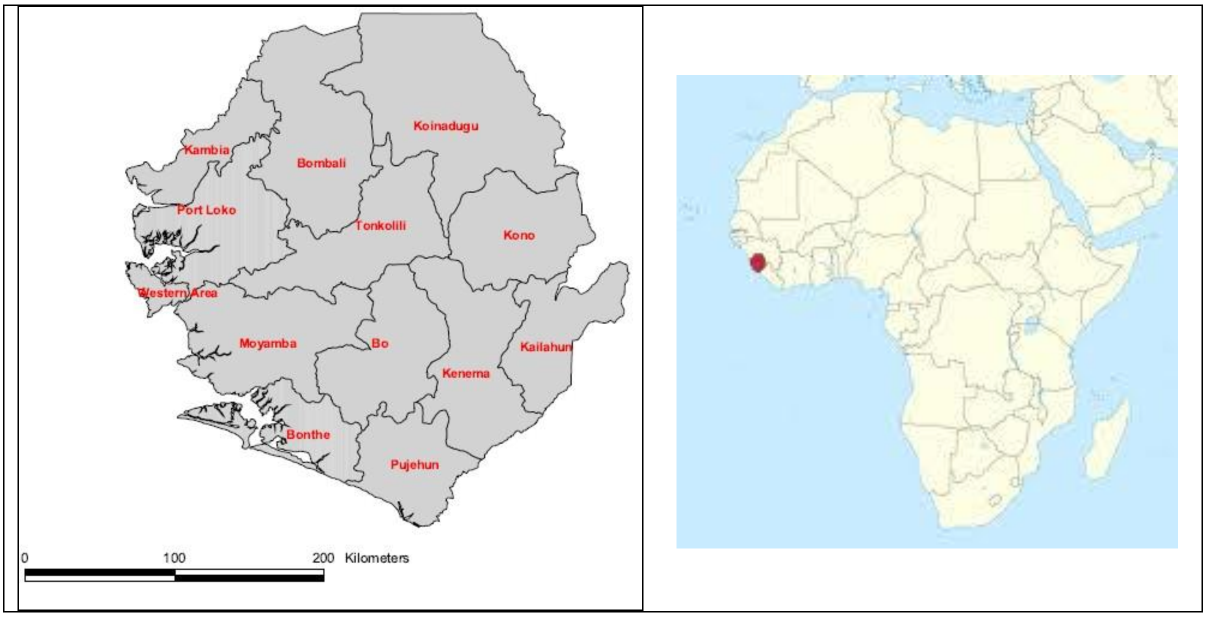


Figure 1. Map of Sierra Leone, and location in Africa

2.1.2 General Development Context

Sierra Leone became independent from Britain on April 27, 1961 and attained Republican status on April 19, 1971. Because of the general absence of public infrastructure at independence, major plans were made for rapid development. These plans were based on Sierra Leone's abundant unexploited natural resources, including a wide variety of rich mineral, agricultural, forest and marine wealth. There were some improvements by the end of the first decade, but with the infringement of global factors such as the oil price crises, fluctuating commodity prices and poor economic response policies, signs of economic decline began to appear. Since the mid-1980s, the country has suffered dramatic economic decline and political instability. It went through five military coups between 1967 and 1991 and endured a brutal armed conflict that lasted for just over ten years from March 1991 to January 2002.

On the economic front, the civil war in the 1990s worsened the situation and the economy plunged at an average of – 4.5 % per annum between 1990 and 2000. However, recent trends indicate that some stability in the economy has returned. Since 2000, the economy has experienced growth of betw een 5.8 and 6.8% per annum. This is largely due to reconstruction and more prudent economic policies.

Sierra Leone is richly endowed in natural resources, especially minerals such as diamonds, titanium bauxite, gold and rutile, and the recently uncovered iron ore on which the economy was recently largely based. Although 75 percent of its land is arable, only about 10 percent is cultivated, mainly for food crops such as rice, cassava, yams, and other root crops.

However, despite this natural wealth, 70% of the total population, of 6 million people (FAO, 2012), live in poverty. Sierra Leone's 11-year civil war (1991-2002) was a large influencing factor in the deterioration of livelihoods, infrastructure, production capacity, and economy. In 2010, the country's GDP stood at approximately 2.2 billion USD (World Bank, 2010). Again in 2015 the Ebola Virus Disease (EVD) which engulfed the country followed by a downturn of revenues from iron ore mining worsened the situation. It is against this backdrop that resilience and economic growth are priorities to the country.

2.1.3 Climate and vegetation cover

Current Climate conditions:

The climate of Sierra Leone is tropical; although it could be classified as a tropical monsoon climate, it could also be describe as a climate that is transitional between a continually wet tropical rainforest climate and a tropical savanna climate (Gabler et al., 2008). There are two seasons: the rainy season from May to November, and a dry season from December to May, which includes harmattan, when cool, dry winds blow in off the Sahara Desert.

Temperatures:

The average temperature is about 26^{O}C and varies from around 26^{O}C to 36^{O}C during the year (Blinker, 2006; Le Vert, 2006). Mean annual temperature has increased by 0.8^{O}C since 1960, an average rate of 0.18^{O}C per decade. During the dry season, the harmattan (dry dusty cool air) causes lowest daily country average temperature of 16^{O}C with a range of between 10^{O}C and 22^{O}C. However, the harmattan period in recent times has been warmer than usual.

Humidity

The humidity, like the temperature is usually high as a result of the heavy rains coupled with high temperature and maritime influences. Humidity rises up to 93% in the wet season and decreases inland to about 47% as the rainfall declines. There is little variation in the day length due to the near equatorial location, but sunshine hours are affected during the wet season.

Precipitation

As stated above, the climate of Sierra Leone is basically divided into two seasons: the rainy and drier seasons. The rainy or monsoon season runs from July to September with a country average rainfall of about 2746 millimeters (mm) and varies from 3659 mm in Bonthe in the South, 2979 mm in Lungi (Freetown) in the West and 2618 mm at Kabala and Bo in the north and central parts of the country. Average rainfall is highest at the coast, 3000–5000 mm per year; moving inland this decreases and at the eastern border of the country, the average rainfall is 2000-2500mm (Hughes and Hughes, 1992). This rainfall season is largely controlled by the movement of the tropical rain belt (also known as the Inter-Tropical Conversion Zone, ITCZ), which oscillates between the northern and southern tropics over the course of a year. When the ITCZ is in this northern position, the dominant wind direction in regions south of the ITCZ is south-westerly, blowing moist air from the Atlantic onto the continent.

When the ITCZ moves southwards, the dominant wind direction north of it is north-easterly.

The precipitation regime has become more erratic in the last 50 years. The mean annual rainfall over the country is about 3000mm and the southern and coastal areas receive from 3000 to 5000mm. The rains fall steadily in the wet season with the heaviest in the months of July and August

Winds

The post monsoon period of October to November has predominant wind direction of south-westerly but with lesser strength and it signals the withdrawal phase of the rainy season and also the Southward migration of the ITCZ. During this time, thunderstorms are also very frequent due the similar high-energy surrounding air mass is weaker. Periodic squall lines result with speed of

Variation of some climate elements

Recently, delays in the start of rains and associated water shortages have been witnessed particularly in Freetown. Heavy rainfall following such dry spells often results in extensive flooding throughout the country. The effects of these unusual temperature and rainfall patterns on agriculture, water supply and sanitation are evident in various parts of Sierra Leone. It has also been observed that the pre-monsoon period which runs from April to June is now associated with stronger winds and more frequent rain/storms causing greater damage to lives and property. Calmer and dryer weather now appears to be associated with the September/November period which was usually characterized by frequent thunder and lightning and short but heavy rainfall.

2.2 Population & Demography

In 2004, Serra Leone's population was estimated at 4,976,871 inhabitants living mostly in rural areas (%).

Demographically, it is a very young country with 75 percent of the population below the age of 35.
This population derives most of its income from natural resources.

According to Statistics Sierra Leone (2012), the population is estimated at 6.0 million in 2011 with a growth rate of 3.3%. The population is 62% rural and 38% urban. The capital city of Freetown is located in the western area of the country and is home to approximately 1.25 million people (~21% of the total population).. The years of conflict, urban migration, and mining industry have created a more mixed distribution of people in the last decades.

Sierra Leone's population almost tripled between 1960 and 2011, and it is projected to almost double again over the next 40 years. The urban annual growth rate has consistently been higher than total growth. These trends are projected to continue until 2050, when the urban population will be 59% and rural 41% of the total, both as a result of enlargements in settlements and in consequence of net rural-urban migration.

The population growth rate was 1.5% in 2004. Fertility index, representing the average number of children per woman (15 – 49 years old), was 6.1.

According to the trend scenario, based on national statistics, the population will reach 6.2 million inhabitants in 2014

2.2.1 Population trends in Sierra Leone's major cities

Table 1 shows the population projections for Sierra Leone's major cities from 2004 to 2014. These projections are based on figures resulting from the 2004 Population and Housing Census. These projections suggest that the population for the major cities by 2014 would be Freetown (1,040,888), Bo (250,960), Kenema (212,130), Makeni (125,518) and Koidu-New Sembehun (89,459). The Population of Sierra Leone is projected to be 6,348,350 by 2014.

Table 2.1 Population projections for Sierra Leone's major cities

City	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Freetown	772,873	841,545	861,066	881,197	901,953	923,341	945,423	968,189	991,618	1,015,829	1,040,888
Bo	149,957	210,071	214,117	218,280	222,561	226,961	231,494	236,155	240,937	245,867	250,960
Kenema	128,402	177,204	180,658	184,213	187,869	191,626	195,498	199,479	203,565	207,778	212,130
Makeni	82,840	103,418	105,595	107,837	69,239	112,251	114,970	117,491	120,081	122,755	125,518
Koidu	82,899	83,533	84,171	84,815	85,463	86,177	86,775	87,439	88,107	88,781	89,459
Sierra Leone	4,976,871	5,094,500	5,216,890	5,343,200	5,473,530	5,607,930	5,746,800	5,890,080	6,037,660	6,190,280	6,348,350

The major social issues that would be significantly affected by this population increase would be the local climate, health, sanitation, housing, transportation, water supply and electricity supply. The consequences for failing to plan for this population explosion are catastrophic.

2.2.2 Population Dynamics

The population growth rate has been estimated at 2.7% (2009). The population is youthful with more than 40% under 15 years. Other social indicators estimated for 2009 are as follows: Maternal mortality rate (annual average) is estimated at 970/100,000(2009); Infant mortality rate/1000 live births (2009) is 192.3, Life expectancy at birth for men is 53 years and for women is 58 years

1.3 Education

In 2007, Sierra Leone joined the Education for All-Fast Track Initiative (EFA-FTI) (currently the Global Partnership for Education-GPE)**.** An EFA-FTI project for US$13.9 million was approved in December 2008. Despite initial delays in implementation, the project was restructured and refocused on quality and system-building activities, and by the closing date of September 2012, it had a number of achievements, including: a review of the Junior Secondary School (JSS) curriculum; a student assessment framework, including training of Ministry of Education, Science and Technology (MEST) staff and other professionals in test and item development, sampling, etc.; and an enhancement of the Girl-Child Support Program with identification of areas for better efficiency and transparency. All the gains which the country had made were reversed by the ebola out break in march 2014 which to date has claimed the lives of over 3000 people.

2.4 Health

The ebola out break had devastating impacts on all facets of the economy, destroying Government's ability to adequately meet the needs of the nation. The health sector is probably the sector which has had most challenges in improvement. Despite efforts by Government and numerous NGOs, access to health facilities has not improved much since the end of the ebola outbreak, stagnating at about 50% and even declining in rural areas. The percentage access of the population to health facilities about 30%.

One of the main challenges has been the lack of capacity in all the sectors of the economy – and with the projections of climate change set to exacerbate the problem – this is the main area which needs to be addressed for resilience and adaptation.

2.5 The Economy and Fiscal Situation.

Sierra Leone operates a mixed economic system; where there are prominent state enterprises alongside a viable private sector. The major sectors of the Sierra Leone's economy are minerals (diamonds, iron ore, rutile, bauxite), fisheries, tourism, agriculture, and manufacturing, with fisheries and mining being the leading foreign exchange earners.

Fiscal performance during the post-war period was mixed. Revenues were below the budgeted level during 2005, although they recovered to reach 12.4% of GDP. They are projected to be 12.6% in 2006 and 13.2% in 2007, albeit with a heavy dependence on trade taxes.

Strict fiscal and monetary policies are being instituted to reduce the budget deficit by enhancing domestic revenue mobilization and improving expenditure management.

Government is encouraging more investment in the agriculture, health, education, infrastructure and other economic sectors in line with its determination to improve on human development status. With the now established local councils, decentralized administration needs considerable resources to deliver services to the rural areas efficiently and effectively.

Growth Rate and Per Capita GDP

On economic co-operation, regional integration and trade, and after falling in 2008 and 2009 due to the financial and economic crisis, export growth resumed in 2010 by nearly 34% and further by 6.2% in 2011 on account of the expansion of mining and agricultural activities. Total export receipts increased by 56.9% from USD 1 065.47 million in 2012, reflecting improvement in earnings from mineral exports, namely diamonds, rutile and iron ore together with the huge jump in earnings from other exports. Comparing the first halves of 2013 and 2012, export grew by 68%. Imports grew by an average of 54.4% during 2008-11 and stabilised in 2012. The huge jump in imports, especially in 2010 and 2011 (averaging 88%), resulted from the increased import of machinery and equipment used to support the expansion in mining and construction activities. Owing mainly to the higher imports related to mining, the current account deficit, including official reserves, widened to 45% of GDP during 2008-11 before declining to 41.2 % of GDP in 2012 as exports surged and imports stabilised. Gross foreign reserves increased to $419.55 million as at end 2012, from $215.48 million at end 2007.

Sierra Leones per capita GNI was $340 in 2010. The Government and people of Sierra Leone have developed and adopted a Third Generation Poverty Reduction Strategy Paper (2013 – 2018), a medium term strategy entitled ***"The Agenda for Prosperity - Road to Middle Income Status".*** To reach the bottom rung of Middle Income status, the size of the economy and subsequently, the per capita GNI will have to triple in 25 years, with GNI per capita rising to $1006. This implies an average growth rate in per capita income of at least 3.9% in the next 25 years, or 5.8% annual growth in total GNI.

2.6 International Trade

Being a typical least developed country (LDCs), Sierra Leone can be classified as an open economy. The country's major trading partners include China, India, the United Kingdom, the United States, etc.

The openness of the economy has also exposed the country to imported inflation which currently, with the recent surge in the price of oil, has affected local price increases. Another critical factor is that imports are major leakages (especially imports of consumer goods which is a major aspect of local imports) and that has also been a factor which has affected the slow rates of growth the economy has undergone over the past decade. Politically this also has implications where with globalization and internationalization being the thrust to which all states have to respond. It creates a situation where LDCs such as Sierra Leone are vulnerable to: [a] free trade agreements by larger economies, e.g. iron ore, bauxite and rutile trade deals, [b] environmental lobbying where, because of their lack of economic power, they are not able to properly table the environmental issues which affect them the most, and, finally [c] trade imbalances that create indebtedness and force countries such as Sierra Leone with few resources to borrow even further.

National Debt and Its Consequences

Public external and domestic debts continued to be a burden on the economy. External debt including arrears was US$1.2 billion at the end of 2005; it then rose to $1.7 billion in June 2006. However, Sierra Leone has benefited greatly from debt relief.

- Interim external debt relief from March, 2001 to October 2005 amounted to US$131 Million.

- The HIPC Completion Point was reached at the end of 2006. Full delivery of debt relief under the HIPC Initiative and the Multilateral Debt Relief Initiative (MDRI) will significantly reduce Sierra Leone's external public debt. The stock of debt would be reduced to US$483million at end 2006 after HIPC relief and to US$110 million aft MDRI. The assistance provided in this way corresponds to approximately US$1,603 million in nominal terms.

Sierra Leone's external **debt** was estimated at 27.3% of non-iron ore GDP during 2013, showing a slight improvement over the 27.8% of non-iron ore GDP recorded at end-2012. About 64% of this debt is owed to multilateral creditors, 13% to bilateral creditors, and 23% to commercial creditors. Public domestic debt stock was expected to amount to 12.7% in 2013, which compared less favourably with 11.6% at end-2012, although it has declined significantly compared to 18.4% in 2007. The stock of total public and publicly guaranteed (PPG) external disbursed and outstanding debt (DOD) amounted to USD 980.68 million as at end-December 2012, which was a 10.2% increase over the USD 890.11 million recorded at end 20112. This growth in debt stock reflects increased disbursement from multilateral creditors, mainly the World Bank (USD 37.42 million); ECOWAS Bank for Investment and Development (USD 29.44 million); African Development Fund (USD 5.6 million); Islamic Development Bank (USD 5.9 million) to name a few. Despite the increase in the public-debt stock, partly to finance infrastructure projects, the ratio of debt-to-GDP has shown a downward trend, which is being driven down by the GDP growing more than the debt stock. External debt as a percentage of GDP declined to 28.5% as at December 2012 from 30.8% in 20113. The medium-term debt strategy anticipates a decline in the stock of domestic debt over time. Accordingly, grants and highly concessional loans should be a priority for the authorities so as to ensure debt sustainability in the medium to long terms. On this note, the government's recent resort to non-concessional lending may put debt sustainability at risk.

To reach the HIPC completion point, Sierra Leone met the following conditions (i) preparation of a full PRSP and implementation for at least one year; (ii) maintenance of macroeconomic stability as evidenced by satisfactory implementation of the IMF supported program; (iii) completion of structural measures in governance and decentralization, private sector development, education and health; and (iv) an increase in spending on designated poverty reducing expenditure priorities that was proportionate to HIPC relief.

2.7 Housing

Most Sierra Leoneans (78 percent) live in separate/detached housing. Over 70 percent of households are owner -occupied or rent free and approximately 20 per cent are rented.

The typical house in Sierra Leone is constructed of block and steel material (approximately 60%) in urban areas. In the rural areas (55%) are constructed with mud and sticks with thatched roofs.

- Between 1996 -06, approximately 68 percent of households were supplied with piped water Public Standpipe comprises 6.7 percent of water supply to households, trucked water approximately 3 percent, spring or pond 3.9 percent, rainwater (tank) approximately 15 percent and wells approximately 3.5 percent.

- Between 1996 -06,65percent of households had access to flush toilets and a further 33 percent used pit latrines. The number of flush toilets is increasing and pit latrines decreasing.

- Electricity is the main source of lighting currently for 45 percent of Sierra Leone's households, followed by kerosene lighting (7.1 percent). Only 2percent of households have no lighting.

- 56.6 percent of households have exclusive access to a kitchen This may be because there is use of more durable materials in construction, and marked increases in exclusive use of utilities and amenities in houses. In short, homes in Sierra Leone are getting more modern.

2.8 The National Development Plans that defines the country's ability to implement climate change policies

The Sierra Leone Government's plans are laid out in five-year national development plan called PRSPs. "*The Agenda for Prosperity*", which succeeded the "*Agenda for Change*" was launched in July 2013[2]. Sierra Leone's Vision for 2013 to 2035 is to become a middle-income country. It would be an inclusive, green country, with 80% of the population above the poverty line. It would have gender equality, a well-educated, healthy population, good governance and rule of law, well-developed infrastructure, macroeconomic stability, with private-sector, export-led growth generating wide employment opportunities; there would be good environmental protection, and responsible natural resource exploitation.

It is planned to increase Sierra Leone's UNDP Human Development Index from 0.33 to 0.62, the average level of middle-income countries, and the strategy will focus on improving health and education for all, and particularly for women and girls. Health will build on the Free Health Care and Scaled-Up Nutrition Initiatives, expanding immunisation and access to water and sanitation. Education access, equity and quality will be improved at all levels, achieving

[2] http://www.publications.parliament.uk/pa/cm201415/cmselect/cmintdev/247/24705.htm

high literacy, and developing a labour force with the skills demanded by the employment-generating sectors of the economy.

Implementation of the Agenda for Prosperity requires sound macroeconomic and fiscal fundamentals; and a society with strong institutions and good governance; with women socially, economically and politically empowered; with social support for disadvantaged groups; and with fair legal protection and justice for all. Accordingly, great emphasis is placed on strengthening governance (with a gender focus), building justice and security, and increasing accountability and transparency.

The Agenda for Prosperity is designed for Sierra Leone to overcome challenges to its economic development from (a) the relatively undiversified nature of the economy, with high unemployment; (b) a recent rate of economic growth which is too low to have the desired impact on poverty; (c) potential external shocks such as inflationary pressures from international food and fuel prices; (d) potential fluctuations in international prices of commodity exports; (e) the possibility of “Dutch Disease”, that is distortion to the economy caused by an appreciating exchange rate due to earnings from commodity exports; (f) high domestic debt; and (g) low domestic revenues.

Macroeconomic and fiscal strategies include: enhancing domestic revenue by improving tax administration and the tax base; improving budget planning, re-orienting public expenditures in favour of capital spending while rationalising recurrent expenditures; monetary policy focusing on maintaining price stability, consistent with high, sustainable economic growth; a flexible exchange rate regime; and developing a medium term debt strategy.

The Agenda for Prosperity is built on the following pillars

- **Pillar 1 – Diversified Economic Growth**
- **Pillar 2 – Managing Natural Resources**
- **Pillar 3 – Accelerating Human Development**
- **Pillar 4 – International Competitiveness**
- **Pillar 5 – Labour and Employment**
- **Pillar 6 – Social Protection**
- **Pillar 7 – Governance and Public Sector Reform**
- **Pillar 8 – Gender and Women’s Empowerment**

The Sectoral Development Plans

These include plans for Agriculture and Food and Nutrition Security which is the main source of food and essential nutrients and an important livelihood source for many poor people.
The sector strategic objectives and priority activities include (a) to increase the production of staple food crops for food security; (b) to promote and increase value-adding activities for agricultural goods; (c) to increase the production and export of cash-crops; (d) improve access to Finance for Farmers and (e) to strengthen the capacity of the Ministry of Agriculture, Forestry and Food Security (MAFFS).

Fisheries Sector
Sierra Leone is blessed with abundant and varied fish resources. Fisheries activities currently contribute about 10% of GDP, and fish is a major source of animal protein for over 80% of the country's population. In addition, the sector currently employs over 500,000 Sierra Leoneans, with women at the forefront of many activities (particularly fish processing and marketing
The Fisheries Sector Strategic Objectives and Priority Activities under the Agenda for Prosperity include (a) to increase the supply of fish for the domestic market by at least 15% annually, particularly from semi-industrial, artisanal, inland, and aquaculture fisheries activities, (b) to increase fish exports by focusing on strategic high-value markets such as the EU; and (c) to promote and increase value-adding activities for fisheries products.

Water Resources Sector

The Water and Sanitation policy is aimed at (a) effective and sustainable development and management of water resources; (b) development of water supply and sanitation services and improving the provision of safe water supplies and sanitation facilities in urban and rural areas; and (c) promoting and scaling up the Community Led Total Sanitation and Open Defecation-Free Communities concepts (Ousman Barrie, 2012).

Health Sector
According to Statistics Sierra Leone (2004), the average population density is about 75 inhabitants per square kilometres. Life expectancy at birth is 41.1 years and the fertility rate (i.e. births per woman) is 6.5. The infant mortality rate is 165.4 out of 1,000 live births.

Forests and Biodiversity Resources

The Forestry Division of the Ministry of Agriculture, Forestry and Food Security (MAFFS) is responsible for forest management and biodiversity conservation. The Forestry and Wildlife division is responsible for natural forest management, management of forest plantations, and management of rangeland and national parks.

The major challenges of forest management include, amongst others (a) poor governance; (b) weak law enforcement (c) lack of coordination among sector ministries and (d) illegal harvesting. To alleviate these challenges identified objectives and strategy for effective forest management include (a) to review and formulate new forestry and wildlife policies; (b) to review and amend the Forestry Act of 1988 and the Wildlife Act of 1972, to accommodate emerging issues such as forest co-management, eco-tourism, biodiversity conservation and climate change; (c) to undertake a national assessment of the forests and woodland resource base; (d) to develop a benefit sharing mechanism that will increase benefits from forest revenue flowing to stakeholders; (e) to promote private sector involvement, including small-holder involvement, in production and value-added activities, including agro-forestry and the long term sustainable utilisation of wood energy resources (f) to mainstream the contribution of forestry and wildlife to sustainable agricultural practices and food security, in cooperation with other agencies; and (g) to mainstream climate change in the forestry and biodiversity policies, strategies, plans and programmes.

Tourism Sector

There is clear potential for growth of Sierra Leone's tourism industry, but some challenges include (a) only a small number of holiday-goers arrive from abroad because of limited infrastructure, Sierra Leone's international image and relatively high costs of travelling to Sierra Leone; (b) weak institutional and legislative frameworks for the sector; and (c) long-term sustainability of key tourist sites could be under threat if necessary steps are not taken.

Mineral Resources Sector

Sierra Leone has substantial mineral resources, including diamonds, bauxite, iron ore gold, cement, ilmenite, and rutile. The sector provides 15–18% of GDP and 90% of export earnings. Oil reserves have been discovered off Sierra Leone's coast. Exploration has also suggested that the country's reserves of iron ore are potentially much larger than previously contemplated (World Bank and AfDB 2010).

The 2009 Mines and Minerals Act and the 2009 Mines and Minerals Regulations regulate the mining sector. The Act: (1) addresses previously unregulated areas of health and safety, environmental protection, and community development; (2) tightens rules for administrators and mineral rights holders, including application and reporting requirements; (3) promotes investment and minerals sector development by ensuring security of tenure and preventing companies from holding land under license without demonstrable activities; and (4) rebalances fiscal benefits among companies, communities, and the government (GOSL 2010; GOSL 2009d).

Additional work in the sector includes the need to address weaknesses in mineral development agreements, poor regulatory enforcement, limited impact of mining activities on economic development in the country, inadequate environmental protection, and inadequate arrangements to ensure that mining operations are accountable to local communities (World Bank and AfDB 2010; GOSL 2009a; World Bank 2009d).

Decentralisation and Local Governance

The Government of Sierra Leone is committed to a policy of decentralisation by devolution, characterised by, for example, (a) the transfer of power, authority and resources from the centre to democratically elected local councils anchored within the national Constitution and articulated in law, promoting autonomy without prejudice to the sovereignty of the national Government; (b) engendering people's ownership of their local development agenda; (c) stimulating economic growth in local communities, including public-private partnerships; and (d) promoting inclusiveness and equality of all citizens within any locality regardless of gender, origin, religion or political persuasion.

The goal of Sierra Leone's decentralisation policy is to ensure that the local people and their communities are empowered and fully involved in political and socio-economic development processes and actually formulate and implement development plans, while governments working in collaboration with the private sector and civil society provide the enabling environment, oversight and effective management of national and local development.

Gender Issues in Sierra Leone

Sierra Leonean women constitute approximately 52% of the population. They continue to suffer from inequalities in terms of literacy rates, per capita GDP, access to land, and legal protection. Women account for approximately 55% of agricultural production, and are primarily responsible for family wellbeing, including for example preparation of food, and paying school fees. Increased poverty among women in Sierra Leone results from a combination of factors, which include: limited skills and knowledge; unfriendly market structures that concentrate women in lower paying and time-consuming work and restrict their access to capital and credit; traditional family structures perpetuating gender inequality through patriarchal norms of property ownership and inheritance; discrimination in the public domain; weak and unequal trade and economic patterns.

Rural women constitute the highest proportion of the informal sector workforce.
Two national policies, the National Policy on the Advancement of Women and the National Policy on Gender Mainstreaming, were adopted in 2009 to guide the Government's gender equality project. These were reinforced by the National Gender Strategic Plan (2009-2012), and the Sierra Leone National Action Plan (SILNAP) on United Nations Security Council Resolution (UNSCR) 1325 on Women, Peace and Security and UNSCR 1820 on Sexual Violence were adopted in 2009 and 2010 respectively.

Government has recognised that gender equality and women's empowerment contribute significantly to national development and cohesion. Government is committed to ensure that gender analysis is embedded within all national development programmes. It hopes to improve Sierra Leone's Gender Inequality Index (0.643 in 2012), and consequently it's Human Development Index (0.359 in 2012).

Youth & employment

Sierra Leone currently faces high unemployment among the youth. Unfortunately many of these were unable to complete their education due to the interference of the civil war. Although employment is currently available in Sierra Leone, it is often only for those who are highly skilled and educated. Thus, the unemployed low and semi-skilled youth, particularly in the urban areas of Sierra Leone, remain a risk since they need but are unable to find stable, long-term employment. Short term employment increases the risks to climate change.

Exogenous Risks

Uncertain political, health and economic situations in any neighboring country could disrupt Sierra Leone's economic development. If terms of trade are disrupted for Sierra Leone's exports, this could handicap the country. Sierra Leone is dependent on oil and other petroleum products. If the international price of oil were to continue to increase, it would damage the economy, in terms of supplying power in the short term, as well as in the transportation of goods, since the majority of goods travel by road.

If climate change and environmental changes cause weather patterns to shift, Sierra Leone must be aware of potential changes in climate and how agriculture in particular can be adapted to thrive in a new environment.

Monetary Aid

The national economy is a consistent beneficiary of extensive multi -lateral financial and technical Assistance from organizations such as the World Bank, the International Monetary Fund, and the African Development Bank. Strong assistance from these organizations since the 1980s has been instrumental for the implementation of structural reforms, paving the way for a liberal foreign exchange system, cutting of tariffs and trade controls ,stabilizing the currency and controlling inflation.

References

1. Poverty Reduction Strategy paper "Agenda for Change"
2. Poverty Reduction Strategy paper "Agenda for Change"
3. National Climate Change Strategy and Action Plan Document
4. National Climate Change Policy Document
5. Initial National Communications INC
6. Second National Communications SNC
7. Sierra Leone's Intended Nationally Determined Contributions

Chapter 3: The National Greenhouse Inventory

3.1 Introduction

The National Greenhouse Gas (GHG) inventories of emissions by sources and removals by sinks have been carried out to meet Sierra Leone's obligation to the United Nations Framework Convention on Climate change (UNFCCC).

Considering the Decision 17/CP.8, each non-Annex I Party shall, as appropriate and to the extent possible, provide in its national inventory, on a gas-by-gas basis and in units of mass, estimates of anthropogenic emissions of carbon dioxide (CO2), methane (CH4) and nitrous oxide (N2O) by sources and removals by sinks. Sierra Leone has estimated and reported emissions of these direct GHG.

Inventories of GHGs provide the means for monitoring reductions of GHGs by Parties and are therefore important components of national communications.

Emission estimates presented in the Inventory have been generated as part of the Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

3.1.1 Background

As a signatory and a non-Annex 1 party to the UNFCCC, and in accordance with Article 4.1(a) of the UNFCCC, all Parties to the Convention are requested to update and report periodically on their inventory of anthropogenic emissions and removals of greenhouse gases (GHGs) not controlled by the Montreal Protocol.

For this Third National Communication, Sierra Leone has used the 2006 IPCC Guidelines to prepare it's GHG inventories corresponding to the period 2005 – 2010 with 2005 selected as base year including for the selection of emission factors in all the sectors. The use of the Revised 2006 IPCC guidelines was to ensure that the GHG emission estimates were as much as practicable transparent, complete, consistent and accurate (TCCCA) through time and comparable with those inventories produced in other countries with similar national circumstances.

The inventory was prepared using the following documents:
• *2006 IPCC Guidelines for National Greenhouse Gas Inventories*
• *Good Practice Guidance for Land Use, Land -Use Change and Forestry (IPCC, 2003)*
• *Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories (IPCC, 2000).*

3.1.2 Scope

General assessment of the completeness

Assessments of completeness for each sector have been provided under the sector-specific description section. The general overview of completeness is as follows:

Geographic coverage

The geographic coverage is complete. The inventory covered the entire territorial boundary of the Republic of Sierra Leone. Thus none of the four administrative regions in Sierra Leone was left uncovered by the inventory.

Sectors (sources and sinks)

All sources or removals of direct GHG gases, outlined in the 2006 IPCC Guidelines, were covered in the inventory except the following activities which were considered insignificant in the country or where data were non-existent:

- 1A.2a – Iron and steel
- 1A.2b – Non-ferrous metals
- 1A.2i – Mining (excluding fuel) and quarry
- 1B.2a.iii.5 – Distribution of oil products
- 2F – Product use as substitute to ozone depleting substances
- 3B.4 – Wetlands
- 3B.5 – Settlements
- 3B.6 – Other lands
- 3D.i – Harvested wood products

Gases
Majority of the direct gases have been covered under this inventory. These direct gases included: carbon dioxide (CO2), methane (CH4), nitrous oxide (N2O),): non ‑methane volatile organic compounds (NMVOCs), carbon monoxide (CO), nitrogen oxides (NOx), and sulphur dioxide (SO2).

Sectors Covered
Inventories were compiled for the following four sectors included in the 2006 IPCC Guidelines: Energy; Industrial Processes and Product Use; Agriculture, Forestry and Other Land Use (AFOLU); and Waste.

Within each sector, the methodologies used and data sources (activity and emission factor data) are indicated together with the presentation and discussion of emission estimates. Gaps, data constraints, methodological problems and uncertainties in compiling the GHG emission estimates are identified within each sector.

Brief description of methodology and data sources

The emissions inventory has been conducted from a series of steps using a range of data from diverse sources. The emissions were not directly measured but were estimated through the application of methodologies that link emissions to data on observable economic activities in the country. The estimation of the GHG emissions and sinks used a combination of: (a) country-specific methods and data; (b) IPCC methodologies and; (c) Emission Factors (EFs). These methods are consistent with the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC 2006) and are to the extent possible, in line with international practice. Generally, Tier 1 IPCC methodology was applied, however there were selected categories such as Transport (1.A3), Land (3B), IPPU (2C) and Solid Waste Disposal (4a) for which higher tier (tier 2) methodology was required, but lack of software compatible data could not allow it's use. The methodology has seen some improvements over the previous years. This was because of: (a) the continuous use of new and additional country-specific activity data and (b) the shift from the Revised 1996 IPCC guidelines to the 2006 guidelines. Emission factors were obtained from IPCC Emission Factor Database. Default emissions factors from the IPCC EFDB were commonly used as country or region specific emission factors were non-existent.

Gaps, data constraints, methodological problems and uncertainties in compiling the GHG emission estimates.

Not all emission categories of the 2006 Revised Guidelines (IPCC, OECD.IEA, 1997) are reported on in this chapter of the National Communications. This shortcoming is due to the following:

- Absence of activity data and nonoccurrence of categories and sub-categories in the country.
- HFCs have not been considered in this inventory again due to data unavailability.(Hydro fluorocarbons (HFCs),perfluorocarbons (PFCs) and sulphur hexafluoride (SF6), and the indirect GHGs) which contribute to Tropospheric ozone formation.
- Disruptions in the data collection exercise due to exogenous and health risks.

Setting/Base Year Characteristics

Sierra Leone prepared its Second Communication (SNC) in 2012 taking **2000** as a base year. For the Third National Communication (TNC), **2005** has been selected as base year. Country activity data were collected to the extent possible from the different sectors. IPCC default factors were employed where country data were not available.

However, since 2005, many reforms came into effect that has a direct impact on the results of the present national inventory/communication. Main developments include:

- National Elections of 2007 which ushered into governance the then opposition All People's Congress Party;
- Establishment of an Environment Protection Agency in 2008;
- Setting up of the Climate Change Secretariat and a committee within the EPA-SL in 2012;
- Decentralization with the election of town councilors in 2008 respectively;
- Population and Housing Census 2004 and 2014 respectively;
- Development of the National Adaptation Programme of Action (NAPA) document, 2008;
- Development and adoption of Poverty Reduction Strategy Paper (PRSP) *Agenda for Change* 2008-2012;
- Development and adoption of Poverty Reduction Strategy Paper (PRSP) *Agenda for Prosperity* 2013-2017;
- Development of a Climate Change Policy 2015;
- Development of a National Climate Change Strategy and Action Plan 2015;
- Development and submission of the INDC/NDC in fulfillment of the Lima call to the historic Paris Agreement 2015;
- Revision of the new Mining Act and the just adopted new Petroleum Act 2011 in the energy sector;
- Creation of a Renewable Energy Directorate in the Ministry of Energy (ME);
- Development of and adoption of the new Forest Act and creation of a Forestry Directorate;
- Development of and adoption of the new National Protected Areas Act (NPAA);
- The Local Content Policy in order to increase the number of Sierra Leonean nationals in various positions in foreign companies investing in the economy.

For the Third National Communication, the aforementioned reforms contributed to: (i) an improvement in some areas of the national statistics; (ii) building of national capacity and expertise; (iii) appropriate institutional framework; (iv) orientations of policies, in particular more specific policies in agriculture, forestry, land use and energy sectors.

A validation workshop held jointly with the Climate Change Secretariat of EPA-SL on the 20th of November 2016 reviewed the National Inventory Report (NIR). Taskforce leaders have submitted their final draft reports. The final drafts of the sector reports from the sectors were then submitted for review to the GSP as well.

Major social and developmental setbacks

Due to the outbreak of the Ebola Virus Disease-2013-15 (EVD) in Sierra Leone which claimed 3,461 lives by February 2015 (WHO, 2015),the development gains made by Sierra Leone after the country's emergence from a ten-year civil war in 2000 were rudely reversed. The EVD outbreak also saw the collapse of many activities nationwide which hampered timely delivery of the TNC.

Notwithstanding these setbacks, Sierra Leone recently developed and adopted it's National Climate Change Policy (NCCP) and National Climate Change Strategy and Action Plan (NCCSAP) around which the NDC revolved.

The NDC of Sierra Leone has three components, one for Mitigation, one related to Adaptation and the third for Loss and Damage consistent with Sierra Leone' s green growth pathway to development.

3.2.1 Emissions and removals of Greenhouse Gases in 2005-2010

The table below shows 2005 emission levels for the most important greenhouse gases in Sierra Leone.

Table 3.1 National Greenhouse Gas Inventories of Emissions by Sources and Removals by Sinks of all Greenhouse Gases, 2005 (Gg)

GHG Source and Sink Categories	CO_2 Emissions	CO_2 Removals	CH_4	N_20	HFCs	NO_x	CO	NMVOC	SO_2
Total (Net) GHG emissions by source and removal by sinks									
Main activity-Electricity Fuel Combustion Activities	20340.20	NO & NE	NE	NE	NE	NE	NE	NE	NE
Fuel Combustion Activities – Manufacturing Industries and Construction	NE	NE	NE	NE	NE	NE	NE	NE	NE
Mobile Combustion (Transport)	NE	NE	NE	NE	NE	NE	NE	NE	NE
Fuel Combustion Activities – Other Sectors	NE	NE	NE	NE	NE	NE	NE	NE	NE
Fugitve emissions	NO	NO	NO	NO	NO	NO	NO	NO	NO
Carbon dioxide transport and storage	NO	NO	NO	NO	NO	NO	NO	NO	NO
Industrial Processes and Product Use	0.01955								
Mineral Production	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cement Production		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lime Production	0.01014		0.00	0.00					
Chemical Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO
Carbide Use	0.00941	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Metal Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Food Industry	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2D Non-energy Products from Fuels and Solvent Use									

Lubricant Use	NE	NE	NE	NE	NE	NE	NE	NE	NE
Paraffin Wax Use	NE	NE	NE	NE	NE	NE	NE	NE	NE
Solvent Use (Note 8)	NE	NE	NE	NE	NE	NE	NE	NE	NE
Other (Note 9)	NO	NO	NO	NO	NO	NO	NO	NO	NO
Electronics Industry	NO	NO	NO	NO	NO	NO	NO	NO	NO
2F Product Uses as Substitutes for Ozone Depleting substances	NO	NO	NO	NO	NO	NO	NO	NO	NO
2F1Refrigeration and air Conditioning	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F1a Refrigeration and Stationary Air Conditioning	NO	NO	NO	NO	NO	NO	NO	NO	NO
2F1a Mobile air Conditioning	NE	NE	NE	NE	NE	NE	NE	NE	NE
2F3 Fire Protection	NE	NE	NE	NE	NE	NE	NE	NE	NE
2G Other Product Manufacture and Use	NE	NE	NE	NE	NE	NE	NE	NE	NE
2H Other			0.00	0.00					
2H2 Food and Beverages Industry (Note 15)									
AFOLU									
Livestock			10.42						
Land									
Aggregate sources and non-CO2 Emission sources on land									
Waste			151.68						
6.1 Solid Waste Disposal Sites (SWDSs)	151.68		94.9						
6.2 Domestic & Commercial Waste Water	0.00	0.00	7.13	$167.23 * 10^{-5}$	0.00	0.00	0.00	0.00	
6.3 Industrial Waste Water handling	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	

6.4 Human Waste (Indirect N_2O)	NE	NE	NE	NE	NE	NE	NE	NE	NE

3.1 Emissions and removals of Greenhouse Gases in 2005

3.1.1 Carbon dioxide

The total carbon dioxide emission (CO2) for the year 2005 per fuel type is 20340.20Gg CO_2 equ.
This overall emission from the country was calculated based on total fuel import figures from the Petroleum Agency in Sierra Leone per fuel type. The emissions cover all fuel combustion and electricity generation activities for all sectors countrywide. It is to be noted that the overall import figures are not disaggregated to the various sectors. Hence the difficulty of the sector approach.

Trends between 2000 and 2005

The methodologies used in compiling the current inventory (according to the IPCC 2000 Guidelines) are different from those used to compile the 1994 inventory. Archived activity data for the 1994 inventory were incomplete (especially for the agriculture and forestry sectors) and hence it was not feasible to reconstruct the 1994 inventory using the 2006 methodologies. (see below: source SNC based on 1996 guidelines)

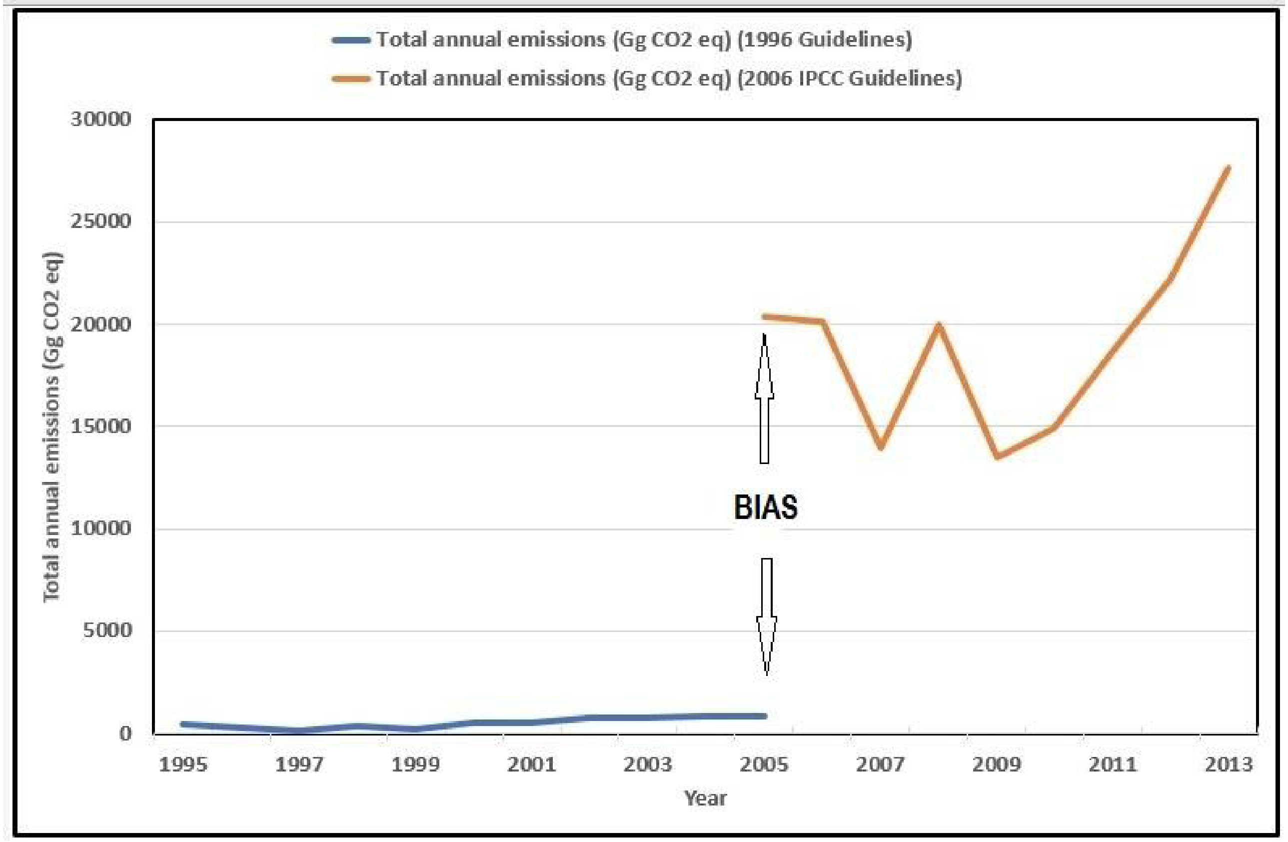
Table 3.2 Summary of $C0_2$ Emissions from 1995 – 2005 (Based on 1996 guidelines)

YEAR	CO_2 EMISSIONS ($GgCO_2$)
1995	476.98
1996	294.06
1997	134.56
1998	334.57
1999	227.78
2000	529.28
2001	549.52
2002	766.95
2003	776.39
2004	814.45
2005	842.40

Table3.3 Total CO_2 emissions ($GgCO_2$ equivalent) per year **(Based on 2006 guidelines)**

YEAR	Total CO2 EMISSIONS (GgCO2)/YEAR
2005	20340.20
2006	20125.68
2007	13946.66
2008	19957.44
2009	13505.66
2010	14938.39
2011	18591.47
2012	22210.59
2013	27678.50

Figure3.1 Bias between total annual emissions 1996 and 2006 IPCC Guidelines (Adopted from GSP review, 2017)



Because of the bias between the 1996 and the 2006 guidelines, trends in emissions are discussed only for 2005 -10.
Overall, annual emissions for CO2, show an overall increasing trend from 2005 -13, as shown above (2006 guidelines), with only a minor drop in 2007 and 2009.
Carbon Dioxide (CO2) emissions increased consistently from 20340.20 Gg in 2005 to 27678.50 Gg in 2010.

The large (46%) increase in CO2emissions in the energy sector was due to increases in fuel consumption in the mining industry and transportation categories (Figure 2.10). There was little change in the magnitudes of the sources and sinks for CO2in the Agriculture, Forestry and Other Land Use sectors between 2005 and 2010.

In the Industrial Processes and Products Use Sector, the CO2 emissions from the cement industry increased over 2005 - 10 but those due to lime manufacture declined. (see sector report).

Carbon Dioxide CO_2 emissions in the waste sector increased over 2005 - 10. The contribution from managed disposal sites decreased while that from unmanaged sites increased (see Figure 2.12). There was a similar pattern for methane (CH_4) emissions in the waste sector. Overall, CH4 emissions rose from 31.1 Gg in 2000 to 41.9 Gg in 2005.

Uncertainties

Uncertainties in the overall GHG inventory for emission factors and activity data were calculated using the 2006 IPCC Guidelines. The Guidelines recommend evaluation of the uncertainties in the annual estimates as well as in trends. This was done for this inventory using 2005 as the base year; estimates of the uncertainty alone were made for 2005.

The overall uncertainties in the 2005 and 2010 inventories were about 10%, while the uncertainty in the trend between 2005 and 2010 was about 20%. CO2 accounted for between 70 and 77% of the emissions on a CO2equivalent basis. Most of the CO2emissions are from fuel combustion.

Conclusion

Improvements to the GHG inventory will greatly facilitate the core business of data suppliers. This is especially true of the energy sector/fuel use data where reliable energy end use information is so critical in identifying opportunities for improving energy efficiency and reducing fuel use.

Sector Emissions

3.3 Energy Sector GHG Emissions

In Sierra Leone, energy sector activities that contribute directly to the emission of GHGs have been identified as electricity production, transportation, domestic consumption of energy, industrial, forestry and agricultural processes and waste generation and disposal. The emissions consist of direct GHGs from energy consumption (Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O), Nitrogen Oxides (NO_x), Carbon Monoxide (CO) and Non Methane Volatile organic Compounds (NMVOC)) and Sulphur Dioxide (SO_2).

The energy sector consists of the following types of activities (source categories):
- Import of primary energy sources, fuels
- Transmission and distribution of fuels,

• Use of fuels in stationary and mobile applications.

Emissions arise from these activities by combustion and as fugitive emissions, or escape without combustion.

Emissions from energy systems are calculated from fuel combustion, excluding fuel wood. It is assumed that all fossil fuel imported are consumed.

3.3.1 Analysis of source categories

Since the SNC, Sierra Leone continues to depend to a large extent on expensive imported petroleum fuel for nearly 60% of her energy requirements. The main sources of energy for power generation are the Hydroelectric Power (HEP), Heavy Fuel Oil (HFO), and diesel with petroleum fuels accounting for about 70-80% of it's present energy requirement using thermal plants.

The source categories covered in the Energy Sector and those that are present in Sierra Leone and therefore relevant for the inventory are summarized in the table below. There is no primary energy industry in Sierra Leone, so this source category was not considered in the energy sector. The sources that are present in the country are indicated by a "Y" or "N" for sources that are absent.

Table 3.4 Energy sector source categories present in Sierra Leone (2006 IPCC GUIDELINES)

Category Code	Category Name	Present in Sierra Leone
1A1	Fuel Combustion Activities – Energy Industries	Y
1A1a	Main Activity- Electricity	Y
1A1b	Petroleum Refining	N
1A1c	Manufacture of Solid Fuels And Other Energy Industries	N
1A2	**Fuel Combustion Activities – Manufacturing Industries and Construction**	
1A2a	Iron and Steel (ISI Group 271 and Class 2731)	N
1A2b	Non-ferrous metals (ISIC Group 272 and Class 2732)	N
1A2c	chemicals (ISIC Division 24)	N
1A2d	Pulp, paper and print (ISIC Divisions 21 and 22)	N
1A2e	Food processing, Beverages and Tobacco (ISIC Division 12 and 16)	Y
1A2f	Non-Metallic Minerals (ISIC Division 26)	N
1A2g	Transport Equipment (ISIC Divisions 34 and 35)	N
1A2h	Machinery (ISIC Divisions 28 to 32)	N
1A2i	Mining (Excluding Fuels) and Quarrying (ISIC Divisions 13 to 14)	Y
1A2j	Wood and Wood Products (ISIC Division 20)	Y
1A2k	Construction (ISIC Divisions 17, 18 and 19)	Y
1A2l	Textile and Leather (ISIC Divisions 17, 18 and 19)	N
1A2m	Non-specified Industry	N
1A3	**Mobile Combustion (Transport)**	
1A3a	Civil Aviation	Y
1A3b	Road transport	Y
1A3c	Railways	Y
1A3d	Waterborne Navigation	Y
1A3e	Other Navigation	Y
1A4	**Fuel Combustion Activities – Other Sectors**	

1A4a	Commercial/institutional	Y
1A4b	Residential	Y
1A4c	Agriculture/forestry/fishing/fish farms (Stationary combustion)	Y
1A5	**Fuel Combustion Activities – Non-Specified**	
1A5a	Non-specified stationary	N
1B	**Fugitive Emissions from Fuels**	
1B1	Fugitive emissions from fuels – solid fuels	N
1B2	Oil and natural Gas	N
1B2a	Fugitive Emissions from fuels – Oil and Natural Gas – Oil	N
1B2b	Fugitive Emissions from fuels - Oil and Natural Gas – Natural Oil	N
1B3	Other emissions from Energy Production	
1D	**Carbon Dioxide Transport and Storage**	N
1D	**Miscellaneous**	

From the table above, it can be seen that most of the source categories are not present in Sierra Leone.

Category code	Category Name	Status
1A1b	Petroleum Refining	NO
1A1c	Manufacture of Solid Fuels And Other Energy Industries	NO

1A2a	Iron and Steel (ISI Group 271 and Class 2731)	NO
1A2b	Non-ferrous metals (ISIC Group 272 and Class 2732)	NO
1A2c	chemicals (ISIC Division 24)	NO
1A2d	Pulp, paper and print (ISIC Divisions 21 and 22)	NO

1A2f	Non-Metallic Minerals (ISIC Division 26)	NO
1A2g	Transport Equipment (ISIC Divisions 34 and 35)	NO
1A2h	Machinery (ISIC Divisions 28 to 32)	NO

1A2l	Textile and Leather (ISIC Divisions 17, 18 and 19)	NO
1A2m	Non-specified Industry	NO

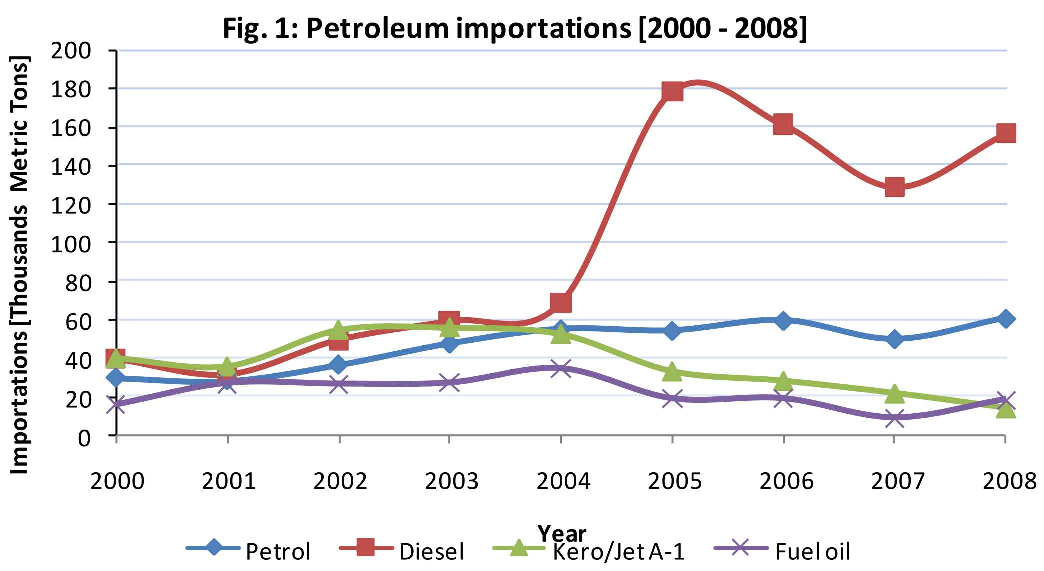
1A3	**Mobile Combustion (Transport)**	
1A3a	Civil Aviation	NE
1A3b	Road transport	NE
1A3c	Railways	NE
1A3d	Waterborne Navigation	NE
1A3e	Other Navigation	NE
1A4	**Fuel Combustion Activities – Other Sectors**	
1A4a	Commercial/institutional	NE
1A4b	Residential	NE
1A4c	Agriculture/forestry/fishing/fish farms (Stationary combustion)	NE

1A5	**Fuel Combustion Activities – Non-Specified**	
1A5a	Non-specified stationary	NO
1B	**Fugitive Emissions from Fuels**	
1B1	Fugitive emissions from fuels – solid fuels	NO
1B2	Oil and natural Gas	NO
1B2a	Fugitive Emissions from fuels – Oil and Natural Gas – Oil	NO
1B2b	Fugitive Emissions from fuels - Oil and Natural Gas – Natural Oil	NO
1B3	Other emissions from Energy Production	NO
1D	**Carbon Dioxide Transport and Storage**	NO
1D	**Miscellaneous**	NO

3.3.2 Energy Sector circumstances

Sierra Leone depends mainly on petroleum products (petrol, diesel, Liquid Petroleum Gas-LPG, kerosene and Heavy Fuel Oil-HFO) and fuel-wood (wood and charcoal) for its source of energy. All the Petroleum products consumed in the country are imported in refined form. The annual average volume of petroleum products imported into the country is about 200,000 metric tons. Figure 1 shows the volumes of petroleum products imported into the country between 2000 and 2008 by the petroleum marketing companies. These volumes are not 100% accurate due to the unaccounted quantities brought into the country through the porous borders from neighbouring countries.

Figure 3.2 Petroleum importations (2000-2008)



Recently the country has proved to have oil reserves. At present this is at an exploratory stage. A development of this resource is envisaged in the future, therefore emission from this sector will consequently be enhanced.

Sierra Leone has over 20 hydro potential sites of which the Bumbuna Dam is the only one that has been tapped. Phase one of the project to tap the electricity potential of this dam, which has been completed, has a capacity of 50MW. This was considered as the most viable mitigation option for the electricity sector. If five of these hydro potentials including Bumbuna are utilized, it will result in almost zero emission from the electricity sector at least during the rainy season.

3.3.3 Fuel Combustion Activities - Energy Industries (1A1)

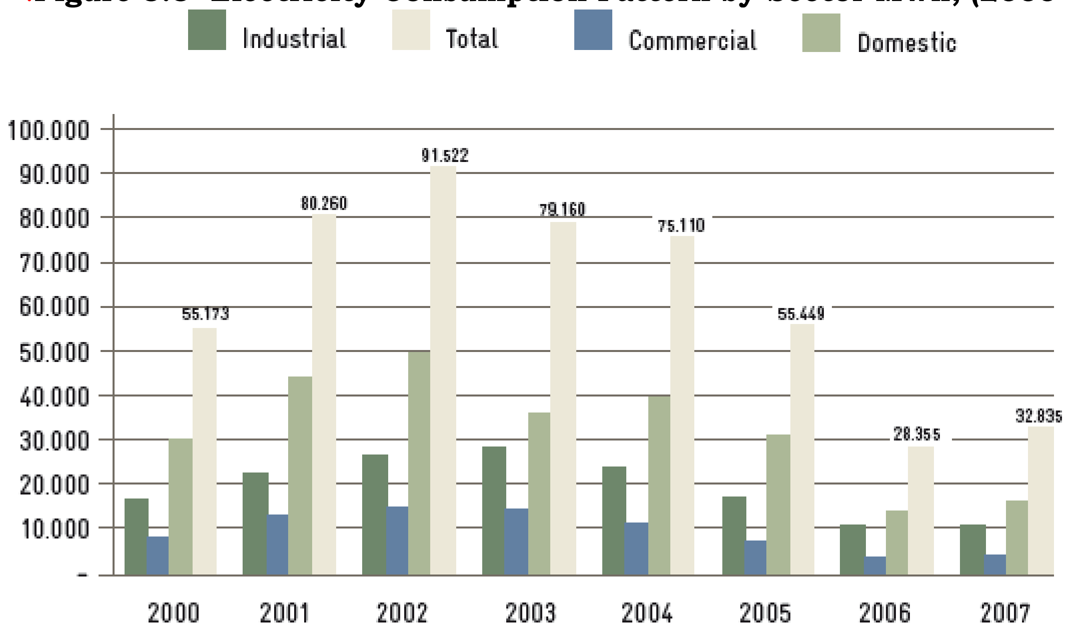
For Sierra Leone, this sub -sector comprises fuel combustion activities (1A1) and main activity i.e electricity (1A1a), 1A4 Fuel Combustion Activities – Other Sectors sub -sector of which comprises fuel combustion activities (1A4a) Commercial/institutional, (1A4b)Residential, (1A4c)Agriculture/forestry/fishing/fish farms (Stationary combustion)

Emission estimates from these sub -sectors in **totality** are described below. For all calculations in the energy sector, the default values for the net calorific values, carbon content and CO_2 emission factors found in the 2006 IPCC Guidelines were used.

1A1a Main Activity- Electricity

Electricity for public consumption is supplied by the Electricity Distribution and Supply Authority (EDSA) and the Electricity Generation and Transmission Company (EGTC) which is the main generator of electricity in Sierra Leone, decoupled from the former National Power Authority (NPA). The consumption pattern is showed below.

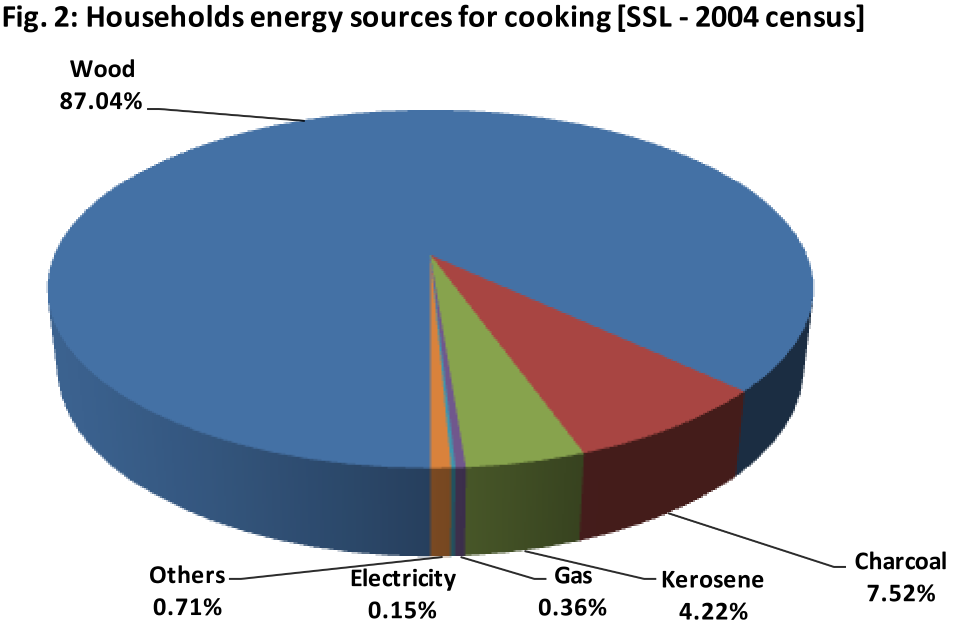
.**Figure 3.3 Electricity Consumption Pattern by Sector MWh; (2000-2007)**



Sources of Energy for Cooking

Figure 2 shows the percentages of the various energy sources used for cooking in Sierra Leone. It is obvious from the chart that fuel-wood and kerosene are the main sources of energy used for cooking and they account for about 87% and 7.5% respectively. LPG and electricity are also used for cooking, but their use is insignificant.

Figure 3.4 Households energy sources for cooking (SSL-2004 census)



National Power Generation

The electricity industry in Sierra Leone is state owned. It consists of the Western Area grid centred in Freetown and the Provincial Systems. The provincial systems originally consisted of 12 isolated systems located at the headquarter towns. Between 1960 and 1995, the country's total installed and operating electricity-generating capacity was about 42 MW. Apart from the Bo-Kenema system, all other systems are beyond economic repair. Generally, the national power systems in the country are operated by EGTC and the Bo-Kenema Power Services (BKPS). BKPS is responsible for the provision of electricity in Bo (the Provincial Headquarter of the Southern Province), Kenema (the provincial Headquarter of the Eastern Province) and their environs while EGTC is also responsible for the generation of electricity in the Western Area and the rest of the country. Currently, EDSA supplies electricity in Freetown and Makeni (the provincial headquarter town of the Northern Province). For the rest of the country, individuals or institutions provide their own electricity supply using personal generators.

In 2007 the electricity generation in Freetown was very unsatisfactory; it declined continuously and the available generating capacity by the end of that year was about 6 MW. As a result of the low available generating capacity, the electricity market was opened to the private sector. Thus, GoSL engaged two Independent Power Providers; Global Trading Group (GTG) for the provision of 15 MW at

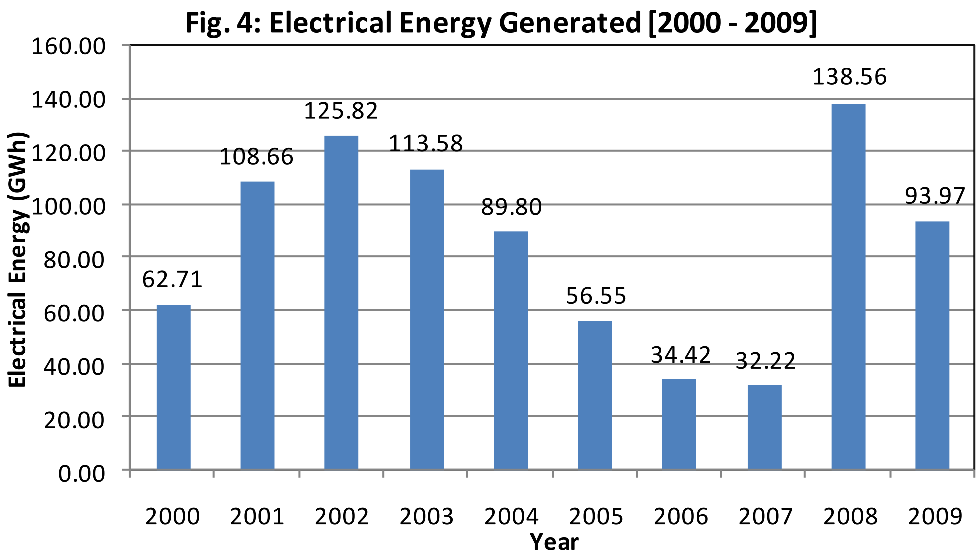
Kingtom and Income Electrix Limited (IEL) for the provision of 10 MW installed at Blackhall Road in Freetown to salvage the electricity supply crisis.

The current national installed thermal generating capacity is 83.44 MW and the available capacity is 40.1 MW. GTG's available capacity was between 12 and 15 MW and started operation in December 2007 to date while IEL's available capacity was on average 2 MW and also started operation in February 2008 till September 2009. The Sulzer engines were put out of operation from January 2008 to date but were test run in 2009. Nigata 7 and 8 are newly commissioned generators that started operating in April 2010. The commissioning of the Bumbuna hydroelectric plant in October 2009 caused GTG not to operate its available capacity. A 17 MW thermal plant is under construction in Freetown.

The Bo generators have available capacity of about 3.7 MW. BKPS and uses a mix of hydro and generators (located in Bo) to generate its electricity. Thus, the generators are used exclusively for about five months during the dry season while the hydro is used exclusively during the raining season. The thermal generators will come on occasionally when there is a problem with the hydroelectric plant.

The fuels used by the thermal plants in the country are MFO and diesel. Fig. 4 shows the annual electrical energy generated by the thermal plants of NPA and BKPS.

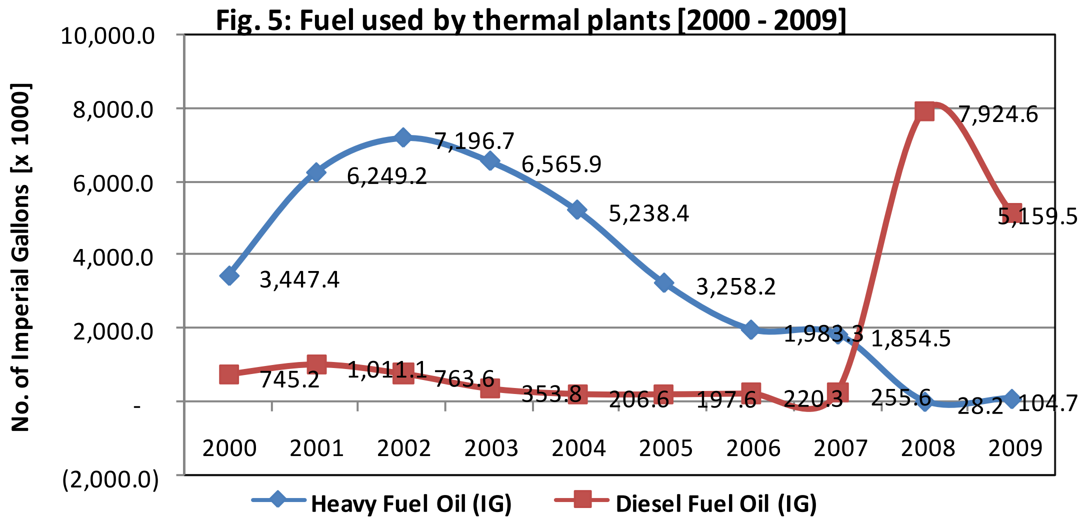
Figure 3.5 Electrical Energy Generated(2000-2009)



Source: NPA and BKPS

Figure 5 shows the annual MFO and diesel consumed by NPA and BKPS between 2000 and 2009. The highest peak of the diesel in 2008 was due to the exclusive use of GTG and IEL to generate and supply electricity in Freetown.

Figure 3.6 Fuel used by thermal plants2000-2009)

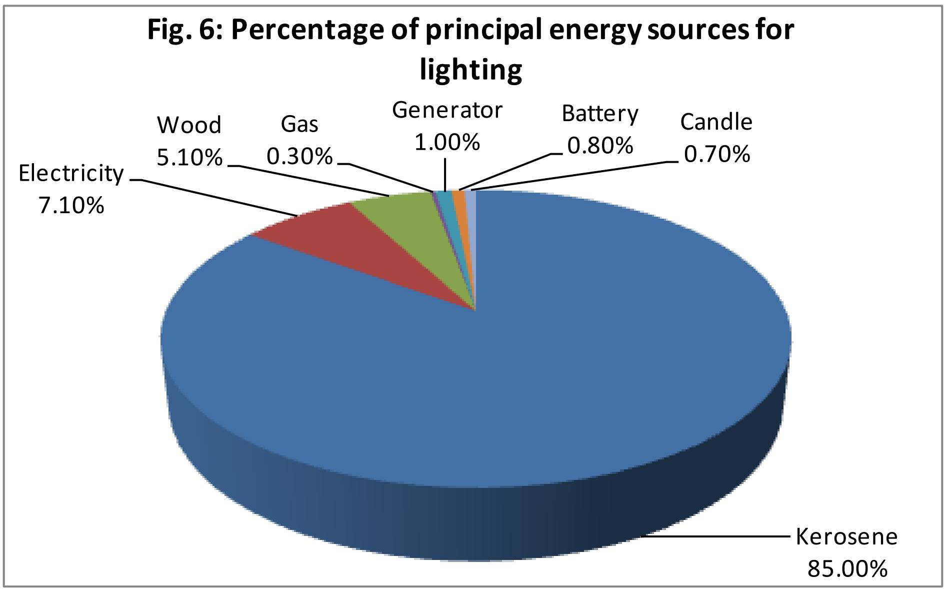


Source: NPA and BKPS

Private Sector Generators

Figure 6 shows the national percentages of principal energy sources used for lighting in Sierra Leone; kerosene is predominantly used for lighting (85%) followed by electricity (7.1%)

Figure 3.7 Percentage of principal energy sources for lighting



Source: Statistics Sierra Leone (2004 Census)

As a result of the ages of the NPA generators compounded with the increase in demand for electricity, frequent and long periods of power failure were experienced in the Western Area. Thus, the national electricity production between 2000 and 2007 was not satisfactory. Within this period the use of imported petrol/diesel generators became the only alternative for the various sectors.

Some of the major private auto producers are the Rutile mining company, the Sierra Leone Brewery, the Sierra Leone Cement factory, Shankerdas, UN institutions and Embassies. For instance, the Sierra Leone Brewery has a generating capacity of 800 kW, the Sierra Leone Cement factory has a generating capacity of 6MW, the Rutile mining company has a total of about 14 MW and the Embassy of the United States of America in Freetown has an installed capacity of 4.8 MW.

The estimated national private generation is in the order of 80 MW. The actual capacity is higher than this value due to non-registering of some generators. All these private generators are using either petrol or diesel, but unfortunately no reliable data exist on them.

GHG Emission from Electricity Generation

For this sector, only emissions from the public utilities (NPA and BKPS) are considered as no reliable data are available on fuel consumption rates for the private sector and institutions that generate their own electricity. Table 3.5 shows the emissions factors used in the computation of the amount of the various GHGs emitted from the electricity sector, whilst Table 3.6 shows the annual emission of GHGs from the electricity sector.

Table 3.5 Emission Factors of HFO and Diesel

Emission Factor [kg/GJ]	CO	SO2	CH4	N2O	CO2
HFO	0.015	0.15	0.0031	0.00034	78.4
Diesel	0.017	0.0065	0.00083	0.00037	76.2

Source: www.tpub.com/content/altfuels05/3813/38130304.htm

Table3.6 Annual emission of GHGs from the electricity sector

	CO	SO2	CH4	N2O	CO2
2000	11,088.96	90,956.24	1,964.58	249.48	56,415,648.18
2001	19156.07	164,515.81	3,515.07	431.67	98,029,392.76
2002	20,945.87	189,033.16	3,993.59	472.86	107,896,319.98
2003	18,156.53	172,100.21	3,597.01	410.66	94,165,621.49
2004	14,274.90	137,223.79	2,859.47	323.05	74,182,541.90
2005	9,071.02	85,425.05	1,787.94	205.11	47,002,156.80
2006	5,799.70	52,104.53	1,101.90	130.91	29,857,062.35
2007	5,561.11	48,773.48	1,037.08	125.41	28,536,904.25
2008	22,114.16	9,165.46	1,091.34	481.37	99,178,409.52
2009	14,623.71	8,225.33	757.21	318.53	65,752,468.82

3.3.4 1A2 Fuel Combustion Activities - Manufacturing Industries and Construction

For Sierra Leone, this sub-sector comprises Food processing and Beverages. The main manufacturing industries present in Sierra Leone are Food processing, Beverages and Mining (excluding fuels) and Quarrying. Activity data (fuel consumption) for food and beverage are not compiled routinely, and hence emissions from these sub-sectors are included in Non-Specified Industry.

Table 3.7 Manufacturing Industries and Construction

	CO2	CH4	*N2O*	NOx	CO	NMVOCs	SO2
1 ENERGY							
1A2 -Manufacturing Industries and Construction	*NE*	*NE*	*NE*	*NE*	*NE*	*NE*	*NE*
1A2c - Chemicals	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
1A2e - Food Processing, Beverages and Tobacco (Sugar)							
1A2f – Non-Metallic Minerals	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*	*NO*
1A2i - Mining (excluding fuels) & Quarrying	*NE*	*NE*	*NE*	*NE*	*NE*	*NE*	*NE*
1A2m - Non-specified Industry	*NE*	*NE*	*NE*	*NE*	*NE*	*NE*	*NE*

Sugar Industry (1A2e)
The energy requirements for the manufacture of sugar from sugar cane are derived from renewable sources (bagasse, wood) as well as from heavy fuel oil. Best practices in the sugar industry entail the use of bagasse for all factory (steam and electricity) needs with excess energy used to supply electricity to the public grid. The isolation of heavy fuel oil (to supplement bagasse) in the two sugar factories (Magbass and ADDAX) allows the identification not only of the GHG emissions associated with heavy fuel oil combustion in the sugar industry, but also the potential for eliminating heavy fuel oil use if bagasse were in sufficient supply. The CO2 emissions from the renewable fuels (bagasse, wood

and elephant grass used as brickets) are noted as memo items and are not included in the national CO2 emissions.

12Ae Food processing, Beverages and Tobacco (ISIC Division 12 and 16)

Food processing is very low but the production of soft drinks and other beverages do occur. The then only tobacco company (Aureol Tobacco company closed down many years ago). Most of the fuel used for these activities is captured under the energy sector.

1A2i Mining (Excluding Fuels) and Quarrying (ISIC Divisions 13 to 14)

Mining of diamonds, bauxite, iron ore, rutile, gold etc. are major activities in this sector. There is also quarrying for sand (for road and building construction). Fuel use data are compiled for the mining industries but data are not available to allow estimates of fuel use for their activities. Most of the fuel used in quarrying is associated with the transportation of materials and is captured in the energy/ transportation sub -sector. **There is however no estimates for the mining sector reported here.**

For mining companies, diesel fuel is used for off -road mining equipment and for transporting mined minerals to ports for export and processing abroad. Fuel used in this sector is from the national pool and sector quota is not prescribed.

1A2j Wood and Wood Products (ISIC Division 20)

Activities included in this sector consist of all logging operations mainly by foreign based companies. They export timber (round wood), whilst sawn timber for the local construction market is provided by numerous cottage industries.

Non -specified Industry (1A2m)

Activities included in this sector consist of all manufacturing other than those described above. It includes food and beverage industries.

3.3.5 1A3 Mobile Combustion (Transportation) Sector

For Sierra Leone, this sub -sector comprises road transportation, railways, waterborne navigation, other navigation and civil aviation.
The transport sector of Sierra Leone is characterised by on-road vehicles that ply the roads, boats with outboard motors that ply the river estuaries, ferries, the navy division of the military, trains used by the mining companies and local fishing trawlers. The transport sector energy consumption for the year 2010 is given below.

Table 3.8 Transport sector energy consumption for the base year 2010

Year 2010	Energy Consumption by type of transport (GWh)			Total (GWh)
	Aviation	Mariti	Land	

		me/River	Road	Railway	
Gasoline	4	8	597	-	**609**
Aviation fuels (ATK, etc.)	41	-	-	-	**41**
Gas Oil (Diesel fuel)	3	65	443	-	**511**
Natural Compressed Gas	2	3	-	-	**5**
Electricity	-	-	-		**-**
Others…	-	-	-		-
					1166

ATK: Aviation Turbine Kerosene; Source:

The sector includes emissions from on-road and off-road mobile sources, aviation, railways and water-borne navigation. Fuel combustion from mobile sources produces the direct GHGs (CO_2,CH_4, N_2O) as well as the indirect GHGs (CO, NMVOCs, SO_2, PM and NOx). Fuel use for the aviation and marine sources do not include fuel delivered to international bunkers.

Sub-sector Category Description

1A3a Civil Aviation: Sierra Leone has only one International Airport namely; Lungi International Airport. Aviation emissions from the use of jet fuel and aviation gasoline include CO_2, smaller amounts of NOx, CO, SO_2, NMVOC and particulate matter, and much smaller amounts of CH_4 and N_2O. Aircraft emissions are generally disaggregated into emissions during landings and take-offs (LTOs) and cruising mode. Aviation emissions relevant to Sierra Leone are those for International Aviation (category 1A3ai) only and not Domestic Aviation (1A3aii) since there are no domestic flights within the country.
The Republic of Sierra Leone Armed Forces (RSLAF) does not own military jets hence estimates for this category **1A5b** was not done.

Transport Sector Data
Data for vehicle population in the transport sector was collected from the Sierra Leone Road Safety Authority (SLRSA) but could not be used for emission calculations.

1A3b Road Transportation

The Road Transportation sub-sector includes all types of light-duty vehicles such as private cars, taxis, light vans, lorries , automobiles and light trucks, and heavy-duty vehicles such as trucks, tractor trailers and buses and on-road motorcycles. These vehicles operate on liquid (petrol,gasoline and diesel) fuels. The GHGs emitted from fuel combustion in road transportation are CO_2, CO and NOx as well as emissions associated with catalytic converter use (NOx, N_2O, and CH_4) or vehicle operation (NMVOCs).

Although road transport is **a key category** sector for Sierra Leone, it was not feasible to collect historical country specific fuel (petrol, gasoline and diesel) carbon content data (as required for Tier 2).
Generally, CO_2 emissions and other GHGs from the transport sector are usually calculated based on the following factors;

1. Age
2. Vehicle mileage travel (VMT).
3. Driving profile of vehicle.
4. Type of fuel vehicle is using and consumption rate.
5. Class of vehicle that ply the roads.
6. The technology type
7. Hot exhaust emissions and Cold-start emissions.

One other major difficulty is that the transport sector is dominated by second hand vehicles (taxis, light vans, trucks etc) from developed countries. Since these relevant data were not readily available, GHG emissions were not estimated for the transport sector.

1A3c Railways

Rail transportation in Sierra Leone is limited to the movement of bauxite and iron ore by two giant companies, namely; Timis corporation and Shang Steel all operating in the Southern and Northern part of Sierra Leone. There are no passenger rail services in the country.
Fuel consumptions by the railways for these two companies were not available, hence GHG emissions for rail road could not be estimated.

1A3d Water -borne Navigation

Waterborne vessels in this category are mainly dugout canoes with outboard engines used by local fishermen, recreational with limited movement of goods between Sierra Leonean ports and also boats used by water taxi companies to ferry passengers from mainland Freetown across the estuary to the country's only international airport.

1A3e Other Navigation

These sub -sectors include emissions from fuels used to propel domestic and international water -borne vessels excluding fishing vessels (Category 1A3d), Fishing (1A4c) and other [primarily military] (1A5b) and off -road vehicles.
Fuel deliveries to local end users and to international bunkers are tracked but some fuel use data for domestic vessels are likely included in retail fuel sales at service stations and to some commercial customers.

1A4 Fuel Combustion Activities – Other Sectors

This sector includes emissions from combustion activities in commercial and institutional buildings (1A4a), residential buildings (1A4b) and emissions in agriculture, forestry and fishing industries. The emissions include those from fuel combustion for the generation of own -use electricity and heat. These were however not estimated due to unavailability of relevant sector specific data, hence the promoting the use of the Tier-1 approach.

1A4b Residential Buildings

Residential fuel use in Sierra Leone is limited to LPG for cooking and smaller amounts of kerosene. Wood and charcoal are also mostly used for cooking. Emission factors (Tier 1) could be taken from the 2006 IPCC Guidelines. However, due to the absence of disaggregated data, emissions from residential buildings were also not estimated in this inventory.

1A5 Fuel Combustion Activities - Non -Specified

Sources in this category include stationary combustion sources not elsewhere listed and mobile emissions from military aviation and marine activities. Military fuel use data were however not available hence not estimated.

1B2 Fugitive Emissions from Fuels – Oil and Natural Gas

Fugitive emissions mainly result from mining and processing of coal, oil and natural gas. Coal reserves are currently not in existence in Sierra Leone. However, exploration activities for oil and natural gas are underway and until this is realized, fugitive emissions will not be included in the inventory of Sierra Leone's GHG emissions.

INVENTORY DATA SOURCES AND METHODOLOGY FOR THE ENERGY SECTOR

Fossil fuel is widely consumed in almost every sector of the economy for national development; e.g., electricity generation, large-scale agricultural activities, mining, industries, residential areas, transport (air, sea and land), infrastructural developments etc. In this regard, a complete record of the quantities of each fuel type consumed in each "end use" activity is a considerable task since it is data intensive.

The choice of method is country-specific and is determined by the level of detail of the activity data available. The "bottom-up" (Tier-2 or 3) approach are generally the most recommended methods for those countries whose country energy consumption data are reasonably complete.

For least developed countries like Sierra Leone, where required activity data are incomplete or in most cases not available at all, the "top-bottom" or "Reference Approach" method Tier-1) is preferred. That is, only import data by fuel-type are used. In view of the above therefore, since detailed activity data by sector for fuel consumptions were not available, only primary country activity data for apparent fuel consumptions were collected to the extent possible from the National Petroleum Unit/Agency-Sierra Leone.

DATA SOURCE

Primary country activity data for apparent fuel consumptions were collected to the extent possible from the **National Petroleum Agency-Sierra Leone.** (see table 3.9 below).
Relevant data on Sierra Leone's fuel import for the period 2005-2013 was organized in a format prescribed by the Reference Approach method of the 2006 IPCC Guidelines for GHG inventories.
Apparent fuel consumption statistics and the appropriate IPCC default emission factors that reflect the fuel types in Sierra Leone were used to estimate CO_2 emissions from the energy sector in the country.
Care was taken to the extent possible to avoid "*double counting*" of emissions. This was achieved by only considering total imports of the various categories of fuel types instead of considering consumptions in the various energy sub-sectors (e.g. industrial, residential, and transport sectors).

Table 3.9 Data source for the energy sector

Sector	Data Type	Data Source	Principal Data Providers
Energy sector	Petroleum Products Imports Volumes	National Petroleum Unit	National Petroleum Agency

Table 3.10 PETROLEUM PRODUCTS IMPORTS VOLUMES – METRIC TONS

2005 - 2013

Period	Petrol Mts	Diesel Mts	Kerosene/Jet A1 Mts	Marine Fuel Oil Mts	Total Quantity (Mts)
2005	54,105.434	177,931.077	33,087.807	18,767.779	283,892.097
2006	61,853.335	173,151.229	28,145.271	18,824.618	281q,974.453
2007	51,683.768	114,697.696	21,557.454	8,798.891	196,737.809
2008	88,564.436	161,143.440	15,176.065	18,324.754	283,208.695
2009	64,633.149	107,997.337	13,320.143	6,443.538	192,394.167
2010	79,881.049	99,759.384	12,090.485	22,390.951	214,121.869
2011	86,620.287	144,624.715	14,111.209	19,100.822	264,457.033
2012	90,662.986	188,963.260	14,159.749	20,125.184	313,911.179
2013	110,423.858	236,282.695	14,050.960	29,980.402	390,737.915

Source; National Petroleum Agency

METHODOLOGY

The methodology used here is based on the Revised 2006 IPCC Guidelines for National GHG inventories recommended for use by parties to the UNFCCC in preparation for national communications with regards to inventories. The energy sector worksheets in the IPCC workbook were duly completed using the recent IPCC Inventory software.

The Tier 1 approach was adopted and used here in estimating GHG emissions in the energy sector with CO_2 as the dominant GHG considered. This is achieved by simply obtaining estimates of total national emissions by just accounting for the carbon content in various fuel types supplied to the economy. In accounting for fuels supplied, the distinction has been made between primary fuels (i.e. fuels found in nature such as crude oil, natural gas, coal which the country does not produce and secondary fuels or fuel products, such as gasoline and lubricants, which are derived from primary fuel on which Sierra Leone depends.

Results

CALCULATED CO_2 EMISSIONS BY FUEL-TYPE FROM (2005-2013)

The calculated energy sector GHG emissions by fuel-type are given below in Tables 3 – 12 and Figures 1-22.

Table3.11 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2005

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	54,105.434	3414.05
Diesel Oil	177,931.077	13184.69
Jet Kerosine	33,087.807	2365.78
Marine Fuel Oil	18,767.779	1375.68
TOTAL	**283,892.097**	**20340.20**

Fig.3.8 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2005

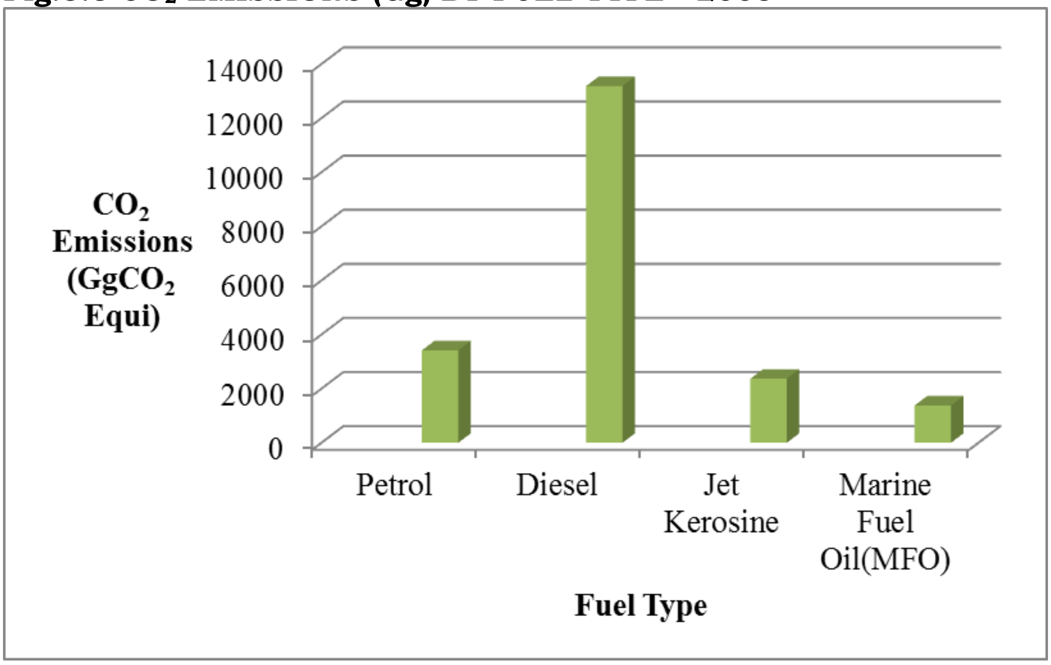


Table3.12 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2006

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	61,853.335	3902.95
Diesel Oil	173,151.229	12830.50
Jet Kerosine	28,145.271	2012.39
Marine Fuel Oil	18,824.618	1379.84
TOTAL	**281,974.453**	**20125.68**

Fig.3.9 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2006

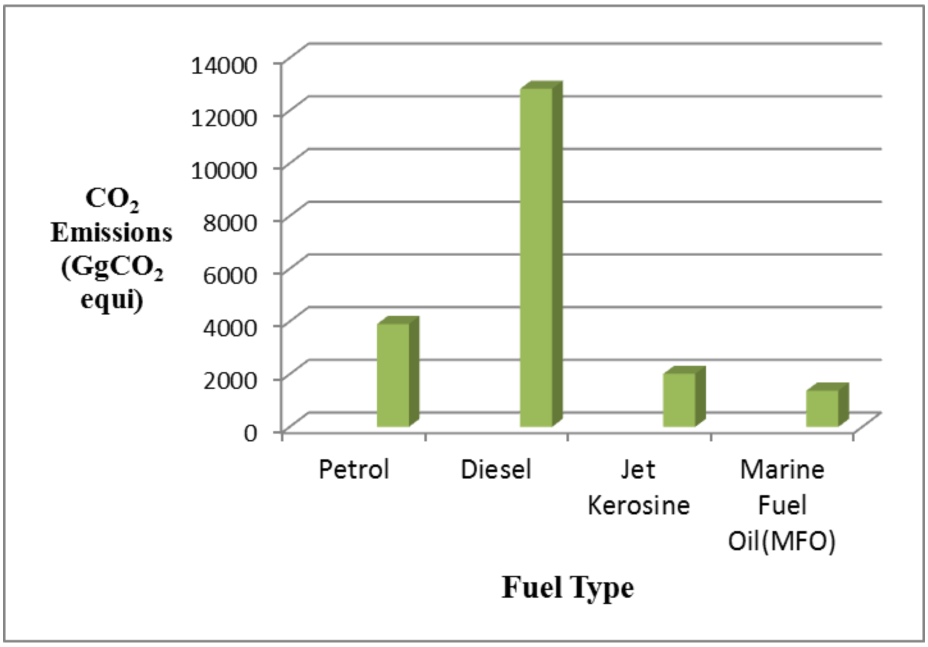


Table 3.13 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2007

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	51,683.768	3261.25
Diesel Oil	114,697.696	8499.01
Jet Kerosine	21,557.454	1541.36
Marine Fuel Oil	8,789.891	644.96
TOTAL	**196,737.809**	**13946.66**

Fig.3.10 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2007

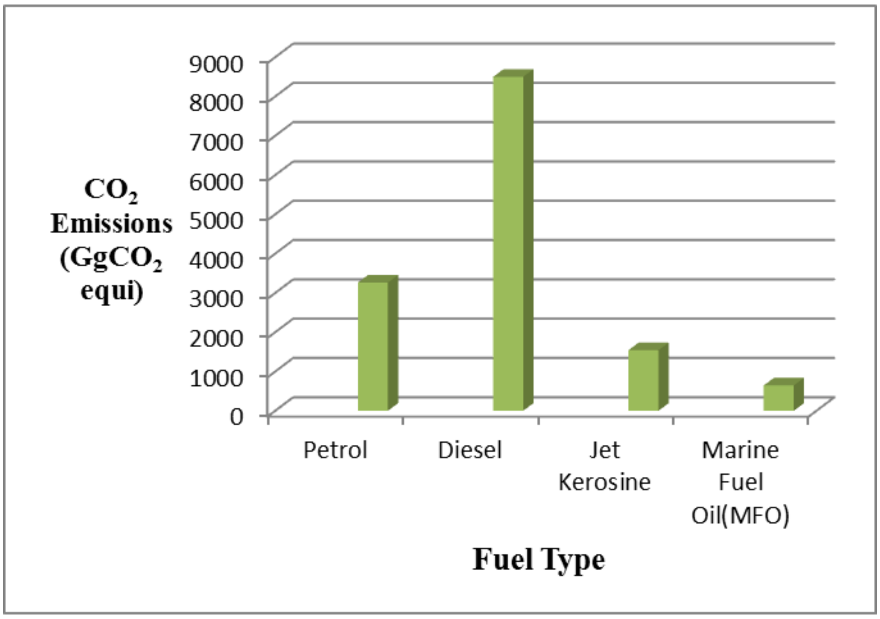


Table 3.14 CO_2 EMISSIONS (Gg) BY FUEL TYPE –2008

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	88,564.436	5588.42
Diesel Oil	161,143.440	1194.73
Jet Kerosine	15,176.065	1085.09
Marine Fuel Oil	18,324.754	1343.20
TOTAL	**283,208.695**	**19957.43**

Fig.3.11 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2008

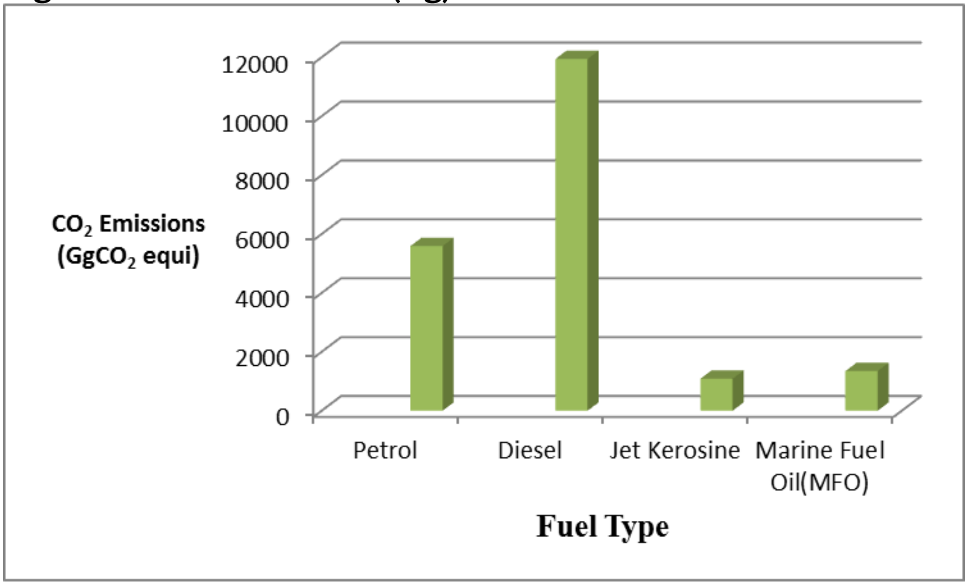


Table3.15 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2009

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	64,633.149	4078.35
Diesel Oil	107,997.337	8002.60
Jet Kerosine	13,320.143	952.39
Marine Fuel Oil	6,443.538	472.31
TOTAL	**192,394.167**	**13505.65**

Fig.3.12 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2009

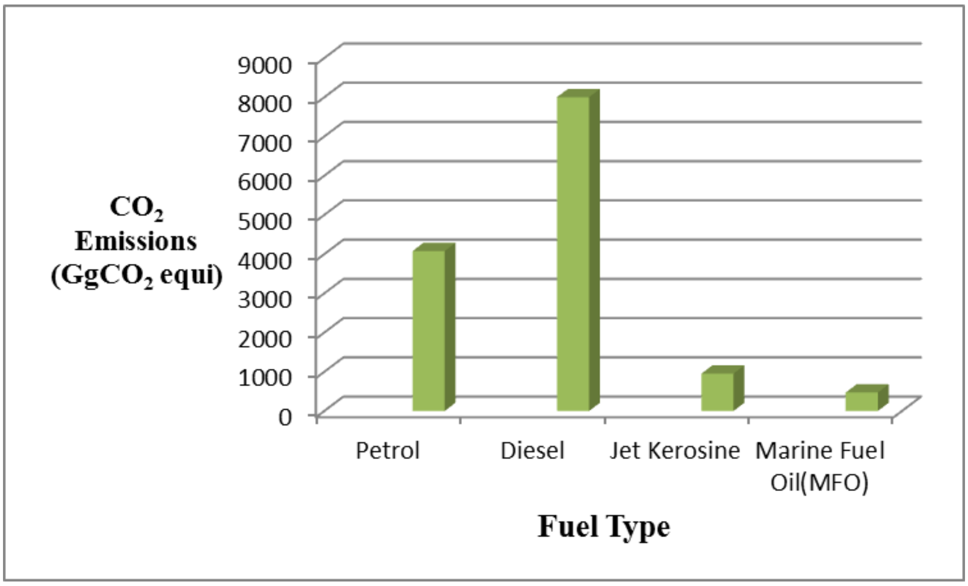


Table 3.16 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2010

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	64,633.149	5040.49
Diesel Oil	107,997.337	7392.17
Jet Kerosine	13,320.143	864.47
Marine Fuel Oil	6,443.538	1641.26
TOTAL	**214,121.869**	**14938.39**

Fig.3.13 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2010

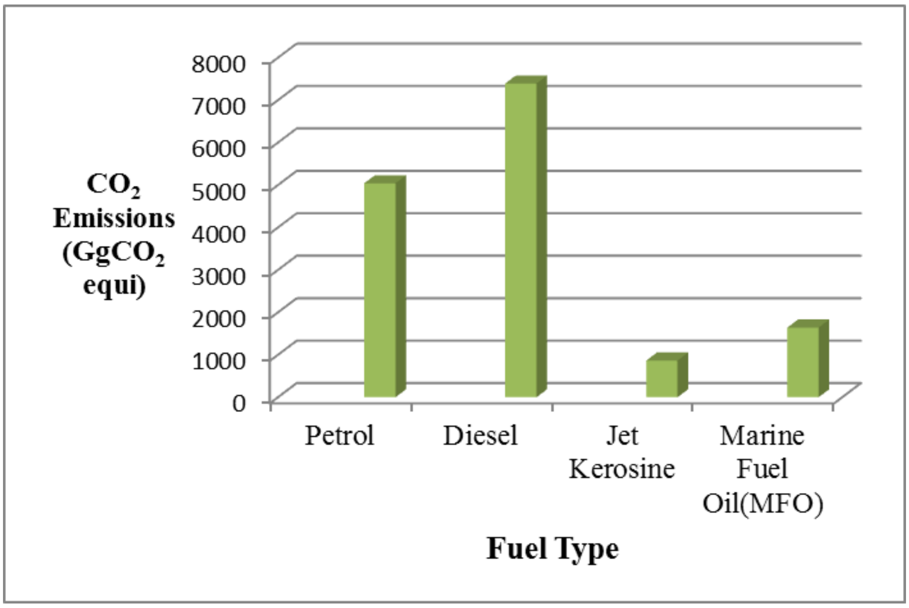


Table 3.17 CO_2 EMISSIONS (Gg) BY FUEL TYPE – 2011

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	86,620.287	5465.74
Diesel Oil	144,624.715	1071.69

Jet Kerosine	14,111.209	1008.95
Marine Fuel Oil	19,100.822	1400.09
TOTAL	**264,457.033**	**18591.47**

Fig.3.14 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2011

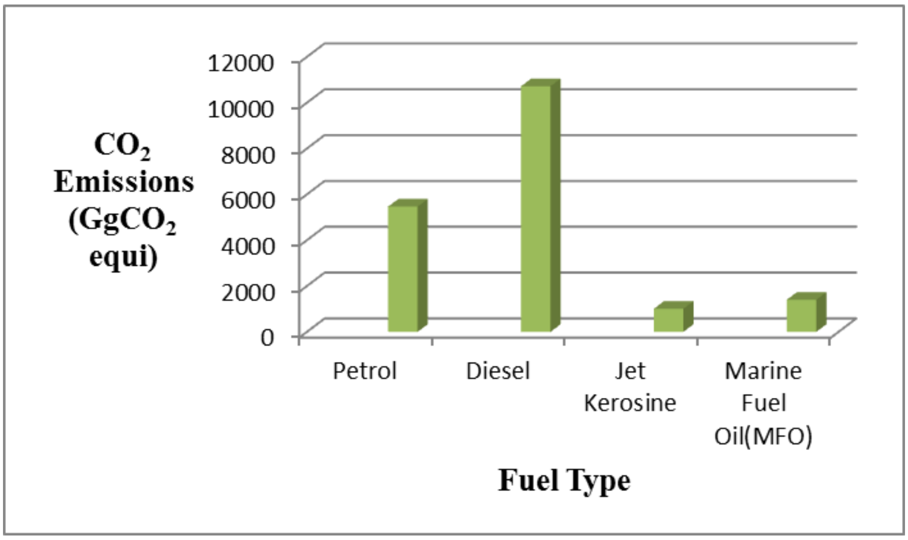


Table 3.18 CO_2 EMISSIONS (Gg) BY FUEL TYPE – 2012

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	90,622.986	5720.83
Diesel Oil	188,963.260	14002.16
Jet Kerosine	14,159.749	1012.42
Marine Fuel Oil	20,125.184	1475.18
TOTAL	**313,911.179**	**22210.59**

Fig.3.15 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2012

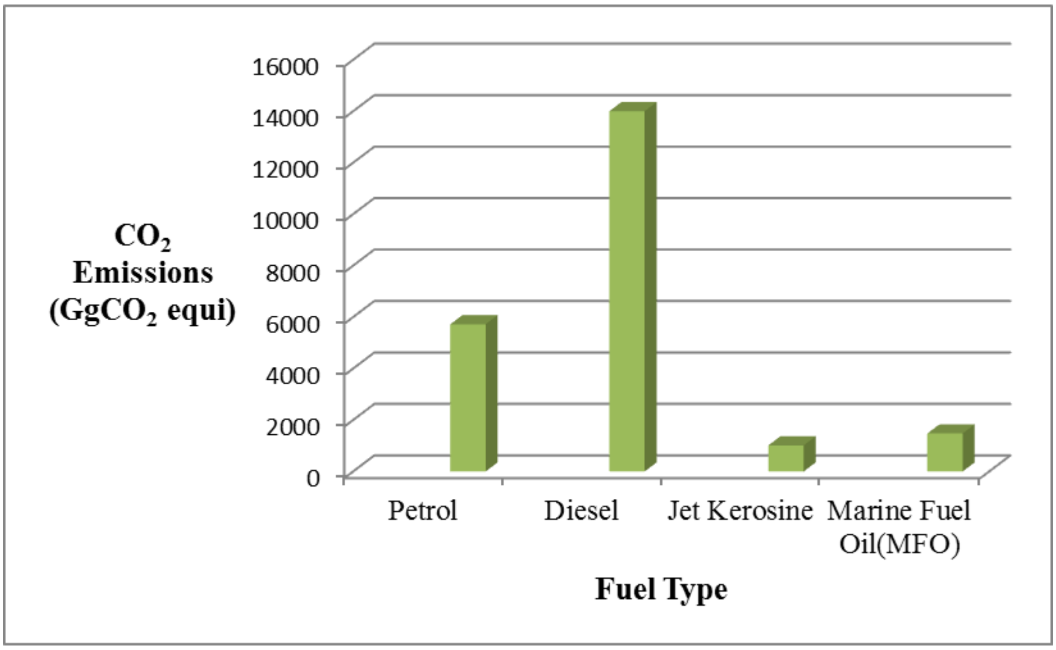


Table 3.19 CO_2 EMISSIONS (Gg) BY FUEL TYPE – 2013

FUEL TYPE	APPARENT CONSUMPTION (MT)	CO_2 EMISSIONS ($GgCO_2$ equ.)
Petrol	110,423.858	6967.75
Diesel Oil	236,282.695	17508.55
Jet Kerosine	14,050.960	1004.64
Marine Fuel Oil	29,980.402	2197.56
TOTAL	**390,737.915**	**27678.50**

Fig.3.16 CO_2 EMISSIONS (Gg) BY FUEL TYPE - 2013

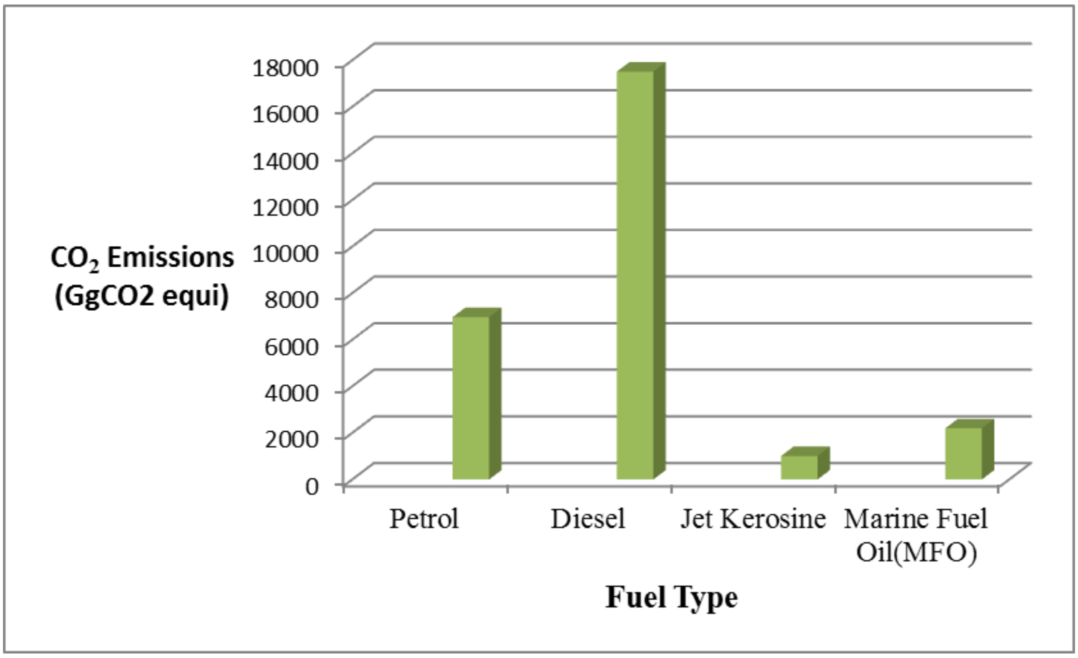


Fig. 3.17 Disaggregated fuel consumptions (MT) by fuel type per year.

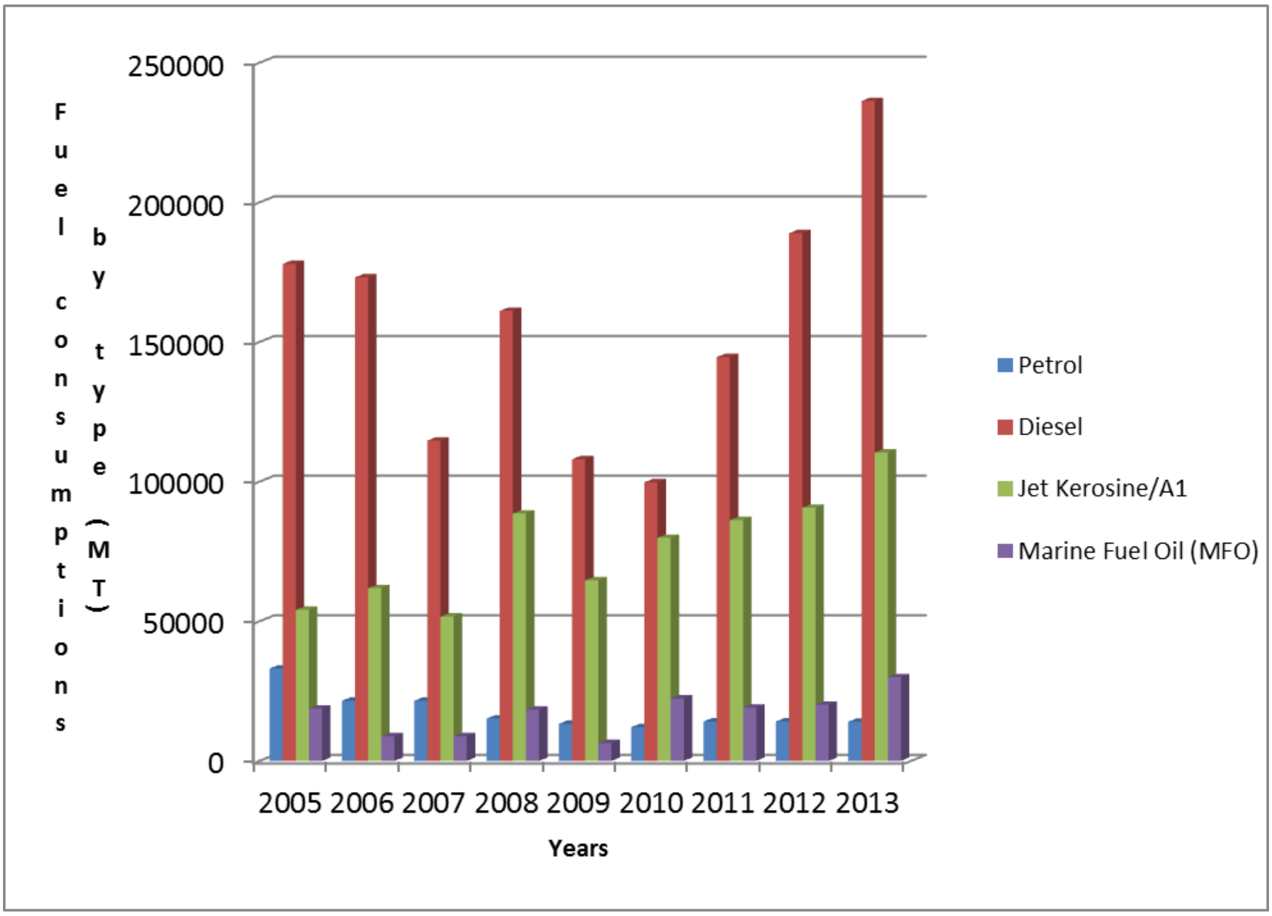


Fig. 3.18 Combined/Total fuel consumptions (MT) per year

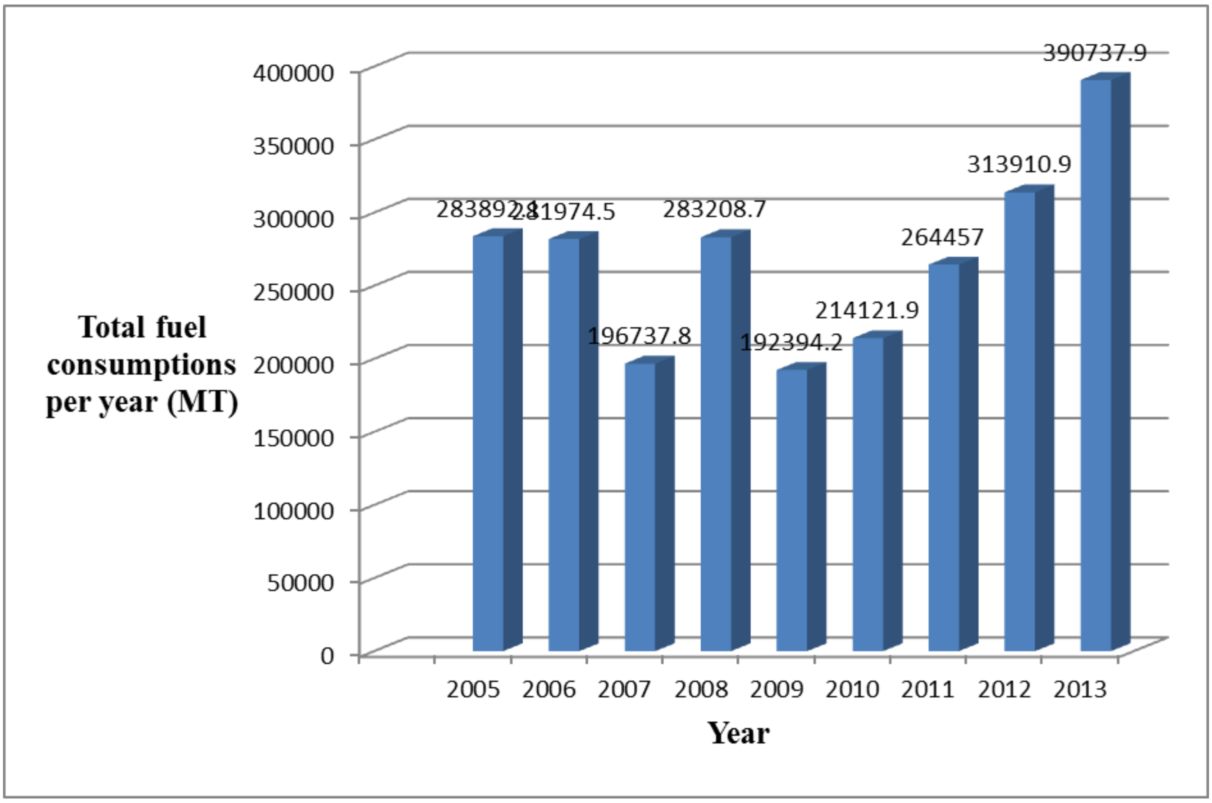
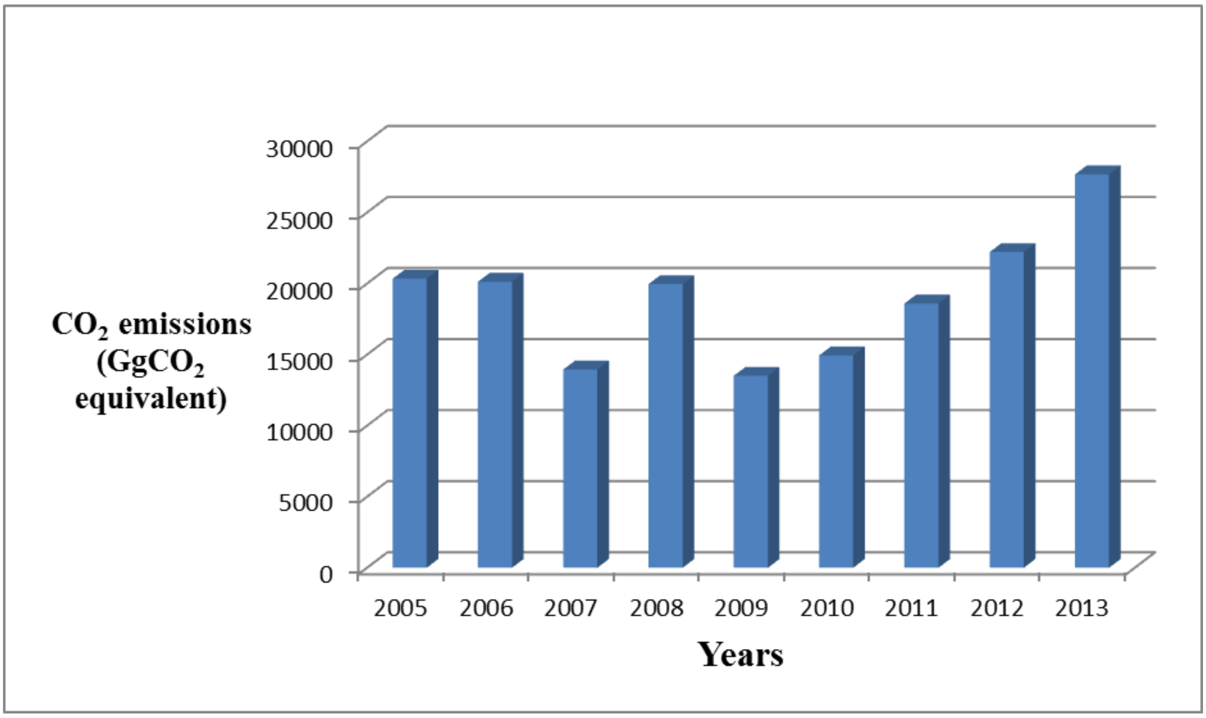


Table 3.19 Total CO_2 emissions ($GgCO_2$ equivalent) per year

Years	Total CO2 Emissions(GgCO2)/Year
2005	20340.00
2006	20125.68
2007	13946.66
2008	19957.44
2009	13505.66
2010	14938.39
2011	18591.47
2012	22210.59
2013	27678.50

Fig. 3.19 Total CO_2 emissions ($GgCO_2$ equivalent) per year



FUEL WOOD AND CHARCOAL CONSUMPTIONS

Most of the energy production and use in Sierra Leone is concentrated in the household sub-sector, where biomass, in the form of fuel-wood and charcoal is used for cooking and kerosene mostly used for lighting. Traditional biomass accounts for over 80% of total energy used in the country. Modern service, electricity, petroleum products, including LPG, and non-biomass renewable, represent only a small percentage of energy used in the country. Almost 80 % of the electricity used is in the industrial, mining and residential sub-sectors, while about 50% of petroleum used is in the transport sub-sector. The country possesses vast potential in renewable energy in the form of biomass from agricultural wastes, hydro, wind and solar power, which remain virtually untapped.

Fuel Combustion Activities – Other Sectors (1a4)

This sector includes emissions from combustion activities in commercial and institutional buildings (1A4a), residential buildings (1A4b) and emissions in agriculture, forestry and fishing industries. The emissions include those from fuel combustion for the generation of own -use electricity.

Commercial and Institutional Buildings (1A4a)

The sub -sector includes emissions from the following activities (ISIC Codes):
• Water supply (ISIC 41)
• Wholesale and retail trade; repair of motor vehicles, motorcycles and personal and household goods (ISIC 50 -52)
• Hotels and restaurants (ISIC 55)
• Supporting and auxiliary transport activities; activities of travel agencies (ISIC 63)
• Post and telecommunications (ISIC 64)
• Financial intermediation (ISIC 65 – 67)
• Real estate, renting and business activities (ISIC 70 – 74)
• Public administration and defense; compulsory social security (ISIC 75)
• Education (ISIC 80)
• Health and social work (ISIC 85)
• Other community, social and personal service activities (ISIC 90 – 93)
• Extra -territorial organizations and bodies (ISIC 99).

Fuel use in this sector is limited to cooking since there is no heating of buildings. Fuel use data for government end users are not routinely captured by ME. The fuels reported include gasoline, diesel, heavy fuel oil and lubricants. Liquefied petroleum gas (LPG) is allocated geographically (urban and rural),to a category called “Other” and “Other Manufacturing”. These allocations do not permit reliable estimates of residential and commercial end users. The category “Other” was arbitrarily assumed to be commercial and institutional end users and urban and rural sales were assumed to be residential. The “Other Manufacturing” category was assigned to the manufacturing sector.

A recent survey of residential consumer energy end use did not include sufficient information to make more reliable estimates of residential LPG use. The gasoline and diesel fuel and lubricants use are assumed to be primarily for transportation with smaller amounts for own -use electricity generation. It was not feasible to estimate the split between these end uses and all of these fuels used were allocated to transportation.
Sales of LPG were assumed to be for cooking at various institutions. It is also possible that some commercial institutions obtained LPG from retailers. Emission from this sector was not estimated.

Residential Buildings (1A4b)

Residential fuel use in Sierra Leone is limited to LPG for cooking and smaller amounts of kerosene in major cities. Wood and charcoal are also used for cooking predominantly in the rural and peri-urban areas. Emission from this sector was not estimated.

Emissions in Fishing Industries.

Activity data (i.e., fuel consumption) for estimating the fuel use by domestic fishing and recreational boating as well as limited commercial (cargo) traffic between ports are not available since some of the sales are recorded in other end -use categories.

3.3.1 Fuel Combustion Activities - Non -Specified (1A5)

Sources in this category include stationary combustion sources not listed elsewhere and mobile emissions from military aviation and marine activities. Military aviation category does not exist in Sierra Leone and hence fuel use data were not available for period under consideration.

Emission factors for CO2 are determined by the carbon contents of fuels which, in general, are reliably known for liquid petroleum based fuels. The fuels of interest in Sierra Leone are motor and aviation gasoline, diesel and residual fuel oils, kerosene, and LPG. Large amounts of charcoal and wood are used. The uncertainties in the CO2 emission factors were based on the ranges provided for the default emission factors for stationary combustion given in the 2006 IPCC Guidelines.
Uncertainties for CH4 and N2O emission factors were taken as -70% to +230% - - also based on values given in the 2006 IPCC Guidelines.

Activity Values

National fuel consumption data are not easy to come by as it is uncertain as to which institution is responsible for it's compilation, while sectoral fuel data for the mining industries are compiled by the industry themselves. In the former case (sales as well as import data), reports are filed by the petroleum marketing companies and the petroleum agency.
Complete fuel uses for some activities (mining, rail transportation and lime manufacture) were not always available. **Activity data are not disaggregated by sectors.**

Because of these groupings, the required reports for some IPCC categories were either not reported separately (Food Processing and Beverages) or were likely incomplete.

Transport Authority should help to provide estimates of the annual vehicle miles travelled.

RESULTS AND DISCUSSIONS FOR NATIONAL TOTALS

As can be seen from above calculations, the total CO_2 emissions from fossil fuel combustion for the respective years 2005 - 2013 is shown in Fig.11 and the corresponding total CO2 emissions in GgCO2 equivalent is shown in Fig. 12. There is an increase trend in the emissions of CO_2 in this interval due partly to the relative positive performance of Sierra Leone's economy during this period. This relative robust economic activity increased the demand for fuels; with an associated increase in the GHG emissions as these fuels are combusted. The combustion of petrol and diesel appear to be the dominant contributing sources of CO_2 emissions. The emission of CO_2 in the energy sector therefore follows an increase pattern in direct proportion to apparent petroleum products consumption.

Difficulties specific to the Energy sector

- fine-tune data to make a better assessment of emissions through the sector method;
- conduct a survey following a relatively less expensive methodology to establish a baseline case with more elaborate collection tools and;
- use this survey to make a better assessment of the technical characteristics of production tools in anticipation of mitigation measures.
- Lack of data on auto-producers due to the low keeping of energy statistics either as a result of lack of interest or for reasons of supply in a parallel market;
- Disregard by many private operators of the energy sector's challenges and the challenges related to climate change particularly the opportunities that the Clean Development Mechanism (CDM) offers;
- Existence of too little official figures on energy data, which tends to prove that this sector is hardly considered at the strategic level by vocational and statistical institutions;
- Confidentiality of energy data for security grounds (army) or taxation (deductible expenses);
- Shortage of energy statistics professionals in institutions..

Uncertainties, Quality Assurance And Control for the Energy Sector
Emission Factors

Emission factors for CO2 are determined by the carbon contents of fuels which, in general, are reliably known for liquid petroleum based fuels but are less accurate for solid fuels. The fuels of interest in Sierra Leone are motor and aviation gasoline, diesel and residual fuel oils, kerosene, and LPG. Large amounts of charcoal and wood are used. The uncertainties in the CO2 emission factors were based on the ranges provided for the default emission factors for stationary combustion given in the 2006 IPCC Guidelines.
Uncertainties for CH_4 and N_2O emission factors were taken as -70% to +230% - - also based on values given in the 2006 IPCC Guidelines.

3.4 Industrial Processes & Product Use (IPPU) GHG Emissions

Description of the sector

This sector addresses GHG emissions that are released from industrial processes that chemically or physically transform materials and from the use of products which contain GHGs.

The industrial sector in Sierra Leone is underdeveloped. The manufacturing industry in Sierra Leone consists mainly of processing raw materials and light manufacturing for the domestic market, small-scale manufacturing (beverages, textiles, cigarettes, footwear); Sierra Leone Brewery Limited produce beer, stout, malt and mineral water. Various cottage industries exist and these process and produce food on relatively small scale.

Table3.20 Production of Manufacturing Establishments, 2000–07(In units indicated)

Products	2000	2001	2002	2003	2004	2005	2006	2007
Food and beverages								
Biscuits (*1000 kilograms)	0	0	0	0	0	0		
Confectionery (*1000 kilograms)	382	500	1,032	1,505	2,724	2,074	1056.8	1424.73
Beer and stout (*1000 crates)	188	401	915	771	942	1,012	832.1	780.11
Spirits (*1000 litres)	0	0	0	0	0	0		
Soft drinks (*1000 crates)	1,429	1,701	1,872	1,113	1,584	1,908	2088.75	2431.7
Household products and construction								
Matches (cartons)	0	0	0	0	0	0		
Washing soap (metric tons)	493	149	460	492	268	417		
Cement (*1000 bags)	1,593	3,108	2,883	3,390	18,046	18,045		
Nails (cases)	0	0	0	0	0	0		
Paint (*1000 litres)	394	318	744	725	169	135	649	713.6
Miscellaneous								
Cigarettes (*1000000 sticks)	...	...	...	...	...	...		
Acetylene (*1000 cubic feet)	100	91	99	114	12	219	291.33	191.45
Carbon dioxide (*1000 cubic feet)	49	0	26	2	0	0		
Oxygen	721	547	1,131	1,609	428	966	791.64	423.85

(thousands of cubic feet)								
Salt (metric tons)	3,970	1,833	1,821	1,005	0	0		
	(Annual percentage change)							
Beer and stout	…	113.0	128.1	-15.7	22.0	7.0		
Soft drinks	81.5	19.0	10.1	-40.5	42.0	20.0		
Cigarettes	…	…	…	…	…	…		

Sources: BSL Bulletin, Bank of Sierra Leone; and data provided by the Sierra Leonean authorities

The Industrial Processes sector

The Industrial Processes sector in Sierra Leone is relatively small, and the main GHG emissions reported are derived from the categories 2A Mineral Products (2A1 Cement production, 2A2 Lime Production, 2A3 Limestone and Dolomite Use, 2A6 Road Paving With Asphalt) and 2D Other Production (2D2 Food and Drink). Most of the categories of this sector do not occur in the country. For example soda ash production, glass production, chemical industry, metal production, glass production and production of halocarbons and SF6 do not exist. Other categories were not estimated due the unavailability of activity data (e.g. consumption of halocarbons and SF6).

Inventory of Greenhouse Gas Emissions from the Industrial Sector

Greenhouse gas (GHG) emissions of industrial processes includes emissions of all green house gases from industrial activities that are not related to energy.

In general, the industrial processes addressed in this sector can be grouped into two categories: mineral product and other products. This grouping is consistent with the general categorization/grouping of Intergovernmental Panel on Climate Change (IPCC) in the Industrial sector worldwide. Minerals produced/and or used includes cement production, lime production and use, road paving with asphalt whilst other products include beverages (beer, Guinness, spirit and malt) and food (bread, biscuits & confectionaries). Other industrial processes are not included either because their associated activities are not practiced in Sierra Leone or their activities do not involve raw material processing but rather imported materials are mixed to obtain the desired product thereby resulting in virtually no emission.

All emission estimates were determined using the IPCC reference manual and software packages. Default values presented in the IPCC guidelines were used in the absence of country-specific (emission) factors. In view of the above, Table 4.1 shows potential type of GHG emissions associated with selected industrial activities carried out in Sierra Leone.

Table 3.21 Potential emissions from industrial activities carried out in Sierra Leone		
		Type of greenhouse gas emitted
MINERAL PRODUCT		
	Cement	CO_2, SO_2
	Lime production	CO_2, SO_2
	Lime use	CO_2,
	Road paving	NO_X, NMVOC, CO, SO_2
FOOD & DRINK PRODUCTION		
		NMVOC

Description of Emission Sources in the Industrial Sector

The industrial sector essentially constitutes the following sub-sectors:-

A. Mining and Quarrying

B. Manufacturing

C. Construction and utilities (Roads,Electricity, Water and Gas)

D. Timber/Wood processing and Metal Works

E. Industrial Fisheries (Large foreign vessels, trawlers, shrimpers etc)

These categories do not necessarily coincide with the IPPC categories. However the manufacturing category has been reclassified as mineral industry and chemical industries to approximate to those classes.

The source categories

Consistent with the structure, activities, and source categories in the 2006 IPCC Guidelines, the IPPU Sector includes the following eight categories each with its corresponding subcategories: 2A Mineral Industry, 2B Chemical Industry, 2C Metal Industry, 2D Non-Energy Products from Fuels and Solvent Use, 2E Electronics Industry, 2F Product Uses as Substitutes for Ozone Depleting Substances, 2G Other Product Manufacture and Use, 2H Other, with the corresponding subcategories. Most GHG emissions from subcategories of this sector do not occur in the country while others were not estimated due to the unavailability of appropriate data.

The source categories covered in the Industrial Processes Sector and those that are present in Sierra Leone and therefore relevant for the inventory are summarized in Table 1. The sources that are present in Sierra Leone are indicated by a “Y” or “N”. In the former case (Y), the inventory includes a specific worksheet to identify emissions while in the latter case (‘N’) the emission estimates are included in sother sector (because data were not available to disaggregate the emissions).

The sub-sections below describe the various industrial activities that have been documented for this inventory exercise. Also, the mode of action resulting to the type of emission has been discussed.

Table 3.22 Industrial Processes and Product Use source Categories Present in Sierra Leone

Category Code	Category Name	Present in Sierra Leone
2A	**MINERAL INDUSTRY**	
2A1	Cement Production	Y
2A2	Lime Production	Y
2A3	Glass Production	N
2A4	Other Process Uses of Carbonate	N
2A4a	Ceramics	N
2A4b	Other Uses of Soda Ash	N
2A4c	Non Metallurgical Magnesia Production	N
2A4d	Other	N
2A5	Other	N
2B	**Chemical Industry**	N
2B1	Ammonia Production	N
2B2	Nitric Acid Production	N
2B3	Adipic Acid Production	N
2B4	Caprolactam, Glyoxal and Glyozylic Acid Production	N
2B5	Carbide production	N/y
2B6	Titanium Diozide Production	N
2B7	Soda Ash Production	N
2B8	Petrochemical and Carbon Black Production	N
2B8a	Methanol	N
2B8b	Ethylene	N
2B8c	Ethylene dichloride and Vinyl Chloride Monomer	N
2B8d	Ethylene Oxide	N
2B8e	Acrylonitile	N
2B8f	Carbon Black	N
2B9	Fluorochemical Production (Note 4)	N
2B9a	By-product emissions (Note5)	N
2B9b	Fugitive Emissions (Note 5)	N
2B10	Other – sulphuric Acid	N
2C	**Metal Industry**	
2D	**Non-energy Products from Fuels and Solvent Use**	
2D1	Lubricant Use	Y
2D2	Paraffin Wax Use	Y
2D3	Solvent Use (Note 8)	Y
2D4	Other (Note 9)	Y
2E	**Electronics Industry**	N
2F	**Product Uses as Substitutes for Ozone Depleting substances**	
2F1	Refrigeration and air Conditioning	Y
2F1a	Refrigeration and Stationary Air Conditioning	Y
2F1a	Mobile air Conditioning	Y
2F2	Foam Blowing Agents	N
2F3	Fire Protection	Y

2F4	Aerosols	N
2F5	Solvents (Note 12)	N
2F	Other Application	N
2G	**Other Product Manufacture and Use**	
2G1	Electrical Equipment	N
2G2	SF6 and PFCs from Other Product Uses	N
2G3	N_2O from Product Uses	N
2G3a	Medical Applications	Y
2G3b	Propellant for Pressure and Aerosol Products	N
2G3c	Other	N
2G4	Other	N
2H	**Other**	
2H1	Pulp and Paper Industry (Note 15)	N
2H2	Food and Beverages Industry (Note 15)	*
2H3	Other	N

2A Mineral Industry

This category includes the subcategories 2A1 Cement Production; 2A2 Lime Production; 2A3 Glass Production and 2A4 Other Process Uses of Carbonates.

Category code	**Category name**	**Status**
2A	**MINERAL INDUSTRY**	
2A1	Cement Production	Y
2A2	Lime Production	Y
2A3	Glass Production	NO
2A4	Other Process Uses of Carbonate	NO
2A4a	Ceramics	NO
2A4b	Other Uses of Soda Ash	NO
2A4c	Non Metallurgical Magnesia Production	NO
2A4d	Other	NO
2A5	Other	NO

2A1 Cement Production– CO2 and SO2

In the 2006 IPCC Guidelines are described three approaches (Tier) to estimate the emissions of CO2 derived from this subcategory. In the Tier 1 method, emissions are based on clinker production estimates inferred from cement production data, correcting for imports and exports of clinker. In Tier 2, emissions are estimated directly from clinker production data (rather than clinker production inferred from cement production) and a national or default emission factor. The Tier 3 approach is a calculation based on the weights and compositions of all carbonate inputs from all raw material and fuel sources, the emission factor(s) for the carbonate(s), and the fraction of calcination achieved.

The cement industry includes establishments primarily engaged in manufacturing straight portland, natural, masonry, pozzolanic, and other hydraulic cements. Currently there is only one cement facility operating in the country, the Sierra Leone Cement Manufacturing (Leocem) Company), though plans are underway for the establishment of a second. The only existing cement producing facility in the country produces three classes of cement:32.5N (meant for); 42.5 N (meant for ..) and 42.5R (meant for…) The cement is mainly used in the building and construction sectors.

However, since in Sierra Leone clinker is imported and not locally produced, there is no process-related emission from this industrial process.

Inventory Results

Data Collected and Their Sources

Data was obtained from different sources: the industries such as the Sierra Leone Brewery, Leocem, Sierra Leone Oxygen factory (SLOF) and from institutions such as the Bank of Sierra Leone.

Data collected for this inventory exercise are presented in the accompanying table, with an indication of their specific sources. In the case of lime production, data was calculated from data for calcium carbide.

Table 3.23 Data source characteristics

	Sector Industrial Process and Product Use	Data Type	Data Source	Principal Data Providers
2A	Mineral Industry			
2A1	Cement Production	Production Figures	Leocem Company	Leocem Company
2A2	Lime Production	Data for calcium carbide	Calculated from available data for calcium carbide	None

The emissions trends for 2005 - 10 are shown in subsequent figures that follow each category.

Emissions from Cement Production

Cement production results in CO_2 emissions from on-site fossil fuel combustion, process-related non-combustion activities, and purchased electricity consumed in manufacturing operations.

The manufacturing of cement requires energy to operate manufacturing equipment and generate and maintain high kiln temperatures. This energy use results in direct emissions of carbon dioxide (CO_2) from fossil fuel combustion and indirect CO_2 emissions from purchased electricity. These are accounted for under the energy sector.

In addition significant non-combustion CO_2 emissions also come from the cement production process—the high-temperature conversion of limestone (calcium carbonate, $CaCO_3$) to lime (calcium oxide, CaO), with CO_2 as a byproduct. This occurs during clinker production.

$$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$$

Lime is then combined with silica-containing materials to produce clinker, which is an intermediate product combined with gypsum to produce portland cement.

It should be noted that emissions from the cement industry that are of concern to climate change emanate mainly from clinker production.

In Sierra Leone clinker is imported and not locally produced, therefore, in accordance with the methodology outlined in the IPPC 2006 Guidelines, **there is no process-related emission and therefore emissions are not occurring.**

Table 3.24 Sierra Leone Cement Manufacturing Company (Leocem)

Year	Clinker consumption (Tonnes)	Cement production (Tonnes)
2006	167,890.00	231,973.00
2007	162,327.00	235,834.00
2008	169,311.00	256,288.00
2009	156,600.00	239,215.00
2010	206,282.00	310,883.00
2011	238,890.00	344,528.00
2012	241,273.00	321,949.00
2013	234,346.00	231,973.00

Table 3.25 CO2 Emissions from the Mineral Industry (2005)

Category	**CO_2 Emissions (Gg)**
2A Mineral Industry	**NE**
2A1 Cement Production	**NO**
2A2 Lime Production/carbide use	0.01014/0.00941

2A2 Lime Production Carbide Use

There are three basic methods for estimating emissions from lime production: an output-based approach that uses default values (Tier 1); an output-based approach that estimates emissions from CaO and CaO·MgO production and country-specific information for correction factors (Tier 2) and an input-based carbonate approach (Tier 3) that requires a plant-specific assessment.

Lime production in Sierra Leone is done locally in a non-mechanized manner in non-formal small-scale industry mainly by residents along the coastal areas in different parts in the country. These local producers collect calcareous shell from oyster and other molluscs. Unwanted materials are first removed from the shells and then the shells are packed with wood to be burnt. Limestone - mostly calcium carbonate present in the shell - is heated at high temperatures using wood to decompose the carbonate thus producing solid calcium oxide (CaO) and carbon dioxide (CO_2) at the end of the chemical cycle shown below. The CO_2 is driven off and is normally emitted to the atmosphere.

$$\mathbf{xsCaCO_3 \xrightarrow{\textit{Heat}} CaO + CO_2}$$

The local lime is produced mainly for construction purposes and is not of very high quality (personal observation.). Following the burning process, the lime is sieved to separate the burnt shell (lime) from the unburnt shell. The unburnt shell is recycled until the burning process is complete. The products are hydrated and after further processing, bagged for sale. It involves three main processes: preparation of the calcareous shell, calcinations and hydration.

There are no standard large-scale industries which produces lime in Sierra Leone. Therefore the CO2 emissions from this local production was not estimated.

However the locally produced lime was used mainly for making calcium carbide. It was against this backdrop, that the this chapter author collected data for lime production and from this data calculated for calcium carbide. The collected data was divided into two fractions: High Calcium and Dolomitic Calcium.

Emission from lime production was calculated by means of the computer software provided using appropriate emission factor for High Calcium (0.75) and Dolomitic (0.77) lime respectively.

Fig. 3.20 Emission of CO_2 in Gg from Lime Production

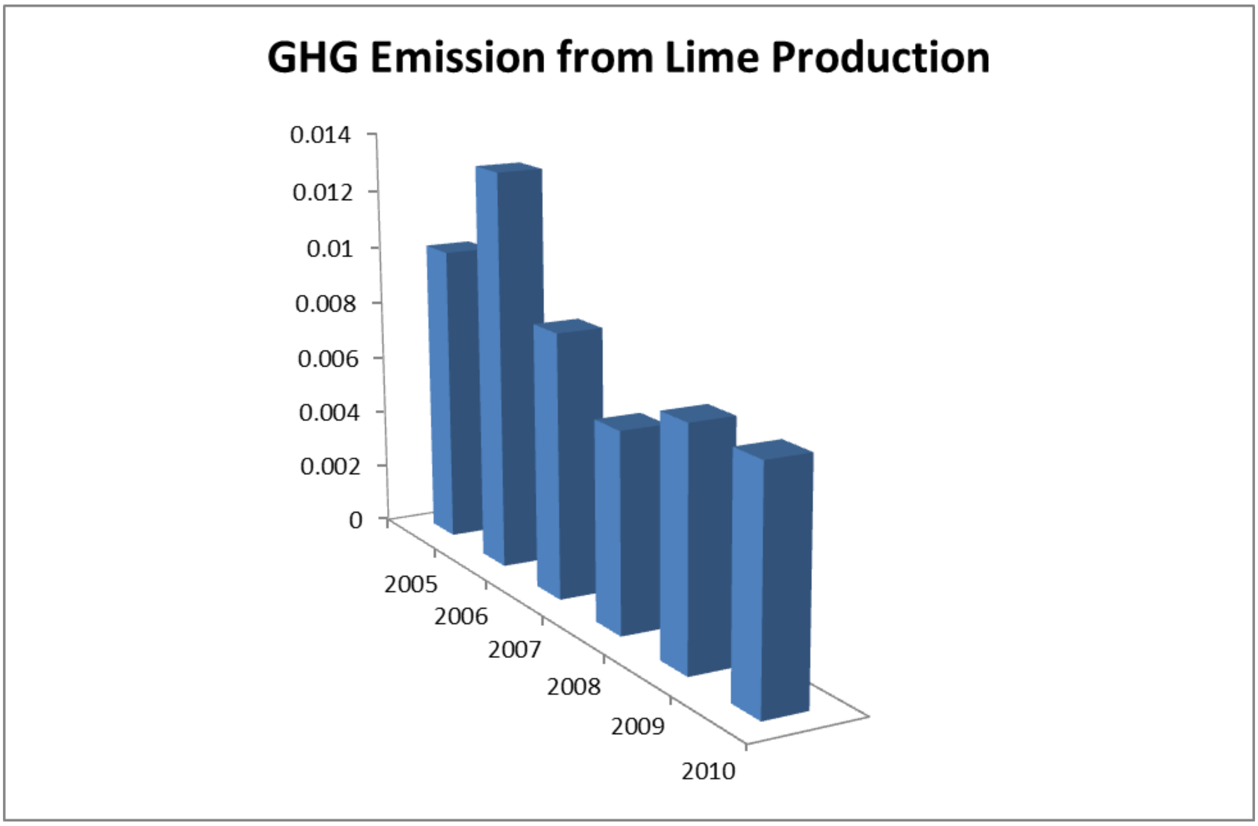
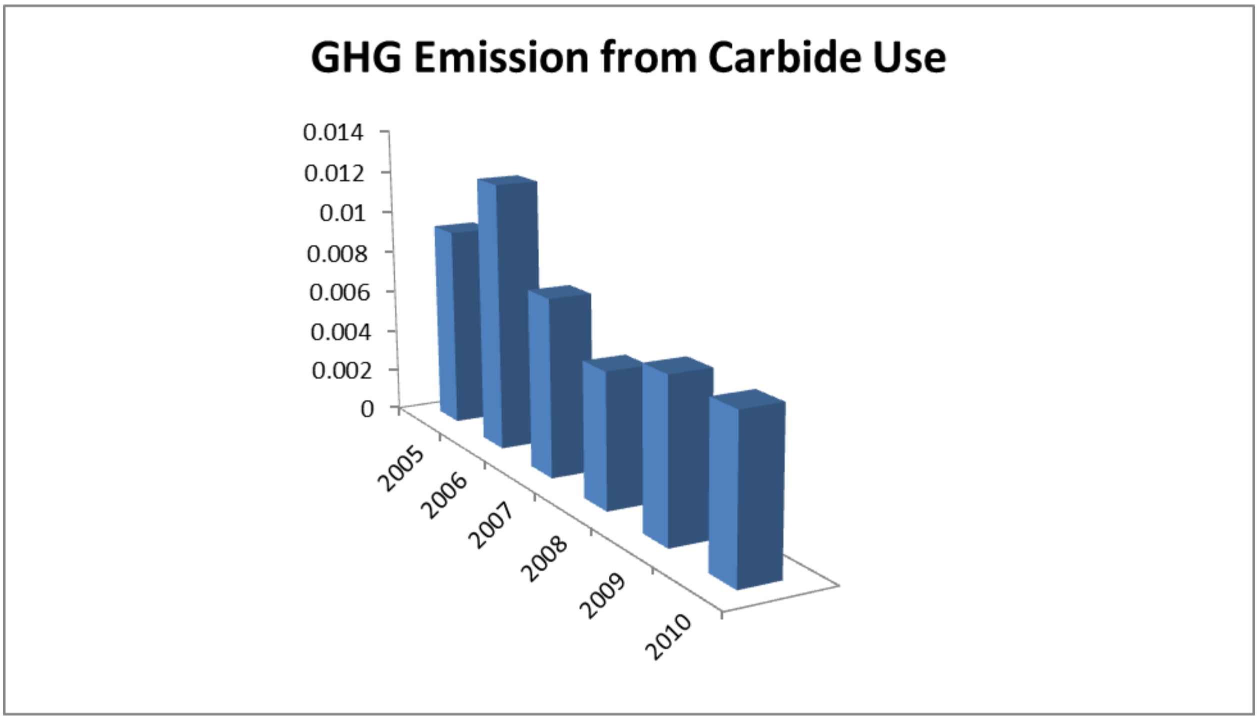


Table 3.26 Emission of CO_2 from Lime Production and carbide use

Year	Lime production (Gg)	Carbide use (Gg)
2005	0.01014	0.00941
2006	0.01347	0.01249
2007	0.00889	0.00823
2008	0.00664	0.00616
2009	0.00783	0.00726
2010	0.0077	0.00714
2011	0.00924	0.00857
2012	0.00888	0.00823
2013	0.01089	0.0101

Fig.3.21 Emission of CO_2 in Gg from Carbide Use



3.4.2 Chemical Industry (2B)

The chemical sector, as defined by 2006 IPPU Guidelines, produces products by transforming organic and inorganic raw materials by a chemical process.

Sierra Leone is one of the least chemicals producing countries in the world. The chemicals produced are limited to: lime (treated under minerals) Calcium carbide, oxygen, acetylene, slaked lime, soaps, bleaches, ethanol (this is different from ethanol produced in the food and beverage industry),

There is no facility qualifying as a chemical industry in Sierra Leone.

Category code	**Category name**	**Status**
2B	**Chemical Industry**	NO
2B1	Ammonia Production	NO
2B2	Nitric Acid Production	NO
2B3	Adipic Acid Production	NO
2B4	Caprolactam, Glyoxal and Glyozylic Acid Production	NO
2B5	Carbide production	N/y
2B6	Titanium Diozide Production	NO
2B7	Soda Ash Production	NO
2B8	Petrochemical and Carbon Black Production	NO
2B8a	Methanol	NO
2B8b	Ethylene	NO
2B8c	Ethylene dichloride and Vinyl Chloride Monomer	NO
2B8d	Ethylene Oxide	NO
2B8e	Acrylonitile	NO

2B8f	Carbon Black	NO
2B9	Fluorochemical Production (Note 4)	NO
2B9a	By-product emissions (Note5)	NO
2B9b	Fugitive Emissions (Note 5)	NO
2B10	Other – sulphuric Acid	NO

3.4.3 Metal Industry (2C)

3.4.4 Non-energy Products from Fuels and Solvent Use (2D)

This category includes the subcategories 2D1 Lubricant Use; 2D2 Paraffin Wax Use; 2D3 Solvent Use and 2D4 Other
The products covered here comprise lubricants, paraffin waxes, bitumen/asphalt, and solvents.

Category code	**Category name**	**Status**
2C	**Metal Industry**	
2D	**Non-energy Products from Fuels and Solvent Use**	
2D1	Lubricant Use	Y/NE
2D2	Paraffin Wax Use	Y/NE
2D3	Solvent Use (Note 8)	Y/NE
2D4	Other (Note 9)	Y/NE
2E	**Electronics Industry**	N/NE
2F	**Product Uses as Substitutes for Ozone Depleting substances**	
2F1	Refrigeration and air Conditioning	Y/NE
2F1a	Refrigeration and Stationary Air Conditioning	Y/NE
2F1a	Mobile air Conditioning	Y/NE
2F2	Foam Blowing Agents	N/NE
2F3	Fire Protection	Y/NE
2F4	Aerosols	NO
2F5	Solvents (Note 12)	NO
2F	Other Application	NO

LUBRICANT USE (2D1)
Lubricants are mostly used in industrial and transportation applications. Lubricants are produced either at refineries through separation from crude oil or at petrochemical facilities. **No such facilities are existing in Sierra Leone**. Most of the lubricants (motor oils , industrial oils and greases), which differ in terms of physical characteristics (e.g., viscosity),commercial applications, and environmental fate used in the cottage industries are imported. The emissions are estimated and reported as part of the combustion emissions in the Energy Sector. The use of these substances result in the release of NMVOC and CO.

PARAFFIN WAX USE (2D2)
The category, as defined here, includes such products as petroleum jelly, paraffin waxes and other waxes, including ozokerite (mixtures of saturated hydrocarbons, solid at ambient temperature). Waxes are used in a number of different applications. Paraffin waxes are used in applications such as: candles, corrugated

boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents) and many others.
CO_2 emissions from the use of waxes derive primarily when the waxes or derivatives of paraffin are burned during use (e.g., candles), and when they are incinerated with or without heat recovery or in wastewater treatment (for surfactants). In the cases of incineration and wastewater treatment, the emissions are reported in the Waste Sector.

SOLVENT USE (2D3)
The use of solvents manufactured using fossil fuels as feedstocks can lead to evaporative emissions of various non-methane volatile organic compounds (NMVOC), which are subsequently further oxidised in the atmosphere. Fossil fuels used as solvent are notably white spirit and kerosene (paraffin oil). White spirit is used as an extraction solvent, as a cleaning solvent, as a degreasing solvent and as a solvent in aerosols, paints, wood preservatives, lacquers, varnishes and asphalt products. White spirit is the most widely used solvent in the paint industry.

There are five sub-categories

- Paint application;
- Degreasing, dry cleaning and electronics;
- Chemical products manufacturing or processing. This Include the processing of polyester, PVC, foams and rubber, manufacture of paints, inks, glues and adhesives and the finishing of textile.
- Other use of solvents and related activities. Including such activities as 'enduction' (i.e. coating) of glass wool and mineral wool, printing industry, fat and oil extraction, uses of glues and adhesives, wood preservation, domestic solvent use (other than paint application) and vehicle underseal treatment and vehicle dewaxing.

Asphalt Production and Use (2D4)
This source category comprises the non-combustion emissions from the production of asphalt in asphalt plants other than refineries and its application (such as paving and roofing operations as well as subsequent releases from the surfaces). It includes asphalt blowing for roofing. The production and use of asphalt results mainly in emissions of NMVOC, CO, SO_2 and particulate matter, while the fate of the remaining hydrocarbons are stored in the product (much less than one per cent of the carbon is emitted). Emissions from the installation of roofing materials are assumed negligible.
The heavy black and very viscous organic liquid mainly produced from refineries and used as a feedstock for the road paving and roofing materials will be termed bitumen, to distinguish it from the products made from it. At normal temperatures bitumen is in a semi-solid state.

Bitumen may be heated and mixed with aggregate of various sizes, diluted with petroleum oils or water/soap emulsions, or heated and blown with air to polymerise/stabilize it and make it suitable for e.g., the treatment of roofing materials. These are termed 'asphalt processes' and their products referred to as 'asphalt products' Bitumen and aggregates are mixed in either a fixed or mobile plant.

Other uses of asphalt products are as binder or sealant in the production of roofing material, as a foundation sealant, and other industrial uses such as pipe coating.

Direct greenhouse gas emissions, e.g., CO2 or CH4, associated with the production and use of asphalt are negligible since the majority of the light hydrocarbon compounds were extracted during the refining process to produce commercial fuels. CH4 emissions from hot mix asphalt and cutback asphalt and from the asphalt roofing industry are negligible.

Greenhouse gas emissions from the use of recycled asphalt pavements as aggregate for new road paving are also negligible.

Road Paving with Asphalt

The production and use of asphalt for road paving and roofing and the use of solvents derived from petroleum and coal are either not sources or are negligible sources of direct greenhouse gas emissions. They are, however, included here since they are sometimes substantial sources of non-methane volatile organic compounds (NMVOC) and carbon monoxide (CO), emissions which eventually oxidize to CO_2in the atmosphere. The resulting CO_2input is estimated from the emissions of these non-CO_2 gases.

Data obtained from Sierra Leone Road's Authority comprised a total between the period 2005 - 2010 and not annual data of asphalt used. A default emission factor of 100 Kg asphalt/m^2 road surface was used which takes care of the type of asphalt and or amount of diluents used. Emissions were estimated according to the relation:

Emission = Area of road paved * emission factor (100 Kg asphalt/m^2 road surface)

Table 3.29 Area of road paved during the period covered by the inventory.

Area of road paved during the period covered by the inventory.	
Year	**Area of road paved with asphalt ($10^6 m^2$)**
TOTAL between 2005 - 2010	
Source: Sierra Leone Roads Authority	

Asphalt paving consist of a mix of aggregate, sand, filler, bitumen and occasionally a number of additives. Asphalt road surfaces are, thus, composed of compacted aggregate and bitumen binder. Hot Mix Asphalt (HMA) is by far the most widely used, generally over 80 percent, and produces very few emissions. Other types of road paving include cutback asphalt and emulsified asphalt, which are both liquefied asphalts . Cutback asphalts are liquefied by blending with petroleum solvents (diluents such as heavy residual oils, kerosene or naphtha solvents) and therefore show a relatively high level of emissions of CO and NMVOC due to the evaporation of the diluent. Therefore most emissions from road paving will arise from the use of cutback asphalts. Depending on the evaporation rate, three types are distinguished: Rapid-Cure (RC), using a naphtha or gasoline-type diluent of high volatility, Medium-Cure (MC) using a diluent of medium volatility and Slow-Cure (SC) cutback asphalt which use oils of low volatility. This is in contrast to so-called emulsified asphalt that contains mostly water and little or no solvent. The amount of diluent used is usually lower in warm countries than in the cooler climates, and hence lower emission factors may be expected in warm countries.

Hot mix asphalt typically contains about 8 percent asphalt cement (bitumen) (EEA, 2005), but this may differ between countries.
If the quantity of asphalt paved is not known but rather the area paved, a conversion factor of 100 kg asphalt/m^2 road surface may be used to calculate the mass of asphalt produced.
Gases are emitted from the asphalt plant (hot mix, cutback or emulsified), the road surfacing operations and subsequently by the road surface.

Asphalt Roofing
The asphalt roofing industry produces saturated felt, roofing and siding shingles, roll roofing and sidings: asphalt shingles, smooth surfaced organic and asbestos felt roll roofing, mineral surfaced organic and asbestos felt roll roofing and sidings, asphalt saturated organic and asbestos felts, asphalt saturated and/or coated sheeting and asphalt compound. Most of these products are used in roofing and other building applications. Asphalt felt, roofing and shingle manufacture involves the saturation or coating of felt. Key steps in the total process include asphalt storage, asphalt blowing, felt saturation, coating and mineral surfacing, of which asphalt blowing is included here. Direct greenhouse gas emissions from asphalt roofing products are negligible compared to emissions such as NMVOC, CO and particulate matter.
Asphalt blowing is the process of polymerising and stabilising asphalt to improve its weathering characteristics. Air blown asphalts are used in the production of asphalt roofing products. Blowing may take place in an asphalt processing plant or an asphalt roofing plant (or in a refinery). Asphalt blowing leads to the highest emissions of NMVOC and CO, more than the other process steps. All asphalt used for non-paving applications has been blown.

Electronics Industry (2E)
All electronic equipment are imported into Sierra Leone mainly by the service sectors. The country is not a producer of any electronic equipment.

Product Uses as Substitutes for Ozone Depleting Substances (2F).
In 2006 IPCC Guidelines, this category includes six subcategories: 2F1 Refrigeration and air conditioning; 2F2 Foam blowing agents; 2F3 Fire protection; 2F4 Aerosols; 2F5 Solvents; 2F6 Other applications.

These major groupings of current usage are referred to in the 2006 IPCC Guidelines as *applications* within the ODS substitutes category. Some of these applications themselves encompass products or uses with diverse emission characteristics, and in order to produce more rigorous estimates it is necessary to account for this diversity through the adoption of disaggregated assessments (higher tier). Additionally, the use of HFCs and PFCs in some applications, specifically rigid foam (typically closed-cell foam), refrigeration and fire suppression, can lead to the development of long-lived banks of material.

HFCs and PFCs have high global warming potentials (GWPs) and, in the case of PFCs, long atmospheric residence times. The various HFCs and PFCs have very different potencies as greenhouse gases. PFCs have particularly high GWPs regardless of the integrated time horizon adopted because of their long atmospheric lifetimes.

2F1Refrigeration and Air Conditioning

Sierra Leone began phasing out the use of CFCs in refrigeration and air -conditioning (RAC) systems in 2010 (Prohibition of Ozone Depleting Substances Regulation 2010); replacing them with Freon 22 and, more recently, with HFCs and blends containing HFCs. Import restrictions for CFCs based on a declining quota system are being put in place and importation of CFCs will hopefully cease soon.

Since there is no production, export or destruction of virgin HFCs and PFCs in Sierra Leone , emissions were therefore not calculated. The required annual chemical consumption data derived from imports of bulk (cylinders) chemicals in products/applications (refrigerators, stationary and mobile air conditioners etc.) are being compiled.

Estimate the number of mobile air conditioning units

The numbers of vehicles imported each year were obtained from Sierra Leone Road Safety Authority (SLRSA), Ministry of Transport and Aviation. The number of mobile air conditioning units and some refrigerated vehicles is not known.

Household refrigerators and mobile air conditioning equipment

All household refrigerators and mobile air conditioning equipment imported between 2000 and 2005 was assumed to be charged with HFC -134a. It was also assumed that all motor cars, trucks and tractors (but not trailers) imported during 2000 -05 were equipped with air conditioners.
Household refrigerators are readily identified in the import data, but data for medium sized and larger systems in industrial, commercial and institutional establishments, the type and size of the units were not always clearly identifiable.

The medium sized and larger systems
In the case of the medium sized and larger systems in commercial and industrial establishments (e.g., refrigerator/freezer chests/cabinets/showcases, air conditioners with reverse cycle refrigeration, chillers, etc.) it was not feasible to determine precisely the sizes of systems and the types of refrigerants charged in the imported systems.

2F2 Foam blowing agents

2F3 Fire Protection
Examination of the import data indicated that the only HFC imported for fire suppression during 2000 - 05 was HFC -227e (trade name FM200). Fire suppression systems using FM200 are typically used in computer and telecommunication rooms. Imports of FM200 occurred only in 2003, even though applications using FM 200 in Sierra Leone have been in use for some time. There were insufficient data to make reliable estimates of emissions.

2F4 Aerosols (Propellants and Solvents)
Most aerosol packages contain hydrocarbon (HC) as propellants but HFCs and PFCs may also be used as propellants or solvents in a small fraction of the total. Emissions from aerosols usually occur shortly after production, on average six months after sale.
The five main sub -applications are as follows:
• Metered Dose Inhalers (MDIs);
• Personal Care Products (e.g., hair care, deodorant, shaving cream);
• Household Products (e.g., air -fresheners, oven and fabric cleaners);
• Industrial Products (e.g., special cleaning sprays such as those for operating electrical contact, lubricants, pipe -freezers);
• Other General Products (e.g., silly string, tyre inflators, klaxons).

The HFCs currently used as propellants are HFC -134a, HFC -227ea, and HFC -152a. The substances HFC - 245fa, HFC -365mfc, HFC -43 -10mee and a PFC, perfluorohexane, are used as solvents in industrial aerosol products. Of these, HFC -43 -10mee is the most widely used. 11 HFC -365mfc is also expected to be used within aerosols in the near future.
However there is no data for Sierra Leone. On this basis the emissions in Sierra Leone were assumed to be negligible.

There is limited use of HFCs as a solvent and the only application identified was the use of HFC -245fa (trade name FC -129) which is used as a surfactant in some paints. Quantities imported into Sierra Leone are unknown. It was assumed that the quantity imported was used over current and the following and that all amounts used were emitted in the year of use and that the amount imported in was the same each year.
The emissions for HFCs were not estimated.

2G Other Product Manufacture and Use

2H Other

Other (2H)

FOOD AND BEVARAGES INDUSTRIES (2H2)
The food and beverage sector represents a wide range of processes by which food products are manufactured and both alcoholic and non-alcoholic beverages are made.

For the purposes of this report, the food and beverage sector includes facilities that manufacture food products by transforming livestock or agricultural products into products for intermediate (or final) consumption by humans; and facilities that produce non-alcoholic beverages (including water and ice), alcoholic beverages via fermentation, or distilled alcoholic beverages

Sources of Greenhouse Gas Emissions

GHG emissions from the food and beverage sector result from energy use and non-combustion activities. Food and beverage manufacturing involves energy use for heating, cooking, drying, cooling, freezing, and other common processes. Most of these energy inputs come from fuel imports of fossil fuel based petroleum products and purchased electricity. The processes that consume the most energy in the sector are grain milling, fruit and vegetable processing, meat processing, and beverage production.

Non-combustion emissions from the sector include hydrofluorocarbon (HFC) emissions from refrigeration and air conditioning equipment.

Data for food production

Data for food production was obtained from the Bank of Sierra Leone. The 2006 IPPC Guidelines software does not make provision for calculating GHG emissions from food processing. In this regard, GHG emissions from food processing were estimated by multiplying quantity of food produced annually, expressed in tones or hectoliters, by a factor. This factor was calculated using a relationship established between the emissions and the corresponding activity data in the Second National Communication.

Production of Beverages

Data pertaining to the manufacture of both alcoholic and non-alcoholic beverages was obtained primarily from BSL. The Sierra Leone Brewery also provided complimentary production statistics for Guinness stout, star larger beer and maltina for the period 2012 to 1st half of 2014. These are presented in tables 7 and 8 respectively

Table 4.9 Sierra Leone Brewery Limited

Production of Guinness, Maltina and Star Beer in Hectolitres by the Sierra Leone Brewery Limited			
	2012	2013	2014 (Jan - Jun)
Guinness	212,537.00	387,664.00	224,965.00
Maltina	152,099.00	292,355.00	168,084.00
Star	199,748.00	408,146.00	165,106.00

Table 5.0 Production of manufacturing establishments (Data from Bank of Sierra Leone)

Year	Beer, Stout & Maltina	Acety lene	Oxygen	Paint	Confec tionery	Confec tionery	Cement	Soft Drinks	Common Soap	Flour
	(x 10^3 Ctns.)	(x 10^3 Cu.ft.)	(x 10^3 Cu.ft.)	(x 10^3 Galls.)	(x 10^3 lbs)	Kg	(x 10^3M Tons)	(x 10^3 Crts)	(M/Tons)	(x 10^3 M/Tons)

2005	**1,012.42**	**218.88**	**1,008.69**	**158.31**	**2,188.21**	**942863.6**	**11327**	**1,711.78**	**367.06**	
2006	974.68	290.80	791.63	141.96	2,329.87	1059032	234.43	2,074.43	467.36	
2007	952.87	191.47	423.86	156.96	3,140.95	1427705	247.38	1,455.10	621.63	
2008	862.26	143.42	302.62	168.79	2,892.30	1314682	254.18	1,387.45	552.89	
2009	859.05	168.90	244.71	149.91	3,054.85	1388568	236.24	1,541.75	585.69	11.37
2010	996.92	166.17	227.46	221.23	2,947.87	1339941	300.98	1,962.00	422.03	9.63
2011	1,237.23	199.55	267.35	204.02	3,469.93	1577241	317.89	1,881.31	503.22	13.42
2012	1,199.88	191.63	230.20	201.06	3,164.51	1438414	335.40	2,180.03	643.16	23.15
2013	946.54	235.14	273.60	233.11	3516.26	1598300	313.36	2261.80	633.61	NA

Flour: Ann. Growth Rate = 4.26 x 10^3 Metric tones

National production statistics relating to alcoholic beverages have been categorized into beer, Guinness and spirits. As was the case for the Second National Communication, Wines and spirits are imported into Sierra Leone either as finished products for direct human consumption or as ethanol. In the case where ethanol is imported, only blending to give desired taste and flavour is done within the country (Personal research with wines and spirits producing industries in Sierra Leone, Karim 2017). It must be reported that within the last ten years there has been an upsurge in these industries in the country. Data on locally brewed spirits (known locally as 'omole') in selected localities (mountain rural villages, Murray Town and other places around the capital Freetown and elsewhere in the provinces), where these activities are practiced, is unavailable. Consequently, estimates of GHG emissions relating to locally brewed spirits could not be made. It must be stated that the process involves fermentation and leads o the release of CO_2. Personal observations point to variation in ethanol content of products at a given outfit and from one outfit to another.

Table 3.32 Emission of NMVOCs from Soft Drinks and Confectionary Production

	Emission of NMVOCs from soft drinks production		**Emission of NMVOCs from connfectionary production**	
Year	No. of crates	Emission x 10^{-11} Gg	Mass of Confectionary Kg	Emission x 10^{-4} Gg

2005	1908020	2.861	942863.6	9.4286
2006	2,074430	3.110	1059032	10.59
2007	1,455100	2.181	1427705	14.277
2008	1,387450	2.080	1314682	13.147
2009	1,541750	2.311	1388568	13.886
2010	1,962000	2.941	1339941	13.399
2011	1,881310	2.820	1577241	15.772
2012	2,180030	3.267	1438414	14.384
2013	2261800	3.390	1598300	15.983

Table 3.32

Category code	Category Name	NMVOC Emission , 2005
2H	**OTHER**	
2H1	Pulp and Paper Industry (Note 15)	NO
2H2	Food and Beverages Industry (Note 15)	9.4286 x 10^{-4} Gg
2H3	Others-Flour production	0.529

Flour Production

Data for annual flour consumption (2005 - 2010) for the production of bread, biscuit and other pastries are presented in the table 4.6. The data captures flour manufactured in the country and that imported from overseas. The overall data was obtained by combining UNdata and annual statistics from NRA and BSL. Data for confectionary was obtained from BSL.

Table 3.33 National Flour Consumption and Corresponding NMVOC Emission

Year	Flour consumption(metric tones)	Emission of NMVOC(Gg)
2005	66470.0	0.529
2006	87305.4	0.695
2007	110004.8	0.876
2008	138606.1	1.103
2009	174643.6	1.390
2010	220051.0	1.752
Source: Combination of UNdata and estimates from NRA and BSL		

Fig.3.22 Emission from confectionary production

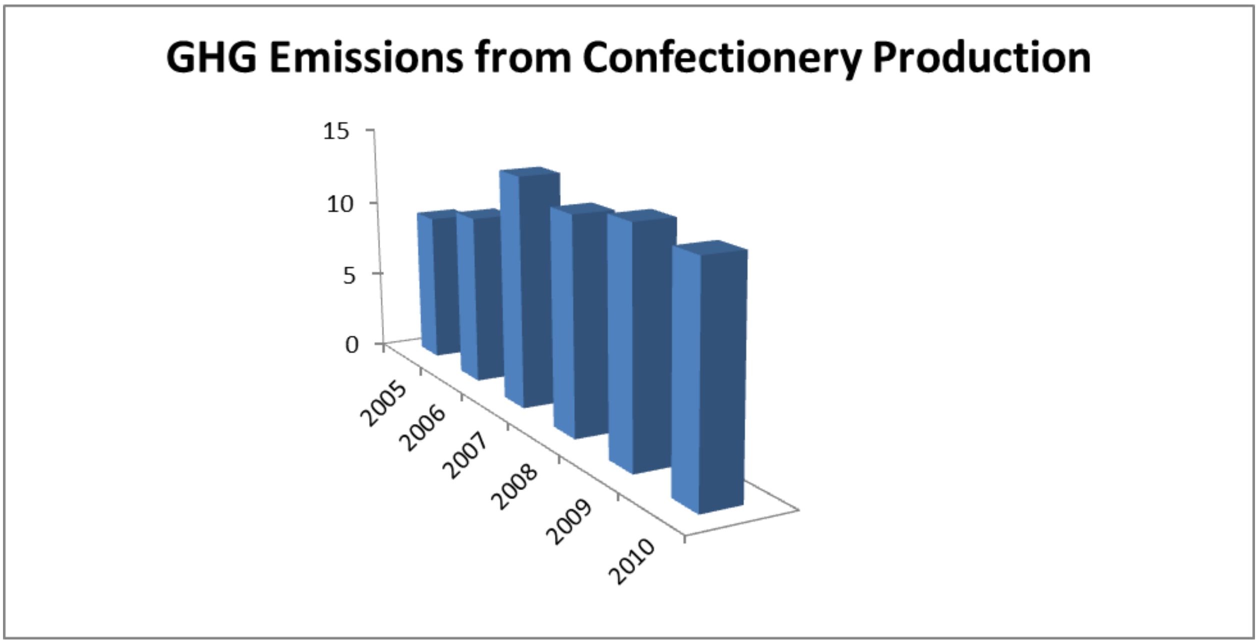
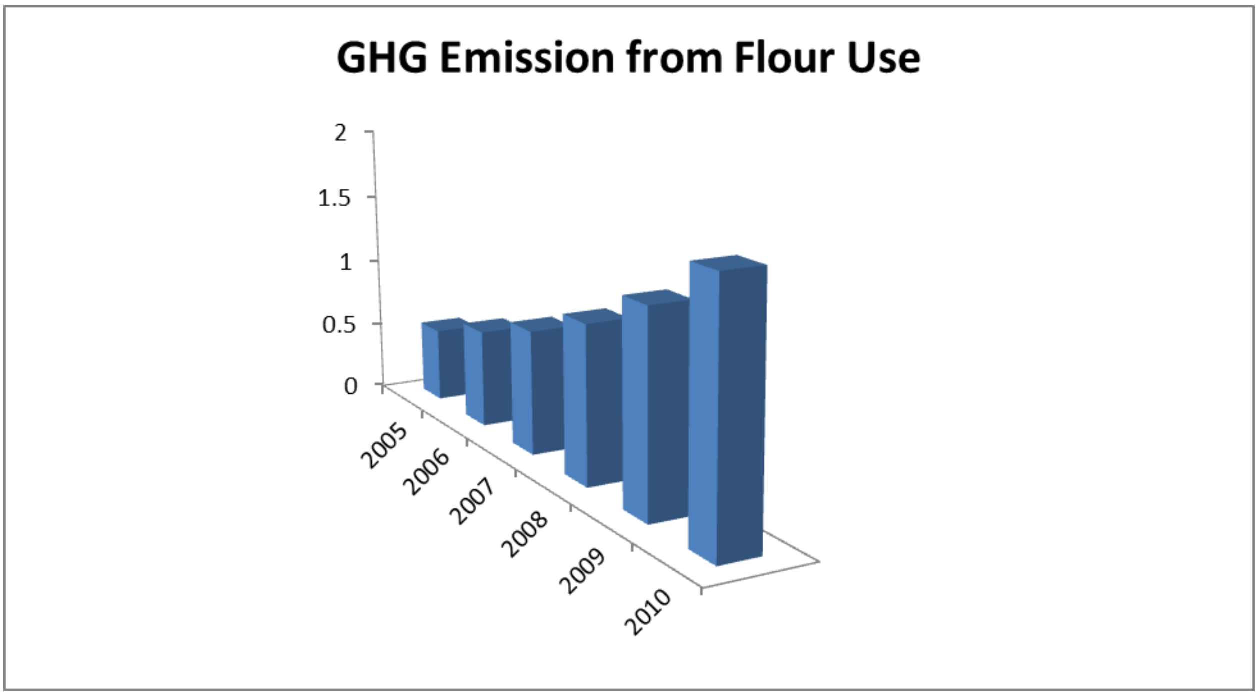


Fig.3.23 Emission from Flour Use



Construction

The construction sector comprises establishments engaged in the construction of buildings, roads and engineering projects. The work performed includes new work, additions, alterations, maintenance and repairs, and demolitions.
The activities included in the construction sector may be divided into:

- Building Construction: defined as those establishments primarily responsible for the construction of buildings.
- Heavy and Civil Engineering Construction: defined as those establishments whose primary activity is the construction of entire engineering projects (e.g., roads/highways and dams), and special trade contractors, whose primary activity is the production of a specific component for such projects.
- Special Trade Contractors: defined as establishments whose primary activity is performing specific activities (e.g., pouring concrete, site preparation, plumbing, painting, and electrical work) involved in building construction or other activities that are similar for all types of construction but that are not responsible for the entire project.

Sources of Greenhouse Gas Emissions

GHG emissions from the construction sector result from fuel consumed by on- and off-road construction equipment and from electricity consumed to provide power to construction tools and offices. Off-road diesel engines used by construction companies include a wide variety of loaders, dozers, excavators, graders, and other specialized equipment. Emissions from this sector are associated with energy use from construction, and do not include the post-construction performance of buildings. These are all accounted for within the fuel combustion activities in the energy sector.

Emissions of concern in the construction sector occur during asphalt road construction and asphalt roofing where NMVOCs are released during the heating of bitumen.

Table 3.34 Main Application Areas for HFCs and PFCs as ODS Substitiutes

	Applications Areas						
Chemical	Refrigeration and Air conditioning	Fire Suppression and Explosion Prevention	Aerosols		Solvent Cleaning	Foam Blowing Agents	Other Applications
			Propellants	Solvents			
HFC-23	✓	✓					
HFC-32	✓						
HFC-125	✓	✓					
HFC-134a	✓	✓	✓			✓	✓

HFC-143a	✓						
HFC-152a	✓		✓			✓	
HFC-227ea	✓	✓	✓			✓	✓
HFC-236fa	✓	✓		✓			
HFC-245fa	✓			✓		✓	
HFC-365mfc	✓			✓	✓	✓	
HFC-43-mee	✓				✓		
PFC-14 (CF4)		✓					
PFC-116(C_2F_6)							✓
PFC-218(C_3F_8)							
PFC-31-10 (C_4F_{10})		✓					
PFC-51-14-(C_6F_{14})					✓		

Types of Data

Two types of may be used to calculate emissions in this category. Data on chemical sales (sometimes referred to as *top-down* data) typically comes on a substance-by-substance basis, although even this can be complicated by the use of blends. Data on markets (sometimes referred to as *bottom-up* data) will tend to come in the form of equipment or product sales at the sub-application level, although this data will typically be influenced by the existence of imports and exports of such equipment or products. **Since these chemicals are neither manufactured nor sold in this country, the second type of data i.e. that based on markets (*bottom-up*) is employed. Also, the approach that employs the use of both types of data is not appropriate in this case.**

Table 3.35 shows summary report of sectoral emission of industrial processes.

Table 5.4 Overall emissions from industrial processes

	CO_2	NMVOC
Cement	474.83	
Lime production and use	0.1021	
		49, 300, 000
Road Paving with asphalt		4.7597
		0.0000018
Food		
Drinks		

Table 3.36 Emission of NMVOCs from soft drinks production

	Emission of NMVOCs from soft drinks production		Emission of NMVOCs from connfectionary production	
Year	No. of crates	Emission X 10^{-11} Gg	Mass of Confectionary Kg	Emission X 10^{-4} Gg
2005	1908020	2.861	942863.6	9.4286
2006	2,074430	3.110	1059032	1.059
2007	1,455100	2.181	1427705	1.4277
2008	1,387450	2.080	1314682	1.3147
2009	1,541750	2.311	1388568	1.3886
2010	1,962000	2.941	1339941	1.3399
2011	1,881310	2.820	1577241	1.5772
2012	2,180030	3.267	1438414	1.4384
2013	2261800	3.390	1598300	1.5983

Table 3.37 Emission of CO2 from Lime Production and carbide use

Year	Lime production X 10^{-11} Gg	Carbide use
2005	0.01014	0.00941
2006	0.01347	0.01249
2007	0.00889	0.00823
2008	0.00664	0.00616
2009	0.00783	0.00726
2010	0.0077	0.00714

2011	0.00924	0.00857
2012	0.00888	0.00823
2013	0.01089	0.0101

Uncertainties, Quality Assurance and Control

Uncertainties in emission estimates for the various industrial processes are due in part to poor inherent statistics obtained from sources from which data were obtained. In most cases, suggested emission factors from IPCC rather than country specific emission factors were used. Therefore uncertainties exists as to the precise accuracy of the emission factor used as these emission factors are not in any way ideally suited for the Sierra Leone situation. Also, for specific cases, such as lime, uncertainty exists in the assumed production and imports respectively as well as carbon dioxide produced from production and use. In other cases, uncertainty exists where available data that falls outside the period of investigation has to be extrapolated to the year under review. Such would have imparted some degree of uncertainty in the production and hence emission estimates.

The year 2013 was the time the Ebola outbreak occurred in Sierra Leone. It is therefore not surprising that most institutions contacted for data were unable to produce data possibly due to lost data from their system.

In comparison to inventory results for the Second National Communication Sierra Leone, emissions from the Third National Communication are much higher reflecting increasing industrial activities. In all categories where SO_2 emission occurs, emission is significantly lower (<1%) compared to carbon dioxide and NMVOCs.

Difficulties specific to the IPPU sector

3.4.3 Conclusions and recommendations

The bulk of the emissions from Industrial Processes and Product Use could not be estimated for all in this category save for, cement, lime/limestone and carbide. The other categories in this sector do not exist. Asphalt roofing, road paving with asphalt, and concrete plumise stone production are conducted but data is lacking and documentation of halocarbons and sulphur hexafluoride (SF6) from refrigeration assembly, operation and disposal could not be quantified due to inadequate labeling, documentation and age of the equipment that enter the country. Similarly, data on foam products, fire extinguishers, solvents, aerosols and propellants, and equipment containing SF6 are not readily available. Some study is necessary because the equipments are found in most public, commercial facilities and residential properties.

Presently, only the alcohol Beverage and Food Production sub-categories of the industrial sector of Sierra Leone can be assessed.

Data on all other sub-categories are not readily available. A futile attempt was made to collect data on other sub-categories. The data has not been properly recorded or not recorded at all. Some of the equipments are so old that labels have faded or non-existent. The Industrial Processes category is difficult to qualify because most of the equipment used is obsolete. These include used refrigerators, freezers, air conditioners, and compressor units that are leaking even at the time of importation.

Recommendation

It is recommended that a complete data gathering and collection study should be conducted for the Industrial processes category in Sierra Leone.
All emissions factors used are those from the 2006 Revised IPCC Guidelines on the development of National GHG emission (IPCC, OECD, IEA, UNEP, 1997). The trend for the GHGs emitted from 2005 to 2010 shows a fairly general increase with some irregularities. It could be noted that data obtained by projection from existing data increased regularly during the gap years. Data supplied directly from offices/industries show an irregular trend. Consequently, the emissions from these data follow the same pattern.
Of the various GHGs investigated, NMVOC accounted for about 98% of the total emission with CO_2 accounting for the remaining 2%. Virtually all of the 98% of NMVOC was due to road paving with asphalt. The significantly low emission from the mineral, chemical, drink and food industry points to the low level of development in Sierra Leone. With little or no industry whose activities involve processing of raw materials, the statistics obtained justifies the significantly low emission from these activities. Table 5.7 shows summary report of sectoral emission of industrial processes.

Table 3.38 Overall emissions from industrial processes

	CO_2	NMVOC
Cement	474.83	
Lime production and use	0.1021	
Road Paving with asphalt		49, 300, 000
Food		4.7597
Drinks		0.0000018

3.5 Agriculture, Forestry & Other Land Use Sector GHG Emissions & Sinks

3.5.1 Introduction

The total land area in Sierra Leone is 72,300km^2. Of this, 60,650km^2 is classified as upland and 11,650km^2 as lowland. It is estimated that about 53, 620km^2 (5.36million ha) is suitable for crop production (i.e. 74.2% of the total area).The remaining 18, 860km^2 (25.8%) of the country's land area is described as non-arable and include rocky lands, towns and creeks (MANR/FAO, 1992).

The agriculture sector is mainly characterized by pastoral and farming activities that are now being transformed from the subsistent level to a more intensively mechanized and large scale based farming as a result of the introduction of the new agricultural commercialization policy. This increasing investments in the agricultural sector is quite likely to increase levels of production and subsequently the relative quantum of emissions of GHG from the sector, especially methane (CH_4) from paddy rice cultivation, and carbon dioxide (CO_2) and precursor gases (NOx, CO) from the slash and burn culture of virgin bolilands, grasslands, savannahs, forests, inland valley-and mangrove swamps and farm bush clearing.

Agriculture mainly includes pastoral and farming activities. The agriculture sector accounts for almost 40% of Sierra Leone's GDP, of which livestock and crops (not including tree crops) represent 3.15 % and 32.39 %, respectively. On a sub-sectoral basis, the contributions of crops and livestock to GDP growth of the agricultural sector were estimated at 3.02% and 0.42 %, respectively, for 2008.

Livestock production systems

Three main livestock production systems exist in Sierra Leone. These include:
Pastoral production: as part of pastureland management. Pastoralists move over long distances, from one region to another or from one country to another.

Agro-pastoral production: this system is used in the intermediate zone where farming is the main activity of the agro-pastoralists, and cattle breeding makes up their secondary activity. It integrates the urban and peri-urban farming systems which involves supplementary feeding.
Intensive production: in this system, animals are confined and generally used for meat production. This type of cattle farming is called fattening. Animals raised in pastureland are given high nutritive feed over a long period time, which enable them to quickly put on weight just before being slaughtered.

Crop production

Crop production is extensive, poorly mechanized and uses little inputs and heavily dependent on rainfall. Cereals are the main crops and staple foods as they represent 80% to 90% of caloric intake of the population in the country. In addition to cereal crops (millet, sorghum, maize, and so on), there are tuber crops (cassava, sweet potatoes and Yams), cash crop (groundnut, Cowpea, cotton, tiger nut, sugar cane, tobacco, Cocoa and Coffee and more recently Cashew) and finally vegetable crops (onion, tomato, hot pepper and pepper, aubergine). Land areas used for cereal production have not changed much over time and represent more than 80% of the total surface areas devoted to crop production. As regards cash crops, land areas used for cowpea production are progressively approaching those used for millet and sorghum. This shows the importance of this crop for the population.

Forestlands

Forestlands account for about 6.3m ha i.e. 87% of total land area of Sierra Leone (UNDP/FAO-LRS 1980).The bulk of the forested area comprises mainly of forest regrowth from shifting cultivation. It is estimated that forestry contributes about 2-4% to Sierra Leone's GDP, of which one-fourth is attributed to artisanal wood processing and export of wood based materials. Imports of wood based products are relatively small and erratic and constitute mostly of plywood, high quality veneers and some sawn coniferous timbers.

Background

In the revised 1996 IPCC guidelines for National Greenhouse gas Inventory, Agriculture and Land Use, Land-Use Change and Forestry (LULUCF) sectors were treated independently in two separate chapters, Chapter 4 and Chapter 5 respectively. In the 2006 IPCC Guidelines for National Greenhouse gas Inventory, Agriculture and Land Use, Land-Use Change and Forestry (LULUCF) sectors were integrated into one chapter as the Agriculture Forestry and Other Land Use (AFOLU) Sector.

In the AFOLU sector, the main greenhouse gases of concern are CO_2, N_2O and CH_4.Other gases of enormous interest are NO_x and CO because they are precursors for the formation of greenhouse gases (GHGs) in the atmosphere. CO_2 fluxes between the atmosphere and ecosystems are primarily controlled by uptake through plant photosynthesis and releases via respiration, decomposition and combustion of organic matter; N_2O is primarily emitted from ecosystems as by-products of nitrification and denitrification; CH_4 is emitted through methanogenesis under anaerobic conditions in soils and manure storage, through enteric fermentation and during incomplete combustion while burning organic matter. The precursor gases emanate from biomass burning in all managed lands.

In accordance with the IPCC 2006 Guidelines the AFOLU sector considered greenhouse gas emissions from four main subcategories: Livestock production (3A), Lands (3B), Aggregate sources and non-CO_2 emissions (3C) and others (3D). Livestock production can result in methane (CH_4) emissions from enteric fermentation (3A1) and both CH_4 and nitrous oxide (N_2O) emissions from livestock manure management systems (3A2).On Land, emissions and removal of CO_2 and non-CO_2 greenhouse gases are considered from each of the six land use categories (Forest land {3B1}, Cropland {3B2} , Grass land {3B3}, Wetland {3B4}, Settlements {3B5} and other lands {3B6}) including both land remaining in a land use category as well as land converted to other land use. Aggregate sources of CO_2 and Non-CO_2 emissions of GHG include emissions from biomass burning (3C1), liming (3C2), Urea application (3C3), Direct N_2O emission from managed soils (3C4), Indirect N_2O emission from managed soils (3C5), Indirect N_2O emissions from manure management (3C6), Rice cultivation (3C7) and others (3C8). Other sources of GHG emissions include Harvested wood Products (3D1) and others (3D2).

The AFOLU module of the inventory considered combined greenhouse gas emissions from agriculture and forestry subject to availability of the relevant activity data in the primary, secondary and/or default status.

The AFOLU sector source category analysis

The AFOLU sector source category analysis (Table A) gives a summary of the occurrence/presence or non-occurrence/absence of a particular source category and whether an activity data is available, or not for a particular source category in Sierra Leone.

Table	**AFOLU SECTOR SOURCE CATEGORY ANALYSIS IN SIERRA LEONE**		
Category code	**CATEGORY NAME**	**PRESENT (P)/ABSENT (A)**	AVAILABILIY/NON-AVAILABILITY OF ACTIVITY DATA
3A	**Livestock**		
3A1	**Enteric fermentation from livestock**	P	
3A1ai	Dairy Cows	A	Data not available (DNA)
3A1aii	Other cows	P	Data available (DA)
3A1b	Buffalos	A	DNA
3A1c	Sheep	P	DA
3A1d	Goats	P	DA
3A1e	Camels	A	DNA
3A1f	Horses	A	DNA
3A1g	Mules and asses	A	DNA
3A1h	Swine	P	DA
3A1j	Rabbits	P	DA
3A2	**Manure management from livestock**	P	
3A2ai	Dairy Cows	A	DNA
3A2aii	Other cows	P	DA
3A2b	Buffalos	A	DNA
3A2c	Sheep	P	DA
3A2d	Goats	P	DA
3A2e	Camels	A	DNA
3A2f	Horses	A	DNA
3A2g	Mules and asses	A	DNA
3A2h	Swine	P	DNA
3A2i	Poultry(Chicken)	P	DA
3B	**Lands**	P	
3B1	**Forest**	P	
3B1a	**Forest land Remaining Forest Land**	**P**	**DNA**
3B1b	**Land Converted to Forest**	**P**	**DNA**
3B1bi	Cropland converted to Forest	A	DNA
3B1bii	Grassland converted to Forest	A	DNA
3B1biii	Wetland converted to forest	A	DNA
3B1biv	Settlement converted to Forest	A	DNA

3B1bv	Other land converted to Forest	A	DNA
3B2	**Cropland**	P	
3B2a	**Cropland Remaining Cropland**	**P**	**DA**
3B2b	**Land Converted to Cropland**	**P**	**DNA**
3B2bi	Forestland converted to cropland	P	DNA
3B2bii	Grassland converted to Cropland	P	DNA
3B2biii	Wetland converted to Cropland	P	DNA
3B2biv	Settlement converted to Cropland	A	DNA
3B2bv	Other land converted to Cropland	A	DNA
3B3	**Grassland**	P	
3B3a	**Grassland remaining Grassland**	**P**	**DNA**
3B 3b	**Land converted to Grassland**	**P**	**DNA**
3B3bi	Forestland converted to Grassland	P	DNA
3B3bii	Cropland converted to Grassland	A	DNA
3B3biii	Wetland converted to Grassland	A	DNA
3B3biv	Settlement converted to Grassland	A	DNA
3B3bv	Other land converted to Grassland	A	DNA
3C	**Aggregate sources and non-CO_2 emissions**	P	
3C1	**Emissions from biomass burning**	**P**	
3C1a	Biomass burning from Forestland	P	DNA
3C1b	Biomass burning from Cropland	P	DNA
3C1c	Biomass burning from Grassland	P	DNA
3C1d	Biomass burning from all Other lands	A	DNA
3C2	Liming	A	DNA
3C3	Urea application	P	DA
3C4	Direct N_2O emissions from managed soils	P	DNA
3C5	Indirect N_2O emissions from managed soils	P	DNA
3C6	Indirect N_2O emissions from manure management	P	DNA
3C7	Rice cultivation	P	DA
3D	Other	P	
3D1	Harvested wood product	P	DNA

Description of Source categories

Livestock (3A)

Emissions of methane from Enteric Fermentation in livestock, and methane and nitrous oxide emissions from Manure Management are considered.

Enteric Fermentation from livestock (3A1) – Methane (CH4)

Methane emissions from enteric fermentation from livestock such cattle, sheep, goat etc. occurs during the normal digestion process by which carbohydrates are broken down by micro-organisms in the digestive tracks of livestock into simple molecules for absorption into the blood-stream. The quality and quantity of methane gas produced during enteric fermentation are much higher than that of methane from manure management and it depends on the type, age and weight of the animal and the quantity and quality of feed consumed. In Sierra Leone, animal rearing is practiced mainly in the northern region but animals are also reared in pockets in areas around the country. Whether it is an underestimate or overestimate, country activity data is available in respect of the number of animals for each life stock type (Appendix 1).

Manure Management from Livestock (3A2) – Methane (CH_4) and Nitrous Oxide (N_2O)

Manure refers to both the dung and urine produced by livestock. Both CH_4 and N_2O are emitted during storage and treatment of manure and from manure deposited on pastures. Manure handling and storage conditions affect its decomposition and subsequently the quantity of methane released. On the one hand when manure is allowed to anaerobically decompose as liquid in lagoons, ponds, tanks etc., significant amount of CH_4 is produced depending on the temperature and the retention time of the storage facility. On the other hand, when manure is handled as solid in piles, stacks or when deposited on pasture and range lands, it tends to decompose under more aerobic conditions and less CH_4 is produced. Similarly during storage and treatment of manure, N_2O is released into the atmosphere either directly via nitrification and denitrification of nitrogen contained in the manure or indirectly from volatile nitrogen losses in the form of ammonia or Oxides of nitrogen (NO_x), the amount depending on the nitrogen and carbon content of the manure, duration of storage and treatment type. Nitrification is an oxidative process where ammonia nitrogen in stored animal manure is converted to nitrate in the presence of sufficient supply of oxygen and in the process N_2O is released. Denitrification is the transformation of nitrates and nitrites to N_2O and nitrogen (N_2) under anaerobic conditions.

The emissions from manure management and treatment accounts for emissions of N_2O resulting from manure handling prior to its addition to the soil. However, manure related N_2O emissions from soils after application to soils are considered as agricultural soil N_2O emissions hence the need to quantify the amount of N retain in manure before application.

In Sierra Leone, substantial amount of manure from livestock is being produced and its utilization as organic fertilizer is only very popular among vegetable growers. Generally livestock manure is not managed although at a very low scale, manure collections are made. However, the management poses a lot of challenges in terms of quantifying the quantity of manure collected, standardization of packaging units and the quantification of nitrogen in the manure before marketing and subsequent application. There are no data on the quantity of manure collected, no standardized packaging units and no quantification of the amount of nitrogen in the manure collected.

Table A: AFOLU SECTOR SOURCE CATEGORY ANALYSIS IN SIERRA LEONE			
Category code	**CATEGORY NAME**	**PRESENT (P)/ABSENT (A)**	**Status**

3A	**Livestock**		
3A1	**Enteric fermentation from livestock**	P	
3A1ai	Dairy Cows	A	NO
3A1aii	Other cows	P	E
3A1b	Buffalos	A	NO
3A1c	Sheep	P	E
3A1d	Goats	P	E
3A1e	Camels	A	NO
3A1f	Horses	A	NO
3A1g	Mules and asses	A	NO
3A1h	Swine	P	E
3A1j	Rabbits	P	E

Lands (3B) –Carbon dioxide (CO_2)

The emphasis in this subcategory is on the emissions/removals of CO_2 on managed lands due to changes in biomass, dead organic matter and soil organic carbon on all land use categories i.e. Forestland, Cropland, Grassland, Wetlands and Settlements and on land converted from one land use category to another. Areas of land where vegetation occur may form complex ecosystems with several interrelated components, each of which acts as a carbon storage pool. As a result of naturally occurring biological processes in forests (e.g. growth, mortality and decomposition) and anthropogenic activities (e.g. harvesting, thinning and replanting), carbon is continuously recycled through these ecosystem components, as well as between the forest and the atmosphere. For instance, the growth of trees results in the uptake of CO_2 from the atmosphere and storage of carbon in living biomass. As trees age, they continue to accumulate carbon until they reach maturity, at which point they are relatively constant carbon stores. As trees die and otherwise deposit litter and debris on the forest floor, decay processes release CO_2 to the atmosphere and also increase soil carbon. In each land use category and land use category converted from one land use to another, the net change in carbon is the sum of the net changes in the total amount of carbon stored in each of the land use category and converted land use categories carbon pools over time.

According to the IPCC 2006 guidelines, CO_2 emissions/removals from lands considered emissions/removals from the following categories:

Category code	**Category name**	**Status**
3B	**Lands**	
3B1	**Forest**	

3B1a	**Forest land Remaining Forest Land**	DNA/NE
3B1b	**Land Converted to Forest**	DNA/NE
3B1bi	Cropland converted to Forest	NO
3B1bii	Grassland converted to Forest	NO
3B1biii	Wetland converted to forest	NO
3B1biv	Settlement converted to Forest	NO
3B1bv	Other land converted to Forest	NO

Forest land remaining forest land (3B1a) and 3B1b Land converted to Forest land i. e Cropland converted to forest land (3.2B1bi), Grassland converted to Forestland (3.2B1bii), Wetland converted to Forest land (3.2B1biii), Settlement converted to Forest (3.2B1biv) and other lands converted to forest (3.2B1bv);

The forestland considers GHG emissions/removals due to changes in biomass, dead organic matter and soil organic carbon from two subcategories: Forest land remaining forestland and land converted to forestland. The forest lands under consideration here include those that are being managed (i.e. subject to human interventions ranging from protecting forest, raising plantations, promoting natural regeneration, commercial timber production, non-commercial fuel wood extraction to abandonment of managed land) and have remained forest for over 20 year (default). In these managed forests, carbon stock changes frequently occur due to human activities and naturally occurring biological processes. When forest lands are abandoned trees tend to grow as result of CO_2 uptake/removal from the atmosphere in the process of photosynthesis and storage of such carbon in living plants biomass (i.e. Biomass (above ground and below ground) is gained). On the other hand human activities such as round wood removal, fuel wood gathering, disturbances from fire, insects, and diseases and natural processes of dead and decomposition result in biomass being lost. Combustion of harvested wood materials and the decomposition of dead wood, litter and soil organic matter result in the release/emission of CO_2 in to the atmosphere.

Cropland remaining cropland (3B2a) and 3B2b land converted to cropland i.e. Forest land converted to cropland (3.2B2bi), Grassland converted to Cropland (3.2B2bii), Wetland converted to cropland (3.2B2biii), Settlement converted to cropland (3.2B2biv) and other lands converted to cropland (3.2B2bv).

Category code	**Category name**	**Status**
3B2	**Cropland**	
3B2a	**Cropland Remaining Cropland**	DA/NE
3B2b	**Land Converted to Cropland**	DNA/NE
3B2bi	Forestland converted to cropland	DNA/NE
3B2bii	Grassland converted to Cropland	DNA/NE
3B2biii	Wetland converted to Cropland	DNA/NE
3B2biv	Settlement converted to Cropland	DNA/NE
3B2bv	Other land converted to Cropland	DNA/NE
3B3	**Grassland**	

Cropland includes arable and tillable land, rice fields, and agroforestry systems where the vegetation structure falls below the thresholds used for the Forest Land category, and is not expected to exceed those thresholds at a later time. It includes all annual and perennial crops as well as temporary fallow land (i.e., land set at rest for one or several years before being cultivated again). Annual crops include cereals, oils seeds, vegetables, root crops and forages. Perennial crops include trees and shrubs, in combination with herbaceous crops (e.g., agroforestry) or as orchards, vineyards and plantations such as cocoa, coffee, tea, oil palm, coconut, rubber trees, and bananas, except where these lands meet the criteria for categorization as Forest Land. Arable land which is normally used for cultivation of annual crops but which is temporarily used for forage crops or grazing as part of an annual crop-pasture rotation (mixed system) is included under cropland.

The amount of carbon stored in and emitted or removed from permanent cropland depends on crop type, management practices, and soil and climate variables. For example, annual crops (cereals, vegetables) are harvested each year, so there is no long-term storage of carbon in biomass. However, perennial woody vegetation in orchards, vineyards, and agroforestry systems can store significant carbon in long-lived biomass, the amount depending on species type and cultivar, density, growth rates, and harvesting and pruning practices. Carbon stocks in soils can be significant and changes in stocks can occur in conjunction with soil properties and management practices, including crop type and rotation, tillage, drainage, residue management and organic amendments. Burning of crop residue produces significant non-CO_2 greenhouse gases.
The term land-use conversion refers to lands coming from one type of use into another. In cases where existing perennial cropland is replanted to the same or different crops, the land use remains Cropland. Land-use conversions to Cropland from Forest Land, Grassland and Wetlands usually result in a net loss of carbon from biomass and soils as well as N_2O to the atmosphere. However, Cropland established on previously sparsely vegetated or highly disturbed lands (e.g., mined lands) can result in a net gain in both biomass and soil carbon.

According to the IPCC 2006 inventory guidelines, the cropland considers GHG emissions/removals due to changes in biomass, dead organic matter and soil organic carbon from two subcategories: Cropland remaining cropland and land converted to crop land. Crop land that has not undergone any land change conversion for a default period of at least twenty (20) years is the type considered under crop land remaining crop land. Thus perennial woody crop plantations (Cacao, coffee and oil palm) which are frequent plantations in Sierra Leone, now increasing in acreage from year to year (See Appendix 6) could be used for estimation of changes in carbon stock in cropland biomass. For annual crops, increase in biomass stocks in a single year is assumed equal to biomass losses from harvest and mortality in the same year and thus there is no net accumulation of biomass carbon stocks.

Grassland remaining grassland (3B3a) and 3B3b land converted to Grassland i.e. Forest land converted to grassland (3.2B3bi), Cropland converted to

Grassland (3.2B3bii), Wetland converted to grassland (3.2B3biii), Settlement converted to grassland (3.2B3biv) and other lands converted to grassland (3.2B3bv).

Category code	**Category name**	**Status**
3B3	**Grassland**	
3B3a	**Grassland remaining Grassland**	DNA/NE
3B 3b	**Land converted to Grassland**	DNA/NE
3B3bi	Forestland converted to Grassland	DNA/NE
3B3bii	Cropland converted to Grassland	DNA/NE
3B3biii	Wetland converted to Grassland	DNA/NE
3B3biv	Settlement converted to Grassland	DNA/NE
3B3bv	Other land converted to Grassland	DNA/NE

Grass lands are ecosystems distinguished by having a tree canopy cover of less than a certain threshold which varies from region to region. Grass lands vary significantly in their degree and intensity of management, from extensively managed ranged lands and savannahs-where animal stocking rates and fire are the main management variables to intensively managed (e.g. with fertilization , irrigation, species changes) continuous pasture and hay land. Generally, grass lands are dominantly characterized by perennial grasses and grazing is the predominant land use. In the grass land ecosystems, the below-ground carbon dominates and is mainly contained in roots and soil organic matter. Since the below –ground biomass is the main carbon pool of grass land ecosystems, estimation of carbon emissions/removal from grass lands is associated with changes in carbon stock due to changes in below-ground biomass and soil organic matter.

Estimation of emissions/removals of GHG from grass lands is often from grass land remaining grass land and land converted to grass land. For grass land remaining grass land carbon emissions/removals are based on estimating the effects of changes in management practices on carbon stocks and for land converted to grass land, carbon emissions/removals are based on estimating the effect of replacement of one vegetation type by grass land vegetation. Grass land remaining grass land simply refers to managed pastures which have been under grass land vegetation and pasture use or other lands converted to grass land for more than 20 years.

The vegetation of Sierra Leone is characterized by a vast expanse of grass land in the northern region where animal raring is commonly practiced. The degree and intensity of management of grass land in Sierra Leone is not very clear. However, extensive ranged lands and savannahs are being utilized as pasture for raring of animals, the areas of which are not ascertained. It is not known whether the area of grass land in Sierra Leone is increasing or decreasing as land use surveys are seldom or virtually not conducted. Similarly, national soil classification into mineral soils and organic soils is a thing unheard of and as such areas of land both managed/unmanaged on both mineral soil and organic soils, which are requirements for estimation of CO_2 flux (emissions and removals) from grass land ecosystems i.e. grass land remaining grass land and land converted to grass land are not documented.

In Sierra Leone, agriculture and mining practices convert substantial areas of forests, grasslands and wetlands including swamps, and bolilands into agricultural croplands, cash crop plantations and abandoned mined-out sites as in the cases of the Diamond mined sites, the Rutile mined sites and Sierra Ore and Metal Company (SIEROMCO) mined sites. Rehabilitation of these mined-out sites by the Mining Companies through replanting of some fruit trees such as cashew and fast growing trees such Acacia trees were attempted. However, to capture the total area rehabilitated and the annual increment of rehabilitated sites and their distribution nationwide are major challenges due to poor management programs. In most cases especially the Diamond Mining sites, no rehabilitation work was done and so the mined sites were left to re-grow naturally, and this takes several decades.

Another major constraint in the land subcategory is the lack of a comprehensive land use and soil classification systems in the country, though one is being developed but yet to be finalized (Personal communication, Director of Forestry). As a result of this, the exact area of each land use type that is managed/unmanaged and their dynamics i.e. the amount of land in one land use category that remained in a particular land use category or that is converted from one land use category into another are not documented. This poses a very serious challenge regarding land management system in Sierra Leone making it impossible to acquire data such as area of each land use category, area of each land use category converted from land use type to another, areas of mineral and organic soils that are being managed/unmanaged.

Wetlands (3B4) -CO_2, CH_4 and N_2O
Wetlands include any land that is covered or saturated with water for all or part of the year and that does not fall into the forestland, cropland or grassland categories. Managed wetlands for the purpose of GHG inventorying, are referred to wetlands where the water table is artificially changed (drained or raised) or those created through human activities such as damming of rivers.

In wetland ecosystems biological and geochemical processes resulting in the GHG emissions and removals are controlled by the degree of water saturation, climate type and nutrient availability. The net carbon flux to and from the atmosphere is a result of the balance between carbon uptake from the atmosphere by photosynthesis and its release as a result of decomposition. The rates of carbon uptake and decay losses are influenced by climate, nutrient availability, water saturation or oxygen availability. In aerobic conditions, decomposition releases CO_2 and CH_4 emissions prevail in anaerobic conditions. Wetlands are recognized for their being saturated or flooded with water and thus the activity of aerobic bacteria and other decay organisms is limited by oxygen unavailability and as such the activity of anaerobic bacteria (the methanogens, sulfurgens) are enhanced resulting in the emission of CH_4.

N_2O emissions are very low in water saturated wetlands unless there is sustained supply of exogenous nitrogen. In drained wetlands (peatland), N_2O emission rates are largely controlled by the provision of nitrogen by mineralization and soil fertility. In nutrient rich wetlands other controls such as pH, temperature and water level regulate the nitrification of mineral nitrogen and its subsequent reduction into N_2O. Drained wetlands releases less CH_4 and more CO_2 as a result of increased availability of oxygen and increased N_2O emissions in nutrient-rich wetlands.

The Estimation of emissions/removals of GHG from managed wetlands is normally from wetlands remaining wetlands and land converted to wetlands. Ramsar 1996, classified human-made wetlands into nine subcategories. The methodological guidance for the estimation of GHG emissions and removals from wetlands are only available for three of the nine subcategories i.e. seasonally flooded agricultural lands (rice cultivation; this is covered in section 3.2C7), water storage (flooded lands) and peatlands managed for peat extraction.

Flooded lands refer to water bodies where human activities have caused changes in the amount of surface area covered by water for the purpose of energy generation (hydroelectricity), irrigation or navigation. Flooded lands in Sierra Leone are very rare particularly when hydropower plants are limited, only two are known the Bumbuna and Dodo in Tonkolili and Kenema districts respectively, agriculture is heavily rain fed and impoundment of rivers for the purpose of navigation is nonexistent. Similarly, there is no areas of wetland particularly set aside for the extraction of peat in Sierra Leone.

2.2 Settlements (B5)-CO2

The category of land referred to as settlements is defined as all developed land i.e. residential, transportation, commercial and production infrastructure of any size unless classified as being under other land use category. It also includes soils, herbaceous perennial vegetation such as turf grass and garden plants, trees in rural settlements, homestead gardens and urban areas.

The estimation of carbon stock change and GHG emissions and removals associated with changes in biomass, dead organic matter and soil carbon on land classified as settlements is often calculated from settlement remaining settlement and land converted to settlement. For settlement remaining settlement, which is any urban formation that have been in use as settlement (public/private lands in cities, villages) since the last time data were collected, estimate of CO_2 emissions and removals is from carbon stocks in biomass (woody and herbaceous components), in dead organic matter (DOM) and soil. The woody biomass carbon stock change is calculated as the difference between biomass increment and biomass loss due to management activities. The herbaceous components carbon stock change in biomass is usually assumed to be zero. Of significant concern too is land converted to settlement because conversion of particularly forestlands, croplands and grasslands to settlement precedes deforestation of original vegetation cover which could lead to huge emissions of GHG. This is exacerbated by the increasing evidence of rural-urban migration and urban sprawl in the country which ultimately could lead to the conversion of lands of different land use to settlements and intense agricultural activities within the settlements areas.

2.2 Other Land (B6)-CO_2

This includes bare soil, rock, ice and all land area that do not fall into any of the land use categories. This is often not managed and therefore changes in carbon stock and non-CO2 emissions and removals are not calculated. However, guidance is provided for the case of land (forestland, cropland, grassland, wetland and settlement) converted to other land use.
Although other land is usually not managed, information on the area of other land country wide is very important for maintaining consistency in land us matrix. Of course such data are yet to be compiled.
Anthropogenic activity such as mining which is currently being massively undertaking within the geographic boundaries of Sierra Leone is absolutely converting hectares of land to other lands such as bare and unproductive soils and even water bodies.

2.2C-Aggregate Sources and Non-CO_2 emissions-CO_2, CH4, N_2O, CO & NO_x
The greenhouse gases considered in this category are CO_2, CH_4, N_2O, CO and NO_x .These are emitted from the following subcategories: biomass burning (3.2C1), liming (3.2C2), and Urea application (3.2C3), directly and indirectly from managed soils (3.2C4 and 3.2C5 respectively) and indirectly from manure management (3.2C6) and Rice cultivation (3.2C7).

Category code	**Category name**	**Status**
3C	**Aggregate sources and non-CO_2 emissions**	
3C1	**Emissions from biomass burning**	
3C1a	Biomass burning from Forestland	DNA/NE
3C1b	Biomass burning from Cropland	DNA/NE
3C1c	Biomass burning from Grassland	DNA/NE
3C1d	Biomass burning from all Other lands	NO
3C2	Liming	NO
3C3	Urea application	0.077
3C4	Direct N_2O emissions from managed soils	DNA/NE
3C5	Indirect N_2O emissions from managed soils	DNA/NE
3C6	Indirect N_2O emissions from manure management	DNA/NE
3C7	Rice cultivation	DA/NE
3D	Other	
3D1	Harvested wood product	DNA/NE

2.2C1 Emissions from biomass burning- CO_2, CH_4, N_2O, CO & NO_x

Biomass burning from both wild fires or prescribed fires can lead to significant emissions of CO_2 and non-CO_2 greenhouse gases (CH_4, N_2O, CO & NO_x) which result from incomplete combustion of biomass and dead organic matter. In this category major sources of greenhouse gas (GHG) include CO_2 emissions from burning of biomass and DOM from Forestlands remaining forestland and from forestlands converted to other land use types and non-CO_2 emissions from burning of biomass from croplands and grass lands.

CO_2 emissions from biomass burning are only captured for forest land remaining forest land and from forestlands converted to other land use types because CO_2 emissions are not synchronous with rates of CO_2 uptake. In cropland and grassland only non-CO2 emissions are captured because of the assumption that CO_2 emissions are counter balance by CO_2 removals by regrowth of vegetation within one year.

2.2C1a Biomass burning from Forestland- CO_2, CH_4, N_2O, CO & NO_x

In this category emissions of CO_2 and non-CO_2 gases resulting from burning of biomass and DOM from both Forestland remaining forest land and from forest land converted to another land use type such as forest plantations are considered. This is because in these land use categories CO_2 emissions are not equivalent to CO_2 removals.

In Sierra Leone Forest fires are not too common but they do occur sporadically around the country. The contribution of forest fires to CO_2 emissions cannot be underestimated. However, estimate of the occurrence, area and distribution of managed forest lands affected by fire annually is a key challenge in this sector. No country activity data is available on the area of managed forest lands affected by fire.

2.2C1b Biomass burning from Cropland- CH_4, N_2O, CO & NO_x

Under this category only emissions of non-CO2 gases resulting from burning of biomass and DOM from both Cropland remaining Cropland and from land (forest land) converted to cropland are considered. This is because in these land use categories CO_2 emissions are assumed equivalent to CO_2 removals by subsequent regrowth of vegetation within one year. Farming activities are very common in almost every corner of the country. Activity data in terms of the areas cultivated annually for major cash and food crops are available. A problem encountered in this category is, determination of the areas of (i) cropland remaining cropland that is affected by fire, (ii) converted forestland to cropland that is affected by fire and (iii) converted grassland to cropland that is affected by fire. There is no country activity data on the total area of cropland remaining cropland and area of land converted to cropland (Forestland and grassland) that are affected by fire.

2.2C1c Biomass burning from Grassland- CH_4, N_2O, CO & NO_x

Similar to section 3.2C1b, this category also considers only emissions of non-CO2 gases that result from burning of biomass and DOM. However, here burning from grassland remaining grassland and from land (forest/croplands) converted to grassland are considered. This is because in these land use categories CO_2 emissions from biomass burning are assumed equivalent to CO_2 removals by subsequent regrowth of vegetation within in one year.

In Sierra Leone, particularly in the northern region, bush fires (wild and prescribed) are very frequent where cattle herders customarily burn huge areas of grassland in successive stages to produce feed for the animals, especially in the dry season. Burning usually begins after the end of the rainy season and ends only in the beginning of the next rainy season. Similarly in the northern part of the country, bush fires are sometimes deliberately set in bush fallows and savanna wood lands so that access to stands left after burning is made possible which are collected or harvested for fuel wood and/or charcoal burning.

Similar to 3.2C1a&b estimation of the land area (ha) of grassland remaining grassland and area of land converted to grassland (forestland and Cropland) that are affected by fire poses a serious challenge. There is no country specific data on areas of grassland remaining grassland and land converted to grassland (forestland and cropland) that are affected by fire. Also data on the amount of wood (m3) collected/harvested per year in the burnt area are not available.

2.2C2 Emissions from Liming-CO_2

In agricultural lands and managed forests where soils are acidic, liming is a common practice used to ameliorate soil acidity and improve plant growth. Usually, when carbonates in the form of Calcic limestone ($CaCO_3$) or dolomite ($CaMg(CO_3)_2$) are added to soils, CO_2 emissions are the result of carbonate limes being dissolved releasing bicarbonate ($2HCO_3$) which evolve into CO_2 and water.

In Sierra Leone, liming is not a routine practice {Personal discussion, direction of extension, Ministry of Agriculture Forestry and Food Security (MAFFS)} and thus no activity data on the utilization of lime to ameliorate adverse soil conditions (Lower pH soils) in the agriculture sector in Sierra Leone.

2.2C3 Emission from Urea application –CO_2

Adding urea to soil also results in CO_2 emission. Urea in the presence of water and the enzyme urease is converted to ammonium, hydroxyl ion and bicarbonate. The bicarbonate in a similar way as in lime application evolves into water and CO_2 which is release into the atmosphere.

In Sierra Leone the arable lands particularly in the upland ecology are mostly impoverished due to the short fallow periods resulting from population increase and subsequent decrease in fallow period. Hence the use of inorganic fertilizers such as urea in crop production to amend soils for better agricultural outputs is likely on the increase as evidence in the availability of records of urea importation. However, a lot of challenges exist in this subcategory with regards the acquisition of data on the amount of urea fertilizer applied each year by farmers. The situation is made even more complex as the annual importation figures, distribution channels, sales records to and the amount applied by farmers or researchers are ramified. There are many key players involved in importation of urea fertilizer; Government imports, Projects such as IFAD supervised by MAFFS and even FAO import, Private companies and NGOs that are directly involved in farming activities import {these are given free duty waiver by the Government of Sierra Leone (GOSL)} and private individuals also import for commercial purposes (these do not benefit from the duty free waiver from the GOSL). To account for the total urea fertilizer imported by the Government, organizations/NGOs/private individuals and the total annual application figures by organizations/NGOs engaged in farming activities and different individual farmers and farmer groups who are the end beneficiaries is a huge challenge particularly when the possibility of not applying all imported fertilizer within a year do exist.

2.2C4 Direct N_2O emission from managed soils

Naturally N_2O is produced in soils and emitted into the atmosphere through the process of nitrification and denitrification. Direct anthropogenic emissions of N_2O result from the addition of N based fertilizers (inorganic/organic) to managed soils through urine and dung deposition on range/paddock by grazing animal to changes in land use and/or management practices that mineralized soil organic nitrogen. These activities ultimately increase the available nitrogen in the soil, thereby enhancing the rates of nitrification and denitrification processes and subsequent increase in N_2O production. The amount of N_2O emitted is affected by the quantity of N based fertilizer inputs, the area of organic soils cultivated and the quantity of urine and dung deposited by domesticated animals on grazed soils.

Similar to 3.2C3, inorganic N based fertilizers such as urea, NPK etc.as well as organic fertilizers such as animal dung, crop residues etc. are increasingly being used in crop production particularly vegetables to amend soils for better agricultural outputs the farmers/researchers in Sierra Leone. The problems associated with use of N based inorganic fertilizers are the same as in 3.2C3 except for the area (Ha) of each land use category including flooded rice fields and organic soils on which the different N based fertilizers are applied and the determination of the amount of N in manure deposited by grazing animals on pasture, range and paddock. Organic fertilizers are usually packed in bags which are not standardized. Farmers procured and applied these fertilizers without knowledge of the amount of N per unit of bag and areas applied not specified. Furthermore on pastures, paddock and rangelands the amount of N in the animal manure deposited are not quantified. Data on the amount of N in mineral soils of particular land use category and then after a change to another land use/management that mineralized soil organic nitrogen are not available.

2.2 Indirect N_2O emissions from managed soils (C5)

Indirect anthropogenic emissions of N_2O are from the addition of N based fertilizers (inorganic/organic) to managed soils or through the deposition of urine/dung on pasture/range land/paddock by grazing animals followed by the volatilization of N in the added synthetic/organic fertilizers as ammonia (NH_3) and Oxides of nitrogen (NO_x) and subsequent deposition of these gases and their products ammonium (NH_4^+) and Nitrates (NO_3^-) onto soils and surfaces of lakes and other water bodies. Leaching/runoff from land of N from synthetic/organic fertilizers including urine and dung deposited on pasture, range or paddock by grazing animals, mineralization/immobilization of N associated with loss of soil Carbon in mineral/organic soil due to land use mainly in the form of Nitrate (NO_3^-) can also lead to its increase in the surfaces of lakes and other water bodies. The nitrification and denitrifcation processes described earlier transform the (NH_4^+) and (NO_3^-) to N_2O.The challenges in this source category remain the same as for direct N_2O emissions from managed soils.

2.2 Indirect N_2O emissions from manure management (C6)

During collection, storage and treatment of animal manure (dung and urine), the nitrogen in the manure is easily mineralized to ammonia and oxides of nitrogen both of which gases volatilize into the atmosphere. The amount of the excreted organic nitrogen mineralized during collection and storage depends primarily on time and to a lesser degree on temperature. These gases are subsequently deposited as ammonium (NH_4^+) and Nitrates (NO_3^-) respectively onto soils and surfaces of lakes and other water bodies. Nitrogen in the form Nitrate is also lost through runoff and leaching into soils from the solid storage of manure at outdoor areas, in feedlots and where animals graze in pastures/rang or paddock. N_2O emissions from the NH_4^+ and NO_3^- occur as a result of the processes of nitrification and dentrification.

The challenges are, acquiring activity data such as the quantity of animal manure collected and the amount of N in the animal manure collected before and after storage are very difficult to obtain in Sierra Leone. This is probably due to lack of the appropriate infrastructure and trained personnel. The number of animal head per livestock type exists but the total amount of N (Kg N/Yr.) excreted for each livestock type doesn't exist. Hence the possibility of calculation of annual indirect N_2O emissions from manure management does not exist.

2.2 Emissions from rice cultivation (C7) –CH4

This source category of emissions is accounted for by methane produced in anaerobic decomposition of organic material in flooded rice fields from where the methane escapes to the atmosphere mainly by diffusive transport through the rice plants. The level of emissions is dependent on the rice variety, its cultivation period, soil type, temperature, irrigation practices, organic amendment and probably the ecology.

Rice cultivation is the most dominant agricultural activities in Sierra Leone. Its contribution to the overall CH_4 emission is quite significant. However, inventorying CH_4 from this source category is presented with many challenges key among them are

i) Available activity data on area of rice cultivation is not disaggregated either by variety or by ecology (See Appendix 3).
ii) There is no information on variety specific cultivation period
iii) Information/data on organic amendments of rice fields is not available
iv) Information on the use of inorganic fertilizer application both in terms of quantity, type and area is not available.

2.2 Harvested wood products (D) (HWP)-CO_2)

Harvested wood products include all wood materials including bark that leaves the harvest site. It forms a unique carbon pool/reservoir from which CO_2 can subsequently be released to the atmosphere after being in products for differing lengths of time, depending on the product and its uses. For instance, fuel wood and mill residue may be burned in the same year of harvest, paper of any type may have use life of less than 5 years, sawn wood and panels used in buildings may be held for decades to over a century and discarded HWP in solid waste disposal sites (SWDS) can persist for long periods of times. Due to this storage in products in use and in SWDS, the oxidation of the HWP in a given year could be less or potentially more than the total amount of harvested wood in that year.

In Sierra Leone, although timber export/international trade in timber was and is still banned in the country since several years back, wood was harvested as timber and exported before. Besides, fuelwood harvesting and subsequent use as energy source predominates in rural settings of the country. In the urban settings too the use of charcoal as energy source for cooking is still very high. As such, the contribution of CO_2 emissions from HWP to the overall AFOLU sector's contribution cannot be under estimated. Though activity data such as total annual harvest of wood (m^3) for products such as Timber, charcoal are available, this subcategory is not without challenges key among which are

(i) Annual export data of timber and timber products (m^3) are not available.

(ii) Annual import figures of wood based materials (tonnes/m^3) are likewise difficult to obtain.

(iii)The unavailability of the amount of wood used domestically.

Data Sources

The Planning, Evaluation, Monitoring and Statistics Division (PEMSD) of the Ministry of Agriculture, Forestry and Food Security (MAFFS) publishes agricultural statistics data on regular basis in the area of livestock production (Appendix 1), tree crop, other major food crops productions (Appendix 2) and Rice production (Appendix 3) that could be used for the purpose of inventorying.

The Forestry division of MAFFS is a major sources of information for harvested wood products particularly Timber, fuel wood and charcoal (Appendix 4) and together with the Ministry of trade and Industry (MTI) for export figures of harvested wood products especially Timber.

Fertilizer utilization (organic and inorganic) figures cannot be obtained directly from farmers who are the end users due possibly to the high level of illiteracy among the majority of farmers in the country making them adequately ill-prepared for any proper record keeping of fertilizer procurement and application. However, inventorying GHG emissions from the use of either organic/inorganic fertilizers particularly for urea were made by making use of importation figures with the assumption that all fertilizers imported into Sierra Leone were assumed utilized within the same year of importation. Importation figures of fertilizer were sourced from various departments including MAFFS stores at kissy Dockyard, Freetown (Appendix 5A) and Office of the Permanent Secretary MAFFS (Appendix 5B).

Table sector data source characteristics

Sector	Data Type	Data Source	Principal Data Providers
Agriculture, Forestry and Other Land Use		The Planning, Evaluation, Monitoring and Statistics Division (PEMSD) of the Ministry of Agriculture,	The Planning, Evaluation, Monitoring and Statistics Division (PEMSD)

			Forestry and Food Security (MAFFS)	
3.A1	Enteric fermentation from livestock	Number of animals (cows, sheep, goats, chickens etc.)	do	do
3.A2	Manure management from livestock	Number of animals (cows, sheep, goats, chickens etc.)	do	do
3.B1	Forest	Export figures of harvested wood products especially Timber.	Ministry of trade and Industry (MTI)	The Forestry division of MAFFS
3.B3	Grassland	The Forestry division of MAFFS	The Forestry division of MAFFS	The Forestry division of MAFFS
3.C1	Biomass burning	Do	do	do
3.C2	Urea application	Do	do	do

Methodology

The method described in the revised 2006 IPCC manual of inventory guidelines was used to estimate the net carbon dioxide fluxes and other GHG emissions for the subcategories in the AFOLU sector.

Life stock Enteric Fermentation and Manure Management

CH4 Emissions from livestock Enteric Fermentation

Methane Emissions from livestock enteric fermentation were calculated on the basis of IPCC 2006 guidelines using the formula:

$$\text{Emission} = EF_{(T)} * \left[\frac{N_{(T)}}{10^6}\right]$$

Where Emissions=Methane emissions from enteric fermentation, $GgCH_4yr^{-1}$, $EF_{(T)}$ = Emission factor for the defined livestock population, $KgCH_4$ $head^{-1}yr^{-1}$, $N_{(T)}$=The number of head of livestock category T in the country, T= category of livestock.

CH4 Emissions from livestock manure management

Methane emissions from livestock manure management were calculated on the basis of IPCC 2006 guidelines using the formula

$$\text{CH4 Methane} = \sum_{(T)} \frac{EF_{(T)} * N_{(T)}}{10^6}$$

Where $CH4_{methane}$=CH4 emissions from manure management, for a defined population. Gg $CH4yr^{-1}$

$EF_{(T)}$=emission factor for the defined livestock population, Kg $head^{-1}yr^{-1}$

$N_{(T)}$=the number of head of livestock species/category T in the country
T=species/category of livestock

Because national emission factors were not available, different default emission factors for each livestock category for both enteric fermentation (Volume 4 Tables 10.10 & 10.11 of IPCC 2006 Inventory guidelines) and manure management (Volume 4 Tables 10.14, 10.15 & 10.16 of IPCC 2006 Inventory guidelines) were obtained and used in the calculations.

Results

The EFs for the estimate of methane from enteric fermentation were already embedded in the IPCC 2006 inventory software. The CH4 emissions from livestock enteric fermentation and manure management estimated for the year 2005 is shown in table 1below

Table 1					
Sector	**Agriculture, Forestry and Other Land Use**				
Category	**Methane Emissions from Enteric Fermentation and Manure Management for 2005**				
Category code	**3A1 and 3A2**				
Sheet	**1 of 1**				
Equation	**Equation 10.19**		**Eq. 10.19 and 10.20**	**Equation 10.22**	
Species/Livestock category	Number of animals	Emission factor for Enteric Fermentation	CH_4 emissions from Enteric Fermentation	Emission factor for Manure Management	CH_4 emissions from Manure Management
	(head)	(kg head^{-1} yr^{-1})	(Gg CH_4 yr^{-1})	(kg head^{-1} yr^{-1})	(Gg CH_4 yr^{-1})
		Tables 10.10 and 10.11	$CH_{4\ Enteric} = N_{(T)} * EF_{(T)} * 10^{-6}$	Tables 10.14 - 10.16	$CH_{4\ Manure} = N_{(T)} * EF_{(T)} * 10^{-6}$
T	**$N_{(T)}$**	**$EF_{(T)}$**	**$CH_{4\ Enteric}$**	**$EF_{(T)}$**	**$CH_{4\ Manure}$**
Dairy Cows					
Other Cattle	226064	31	7.008	1	0.226
Buffalo					
Sheep	272222	5	1.361	0.2	0.054
Goats	318381	5	1.592	0.22	0.070
Camels					
Horses					
Mules and Asses					
Swine	18372	1	0.018	1	0.018
Poultry	3640747	NA		0.02	0.073
Other[1] Rabbit	4730			0.08	0.000
Total			9.979		0.442
[1] Specify livestock categories as needed using additional lines (e.g. llamas, alpacas, reindeers, rabbits, fur-bearing animals etc.)					

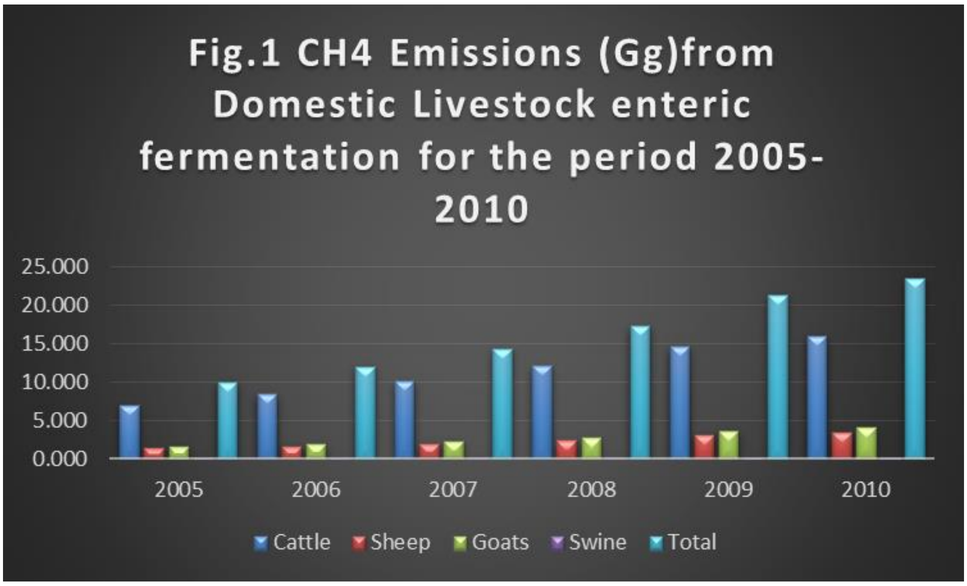
Nitrous oxide (N_2O) emissions from livestock manure management
Estimate of N_2O emissions from livestock manure management was not calculated because in Africa manure from livestock is usually not management. Assessment of manure management system usage in Africa (IPCC 2006 guidelines Table 10A-5,10A-7) indicated that countries in Africa, Sierra Leone not excluded the pasture, range and paddock manure management system is most predominant (95% and 87% for other cattle and swine respectively) manure management system in used i.e. do not manage the manure produced by life stock. The situation is very similar for other life stock categories like goat, sheep and poultry. Instead the manure is left to lie as they are deposited and not managed. N_2O emissions generated by manure in the system 'pasture, range and paddock' occur directly and indirectly from soils and are therefore reported under the category N_2O emissions from managed soils (See section 3.4.3 subsections 3.4.3.4 and 3.4.3.5)

Results
Results of estimations of CH_4 emissions from livestock enteric fermentation for the period 2005-2010 are presented in Tables 2 and Figure 1

Table 2: CH4 emissions (Gg) from enteric fermentation for the period 2005-2010

Sources/Sinks category	**Year**					
	2005	2006	2007	2008	2009	2010
Cattle	7.008	8.410	10.091	12.110	14.570	16.027
Sheep	1.361	1.633	1.960	2.352	3.100	3.410
Goats	1.592	1.910	2.292	2.751	3.650	4.015
Swine	0.018	0.023	0.029	0.036	0.043	0.047
Total	**9.979**	**11.976**	**14.373**	**17.248**	**21.363**	**23.499**

Fig. 3.24 CH_4 emissions (Gg) from enteric fermentation for the period 2005-2010

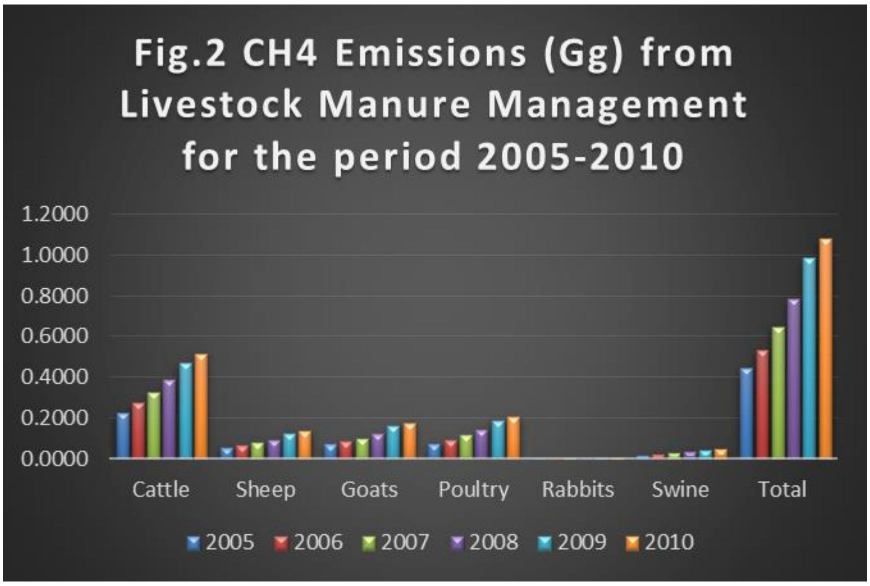


Results of estimations of CH_4 emissions from livestock manure management for the period 2005-2010 are presented in Tables 3 and Figure 2

Table 3: CH4 emissions (Gg) from Livestock manure management for the period 005-2010

Sources/Sinks category	Year					
	2005	2006	2007	2008	2009	2010
Cattle	0.2261	0.2713	0.3255	0.3906	0.4700	0.5170
Sheep	0.0544	0.0653	0.0784	0.0941	0.1240	0.1364
Goats	0.0700	0.0841	0.1009	0.1210	0.1606	0.1767
Poultry	0.0728	0.0910	0.1138	0.1422	0.1866	0.2053
Rabbits	0.0004	0.0005	0.0006	0.0007	0.0009	0.0010
Swine	0.0184	0.0230	0.0287	0.0359	0.0431	0.0474
Total	0.44	0.54	0.65	0.78	0.99	1.08

Fig. 3.25 CH_4 emissions (Gg) from Livestock manure mgt for the period 2005-10



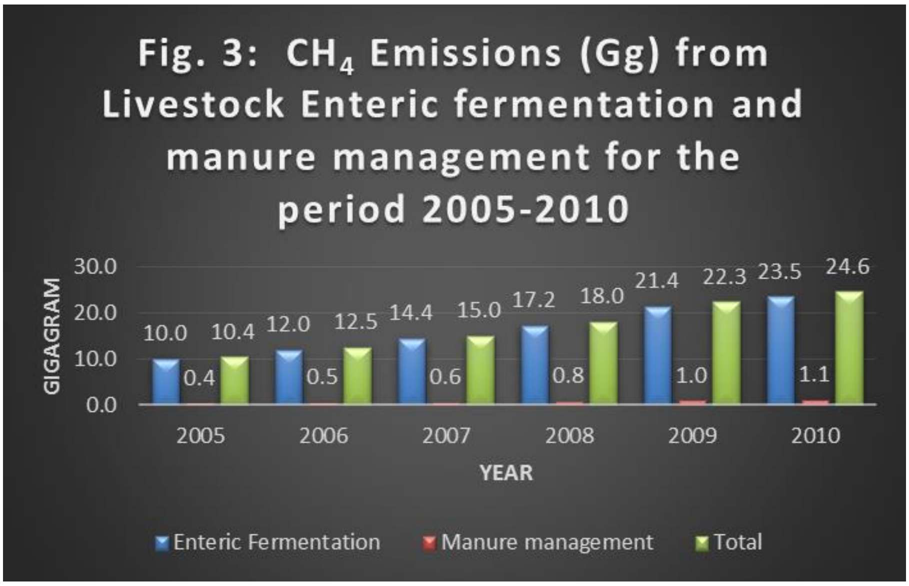
Results of estimations of CH_4 emissions from livestock enteric fermentation and manure management for the period 2005-2010 are presented in Table 4 and Figure 3.

Table 4 : CH4 emissions (Gg) from Enteric Fermentation and Manure management

	2005	2006	2007	2008	2009	2010
Enteric Fermentation	10.0	12.0	14.4	17.2	21.4	23.5

Manure management	0.4	0.5	0.6	0.8	1.0	1.1
Total	10.4	12.5	15.0	18.0	22.3	24.6

Fig. 3.26 CH_4 emissions (Gg) from Enteric Fermentation and Manure management



The bulk of the CH_4 produced by livestock enteric fermentation was obtained from the animal subcategory cattle, this was followed by goat, sheep and the least obtained from swine (Table 2).

The CH4 produced from livestock manure management is very small when compared with enteric fermentation, however the situation is very similar to enteric fermentation for the simple fact that cattle wastes alone contribute nearly half of the overall CH_4 produced in livestock manure management. The least CH_4 emissions when manure management is considered are obtained from rabbits. (Table 3).

The total methane emissions from life stock production take into account emissions from enteric fermentation and manure management. A total of 10.4, 12.5, 15.0, 18.0, 22.3 and 24.6Gg of carbon were emitted from all life stock categories for each year from 2005 -2010 respectively (Table 4). It is very clear that the contribution of enteric fermentation to the overall livestock methane emissions is far greater when compared to manure management. More than 90% of the methane emitted from livestock production is obtained from enteric fermentation. The trend is that there is steady increase in methane emissions from livestock production for each year from 2005 -2010. This could be attributed to the steady increase in the number of livestock rare during the period under investigation.

Estimations of N_2O emissions from livestock manure management for the period 2005-2010 were not calculated due to unavailability of activity data.

3.4.2 Lands
3.4.2.1 Forest land

Estimating the net CO_2 flux (emission or removal) due to emissions from changes in forest and other woody biomass and from removals from abandonment of managed forestlands remaining forest land and lands converted to forest land was impossible due to the unavailability of country specific data appropriate for the IPCC 2006 software.

The specific data that were missing that led to the non-calculation of CO_2 for Forest remaining forest land or land converted to forest land are given below:

- ✓ The total are of forest land (both managed and unmanaged) that has been under forest land for at least 20 year transition period for the purpose of analysing land-use conversion matrix
- ✓ The exact area of forest land that is being managed country wide
- ✓ Basic wood density of trees species harvested for fuel wood in both forest land and land converted to forest land.
- ✓ Annual volume of wood harvested (m^3yr^{-1}) for fuel wood were provided but were in bulk figures rather than by tree species. Example of the kind of data obtained for fuel wood harvesting is shown in appendix 6. And no indication of whether harvesting took place in forest area remaining forest or in land converted to forest.
- ✓ Annual area of forest land or land converted to forestland affected by disturbances such as fire
- ✓ Annual area of land converted to forest land

Cropland
The estimation of the net CO_2 flux (emission or removal) due to emissions from cultivation of perennial crop on organic/inorganic soils and from removals from annual increment of perennial crop biomass crop on land remaining crop land and lands converted to crop land was impossible due to the unavailability of certain country specific data appropriate for the IPCC 2006 software.

However, data on the area of land on which perennial crops were cultivated were obtained from the PEMS Division of MAFFS but they were not disaggregated by soil type for land remaining crop land and for land converted to crop land, by type of land (forest land, grass land or wetland), climatic condition and soil type (mineral/organic) of lands from which conversion were made. Example of the type of data obtained from PEMSD, MAFFS is shown in Appendix 6)

The specific data that were missing that led to the non-calculation of CO_2 for cropland remaining cropland or land converted to cropland are given below:

- ✓ The annual area of perennial crops land cultivated on mineral soils
- ✓ The annual area of perennial crops cultivated on organic soil
- ✓ The type, area (ha), climatic condition and soil type (mineral/organic) of land (forest land, grass land or wetland) converted to cropland

Grass land

As a result of the aforementioned difficulties which created an environment, where acquiring appropriate country specific data compatible with IPCC 2006 software just impossible, the estimation of the net CO_2 emissions and removals from grass land was not done .

The specific data that were missing that led to the non-calculation of CO_2 emission//removals grass land remaining grass land or land converted to grass land are given below:

For grass land remaining grass land the following data were unavailable

- ✓ Area of managed grass land on mineral soils
- ✓ Area of managed grass land on organic soils
- ✓ Estimate of carbon stock in inorganic soils

For land converted to grass land, the following data were unavailable

- ✓ Total area of unmanaged/managed land converted to grass land
- ✓ Area of land converted to grass land by land-use category (Forest lands, Crop lands, Wetlands and Settlement lands) and soil type (mineral and organic).

Wetlands

Thus, the calculation of GHG emissions and removals from wetlands is not possible due to the nonexistence of peat extraction in Sierra Leone and the absence of country specific data with respect to the estimate of the area land annually converted to flooded land from original land use for the only two dams in the country.

Settlements

Activity data for calculation of GHG emissions and removals from settlement remaining settlement and land converted to settlement are not available as such emissions/removals of GHG were not estimated.

Specifically, for settlement remaining settlements

- ✓ Land area of cultivated organic soils on an annual basis,
  and for land converted to settlement data on
- ✓ area of land(forestlands, croplands, grassland, wetlands) converted to settlement
- ✓ area of land use change in mineral soils and
- ✓ land area of cultivated organic soils were not available.

3.4.2.6 Other land

Estimating GHG emissions and removals from land converted to other land was also not possible due to the lack of country specific activity data. Specifically the following data were not available

- ✓ Area of land (forestland, cropland, grassland, wetland and settlement) converted to other land due human interventions
- ✓ Area of land converted to other land in mineral soils
- ✓ Area of land converted to other land from cultivated organic soils

3.4.3 Aggregate sources

3.4.3.1 Biomass burning

A major bottle neck that prevented the calculation of CO_2 and non-CO_2 GHG emissions from biomass burning is the total lack of country specific activity data on area affected by fire on annual basis.

Specifically the following data were not available

- ✓ Annual areas burnt in forestland remaining forestland and land converted to forestland
- ✓ Annual areas burnt in cropland remaining cropland and land converted to cropland
- ✓ Annual areas burnt in grassland remaining grassland and land converted to grassland.
- ✓ Annual area burnt in land converted to wetlands

Liming

CO2 emissions from liming activities were not calculated because there activity data were not available since liming is not done in Sierra Leone.

Urea fertilization

Acquiring activity data on the amount of urea applied poses a major challenge among which are

- ✓ There are many players involve in the importation but no clear cut data base of persons/companies/ NGOs, INGOs/projects involve in importation of fertilizers
- ✓ No clear cut supply /distribution channels farmers
- ✓ No record of the quantity of fertilizer (urea) applied annually by farmers/researchers/project implementers.

Data

Since activity data in terms of annual application of urea were not directly obtained from farmers, data for the calculation of CO_2 emissions from urea application were obtained from import figures with the assumption that all fertilizers imported into country were assumed utilized within the same year of importation. The data obtained from MAFFS stores at kissy Dockyard, Freetown (Appendix 5A) were used in the calculation of CO2 emissions from urea application whilst that obtained from the permanent secretary's office, MAFFS were not used because the data were not disaggregated according to fertilizer type (See Appendix 5B).

CO_2 emissions from urea application were calculated on the basis of IPCC 2006 guidelines following a series of steps

- ✓ Estimating the total amount of urea applied annually to soil in the country (obtained from import figures)

- ✓ Applying an overall emission factor (EF) for urea. Default EF of 0.2 was used because there was no country EF for urea application.
- ✓ Estimating annual CO2-C emission from urea application using the formula

CO_2-C Emission = M * EF
Where
CO_2-C Emission= annual C emissions from urea application, tonnes C yr^{-1}
M=annual amount of urea fertilization, tonnes urea yr^{-1}
EF= emission factor, tonne of C per tonne of urea

- ✓ Converting CO_2-C emission into CO_2 (tonnes)) by multiplying CO_2-C emission by 44/12

Calculations were not made for the period 2005 to 2009 as there were no import figures for urea from MAFFS, Kissy Store. The data obtained from the Permanent Secretary's Office, MAFFS for 2009 and 2010 (Appendix 5B) were not disaggregated by fertilization types which rendered the data invalid for any calculations.

Results

Result of estimation of CO_2 emissions from urea application for 2010 is presented in Tables 5

Table 5: CO_2 emissions (tonnes) from urea fertilization for the period 2010

2010	77

The result clearly indicated that in 2010, urea fertilizer application accounted for 77t of CO_2 emission into the atmosphere.

3.4.3.4 Direct N_2O emission from managed soils

Due to the lack of appropriate activity data in the country calculations for the estimation of N_2O emissions from managed soils were not carried out. The major constraints are outlined below

- ✓ The amount of inorganic/organic nitrogen applied annually not available
- ✓ The annual area of managed organic soils on cropland, grassland and forestland not available
- ✓ The amount of nitrogen in urine and dung deposited annually by animals on grazed soil not available.
- ✓ Estimates of annual nitrogen loss in mineral soils due to land use changes not available.

Indirect N_2O emissions from managed soils

The estimation of the indirect N_2O emissions due to atmospheric deposition of Nitrogen volatilized and leached/runoff from managed soils was again not done due a number of constraints associated with the acquisition of appropriate data compatible with IPCC 2006 inventory software.

The relevant unavailable data that lead to the non-calculation of the indirect N_2O emissions from managed soils included the following

- ✓ Annual amount of synthetic fertilizer Nitrogen by type intentionally (Urea, NPK etc) applied to managed
- ✓ Annual amount organic fertilizers Nitrogen by type (animal manure, compost, etc) intentionally applied to managed
- ✓ Annual amount of urine and dung Nitrogen deposited by grazing animals on pasture, range and paddock.

Indirect N_2O emissions from manure management

Apart from data on the number of animal head (which is available), the absence of other activity data made it impossible to calculate indirect N_2O emissions from manure management.
The key activity data absent include

- ✓ the estimate of total annual amount of Nitrogen (Kg N/Yr.) excreted for each livestock category.

Emissions from rice cultivation
Estimating CH_4 emissions from rice cultivation is again practically impossible due to the lack of appropriate data compatible with the IPCC 2006 software.

The key challenges are

- ✓ Available activity data on area of rice cultivation is not disaggregated by variety and ecology (See Appendix 3).
- ✓ No information on variety specific cultivation period
- ✓ Information/data on organic amendments of rice fields in terms of the quantity of crop residue(tonnes/year) applied is not available

Harvested wood products (HWP)
Irrespective of the non-availability of data, there is no internationally agreed methodology for the estimation of CO_2 emissions from HWP. Therefore CO2 emissions from HWP were not estimated.

Difficulties specific to the AFOLU sector

- realize a national forest inventory with a view to having a better knowledge of the sequestering potential;
- conduct surveys to fine-tune the estimate of trees outside forests, in particular trees in urban and rural centers.
- set up an efficient monitoring mechanism of the progression of cultivated areas and bush fires.
- Absence of monitoring of farm clearing;
- Low monitoring capacity of bush fires in the country;
- Total lack of data on some sub sectors such as the use of biomass (notably agricultural residues) as fuels;
- Inexistence of reliable data on the land areas occupied by organic soils even though they are very few in Sierra Leone.

- Absence of a national forestry inventory which could generate more up to date data;
- An adequate, obsolete or even shortage of data for almost all the Land Use, Land Use Change and Forestry Sector;
- Low concern from holder institutions on data relating to inventory activities;
- Inexistence of an inventory of trees outside forest (towns, villages, grazing areas etc.);
- Obsolete nature of the rate of forest regression.

3.6 Waste Sector GHG Emissions

3.6.1 Introduction

The total land area in Sierra Leone is 72,300km^2. Of this, 60,650km^2 is classified as upland and 11,650km^2 as lowland. It is estimated that about 53, 620km^2 (5.36million ha) is suitable for crop production (i.e. 74.2% of the total area).The remaining 18, 860km^2 (25.8%) of the country's land area is described as non-arable and include rocky lands, towns and creeks (MANR/FAO, 1992).

The waste sector is characterized by poor waste management ,rapid urbanization in the Western Area which has resulted in increased problems of sanitation, drainage and waste management. Total solid waste generation within the capital is estimated to be between 0.4 and 0.6 kg/person/day. Percentage of organics in the country's domestic waste was estimated at 80% (Ndomahina, 2009). In a technical study for the relocation of the two dumpsites (Kingtom and Granville brook) in Freetown, a total deposition of waste in the capital Freetown was estimated at 56,020.37 m^3 tons/year equating to 153.48 tons per day (319.75 m^3 per day) (Lake, 2010). The increasing population in cities and towns in Sierra Leone is quite likely to increase the amount and diversity of wastes and subsequently the relative quantum of emissions of GHG from the sector, especially methane (CH_4) from dump sites, and carbon dioxide (CO_2) and precursor gases (NOx, CO).

Institutional and legislative framework of waste management in Sierra Leone

Freetown Municipality (Western Area)

The legal framework for waste management in the country is old, dating back to the 1970s. Despite developmental changes in population especially due to migration from rural areas to the capital Freetown during the war, municipality structure, waste types etc, the Public Health Ordinance has still not been reviewed since 1978. Until the war, Freetown has been the epitome of waste management in Sierra Leone. Notwithstanding, there have been continued changes in the institution responsible for the leadership of waste management. To illustrate, over the years, waste management in Freetown has moved from the Ministry of Health and Sanitation (MOHS) to the Freetown City Council (FCC), then Ministry of Youth and Sports. Not too long ago, the responsibility was handed over to FCC. Waste management was jointly managed by the Environmental Health Division (EHD) of the Ministry of Health and Sanitation, "Klin Salone (a private Non Governmental Organization – NGO), The Freetown Solid Waste Management Company (FSWMC) and Freetown Municipal Council although only "Klin Salone" are the ones actively involved in the day-to-day collection and disposal services. This current organization of waste collection was established by FCC in 2006 with the support of GTZ and the World Bank. The FSWMC was created in the framework of an emergency Phase Operation for waste management. Presently, waste management is handled by a private company MASADA.

Provincial cities

In April 2012, Sierra Leone established the environment and Social unit in Local Councils. This unit in close collaboration with the District Health Superintendent (DHS) in the Ministry of Health and Sanitation promote proper and effective waste collection and management system. Some key activities undertaken by councils in ensuring satisfactory waste management are as follows:

- Day to day collection of garbage/waste in the municipality;
- Organizing monthly general cleaning exercise in the municipality;
- Maintenance and repairs of solid waste management vehicles and tricycles to ensure their smooth running;
- Educating the general public using jingles and weekly radio discussion on environmental sanitation and the negative implication on the indiscriminate dumping of waste in the city.

Councils collaborate with other partners like MOHS, EPA-SL, Ministries of Health and Sanitation & Lands on issues relating to the protection of the environment and waste management in particular. In addition, councils have also been working with other non-Governmental Organization like Living Earth Foundation, UK, ACEDO-SL and UNDP in managing waste through Public Private Partnership (PPP). Youths are contracted as garbage collectors specifically in market area and other key areas in the city.

Situational Analysis

The waste sector in Sierra Leone comprises:
a) Solid waste disposal facilities
b) Domestic and industrial wastewater
c) Open burning
d) Incineration (industrial and medical)

Sources of wastes in Sierra Leone

Waste is generated from a variety of sources which includes:

Domestic

Results obtained from previous investigations and those reported in literature showed that wastes types, quantities and compositions vary widely from one family/household to the other and from one region of the country to the other. In Urban settings, wastes types, composition and quantities were found to vary from one settlement to the other, reflecting the income levels and lifestyles of the different settlement (See Table 1).

Table 1: Types and composition of wastes generated in the Freetown Municipality

Container sites	**Sankey Street**	**Taylor Street**	**Cape Sierra Hotel area**	**Lightfoot Boston street**	**Average**
Type of wastes	Type 1	Type 2	Type 3	Type 4	
Quantity of wastes sorted (Kg)	519	350.4	465	490	456.1 Kg
Specific weight of wastes (Kg/l)	0.45	0.3	0.44	0.37	0.39 Kg/l
% of biodegradable organic matter	17.4	26.4	48	24.9	29.175 %
Percentage of paper	4.9	3.6	14.1	11.5	8.525 %
Percentage of tins and scraps	3	1.8	2.8	3.1	2.675 %
Percentage of plastics and	2.4	1.4	1.6	2.4	1.95 %

foils					
Percentage of textile	5.6	3.3	1.2	1	2.775 %
Stones (>5cm)	1?	0	1	0.8	0.45 %
Glass	0.8	0.8	3.2	0.9	1.425 %
Wood	0.3	0	0.5	23.3	6.025 %
Toxic wastes (batteries)	0.9	0.4	0.3	0.3	0.475 %
Miscellaneous	1.4	2.7	3.4	3.7	2.8 %
Gravel (<5cm >5mm)	41.7	46.6	22.5	26.6	34.35 %
<5mm	20.5	13	1.5	1.4	9.1 %
Compostable fraction	84.5	89.6	86.1	64.4	81.15
Source: Solid wastes management study, 1995, GOPA Consultants in collaboration with AFRIRELIEF					

Table 2: Waste classification and characterization in the greater Freetown area in 2010

Food	**Garden**	**Paper**	**Wood**	**Textile**	**Rubber**	**Plastics**	**Metals**	**Glass**	**Others (earth, sand, silt & pebbles**
4.65	30.65	9.72	1.30	9.53	9.53	11.20	2.84	3.72	16.60
Compostable fraction = 56.10%									
Source = Waste classification studies by Bah and Sankoh, 2010									

Studies in the past have been conducted to determine the composition of municipal waste in the country. The GOPA studies of 1995 analysed sample wastes collected and stored in wastes collection containers. The sample size in the study was 25 to 30 containers (each has a volume of 5m^3). Containers in the sample were drawn from four different locations in Greater Freetown. This ensures that variations in the quantities and compositions of wastes generated in the different settlements of the city are taken care of and average values obtained are representative of almost all urban settings in the country. Also, different commercial activities and income levels of the different settlements were considered in planning and sampling to reflect the country's level of development.

It could be seen from the table above that wastes generated in the 90s from Freetown consists mainly of garbage and non-hazardous solids. The organic materials in the wastes are of biogenic origin e.g. paper, yard trimmings etc. plastics, broken bottles, synthetic rubber, fibres, cans, used clothing and footwear and packaging materials also form a sizable proportion of the wastes.

Over the years, there have been some changes in percentage composition of waste as the level of plastics and bottles in municipal waste increases.

Commercial

Stockpiling, trading and goods distributions have always been considered one of the main historic reasons for a town to be set up. Freetown is the Sierra Leone market place of excellence with the highest presence of traders. Other main cities include Bo, Kenema and Makeni. Market places are located all along the urban populated areas of these cities. Almost all major streets and roads of these cities featured legal or illegal kiosk, street vendors or wooden frame huts selling various kinds of goods. The hectic trading activity (fortunately) makes these cities and towns alive, productive and attractive for youths from the interior of the country. The different trading activities produce wastes of different categories, predominantly compostable types (ranging from agricultural produce to packaging materials)

In the Western Area which comprises of the capital city Freetown, trade and repairs had the largest share of the labour force (45.5%). There were more economically active persons in the Trade and Repairs industry in the Western Urban (47.0% and Western Rural (39.8%) districts than in all the other districts. Thus the trend that emerges from the 2004 population Census data relating to the industrial distribution of the labour force was that trade and repairs were the main economic activity of the economically active population in the Western Region while agriculture was the predominant economic activity of the population in the provincial areas (SSL, 2004)

Industrial

Formerly, the manufacturing industry in Sierra Leone consisted mainly of processing raw materials and light manufacturing for the domestic market, small-scale manufacturing (beverages, textiles, cigarettes, footwear); petroleum refining, small commercial ship repair[3]. Most of these activities are developed in the Western Area, particularly in Freetown.

The Wellington Industrial Estate area, covering 46 hectares east of Freetown, was developed in the 1960s by the government to encourage industrial investments.

[3] https://www.cia.gov/library/publications/the-world-factbook/print/sl.html

Its factories produce a variety of products, including cement, nails, shoes, oxygen, cigarettes, beer and malt drinks, paint, and knitted goods[4]. Timber for prefabricated buildings is milled, whilst other factories produces modern furniture. Nowadays, factories are emerging in the west (Foam factories) alongside established ones such as Sierra Leone Bottling Company, fishing companies etc. Small factories outside the industrial area process tuna and palm oil. In 1992, the oil refinery in Freetown closed due to lack of capital for crude oil imports; in 1994 the facility was sold to Unipetrol of Nigeria. Its production capacity in 2002 was 10,000 barrels per day[5]. Village craft products include a popular cloth, rope, sail canvas, boats, wood carvings, baskets, and leather goods.

Most manufacturing industries and other industrial wastes producing workshops are each supplied with a $5m^3$ waste collection containers which are periodically emptied into the dumpsite close to their operation site.

Background

Description of the waste sector according to the 2006 IPCC Guidelines

In the 2006 IPCC Guidelines, the Waste Sector includes five categories: 4A. Solid Waste Disposal; 4B. Biological Treatment of Solid Waste; 4C Incineration and Open Burning of Waste; 4D Wastewater Treatment and Discharge; 4E Other.

The Waste sector source category analysis
Description of Waste source Categories Present in Sierra Leone

The categories of wastes present in Sierra Leone according to the IPCC are shown below:

Waste source Categories Present in Sierra Leone

Category Code	Category Name	Present in Sierra Leone
4A	Solid Waste Disposal on Land – CH_4	Y
4B	Biological Treatment of Solid Waste	Y
4C	Incineration and Open Burning of Waste	Y
4D	Wastewater Treatment and Discharge	Y
4E	Other/ Medical waste	Y

[4] Sierra Leone Adding Value through Trade for Poverty Reduction. A Diagnostic Trade Integration Study (Sierra Leone DITIS), October 2006. (http://www.daco-sl.org/encyclopedia/1_gov/1_2/mti/DTIS_FinalNov06.pdf)/
[5] http://www.nationsencyclopedia.com/Africa/Sierra-Leone-INDUSTRY.html

Description of Source categories

Solid Waste Disposal on Land (4A)/Source Category Analysis
Solid waste disposal facilities

Waste Management Framework in Sierra Leone, Collection and disposal

Sierra Leone does not have landfill sites and no proper waste management exist. Consequently, all waste received countrywide are indiscriminately dumped either at dumpsites or elsewhere. In the strict sense of the definition, Sierra Leone practices unmanaged waste disposal at our disposal sites. Unmanaged waste disposal on land occur nationwide. This is because illegal dumping of wastes on land in isolated places is common around the country. These are left unattended to decay naturally. Dumping of solid wastes and treatment of sewage is carried out in Freetown, Bo, Kenema and Makeni. Furthermore, the dumpsites in Bo, Makeni and Kenema are open, unmanaged and shallow, so degradation of the wastes occurs in aerobic conditions. Wastes are picked up mainly by skip trucks. The availability of skip trucks is a major constraint limiting solid waste collection from collection points to dumpsites in the cities.

In other to overcome this challenge, local NGOs e.g. Klin Salone is actively conveying waste from residences to the dumpsites using push trucks. Other means by which nearby residences and free lance waste collectors use to collect and deliver waste at the dumpsites are wheel barrows, construction pans, buckets and plastic bags. In the provinces, controlling waste is a challenge because of scarcity of vehicles as well as lack of spare parts for skip trucks in garages.

Waste containers at collection points in the capital are unevenly distributed. In 1995, GOPA reports indicated 69 in the West, 40 in Central and 54 in the East. Furthermore, an Urban Planning Project for Freetown in 2012 indicated that there are 43 waste transit points in Freetown. These are unevenly distributed with more transit points in the West compared to the East. This can be illustrated as follows: West- 10 in Brookfields and its environs, 3 around Juba Army barracks, East: 2 along Kissy Bye Pass and Low Cost Housing, 1 at Mamba Ridge (Frazer-Williams and Benjamin, 2013). As a result, domestic and other types of wastes are more often left unattended on the streets in the East-end part of Freetown compared to the West-end part of Freetown.

All dumpsites in the country are open, unmanaged and shallow (except Granville brook which is a valley). Hence degradation of the wastes occurs predominantly under aerobic conditions. Furthermore, in other parts of the country, open dumping of agricultural wastes is practiced. Sometimes the wastes is composted in a backyard heap and the decomposed materials used as manure in backyard vegetable gardens. However, this represents a very small fraction of total waste collected.

Solid wastes classification

There is no separation of wastes into its respective categories. Even hazardous infectious waste is mixed with domestic waste. Sankoh (2010) in order to account for variations in waste types due to income levels of households in Freetown and to estimate the greenhouse gas emissions using IPCC guidelines carried out a study in which 100 bin bags were distributed to households in Freetown as follows: 33 bin bags to low income households (living in slum settlements), 33 bin bags in middle income households in the Kissy area, 34 bags to high income households at Spur Road and IMAAT areas. Residents in the sampled household were requested to put all their household waste into the bags and if the bags were small, they should either use additional bags or keep the rest of the waste in private containers for the reseacher. The bags were collected after one week and the waste brought to the laboratory at the Biological Sciences Department and sorted. The sorted fractions of the wastes from each bag were weighed and the percentage composition of the waste recorded (Table 2). Percentage of biodegradable organic matter was estimated as 56.10 % and used in the estimation of methane emission from solid wastes disposal sites. The decrease in compostable fraction and an increase in non-compostable fraction of municipal waste in Freetown over the years is believe to reflect the change in lifestyle and economic situation of residence and more recently to the increase disposal of plastics bags. For instance, GOPA (1994) reported plastic content of household waste at 2% from their study compared to 11.8% reported by Bah (2010). Households are appraised to produce on average 0.45Kg waste per capita/day taking into consideration the settlement structure and income levels in different settlements.

Biological Treatment of Solid Waste (4B)
This source category includes wastes such as food waste, garden (yard) and park waste and sludge.

Incineration and Open Burning of Waste (4C)

In many parts of the country, open dumping of domestic and agricultural wastes or open burning is practiced. Sometimes the wastes is composted in a backyard heap and the decomposed materials used as manure in backyard vegetable gardens. Waste collected at the backyards of residents and dumpsites is often set on fire. The most important gases produced in this source category are Methane (CH_4) and Carbon dioxide (CO_2). In addition to CH_4, and CO_2, substantial amounts of non-methane volatile organic compounds (NMVOCs) are also produced from open burning of wastes. Solid wastes from agricultural sources in rural Sierra Leone are also burned down and a large proportion of carbon derived from biomass raw materials are replaced by re-growth on an annual basis.

As in above, the most important gases produced in this source category are Methane (CH_4) and Carbon dioxide (CO_2). In addition to CH_4 and CO_2, substantial amounts of non-methane volatile organic compounds (NMVOCs) are also produced from open burning of wastes.

Wastewater Treatment and Discharge (4D)

Domestic and industrial wastewaters

In Sierra Leone and many other developing countries, wastewaters are not given any form of treatment. Handling is simply by transporting it into the disposal site. Formal wastewater treatment methods can be classified as primary, secondary and tertiary treatment. In primary treatment or sometimes pre-treatment, physical barriers remove larger solids from wastewater. Remaining particulates are then allowed to settle. Secondary treatment consists of a combination of biological processes that promote biodegradation by microorganisms. This sometimes includes aerobic and anaerobic stabilisation ponds, trickling filters, and activated sludge processes. Tertiary treatment processes are normally used to further purify the wastewater of contaminants and pathogens. This could be achieved by the use of one or a combination of processes, including maturation/polishing ponds- advance filtration, carbon adsorption, ion exchange and disinfections. Sludge is produced in both the primary and secondary stages of treatment. Sludge that is produced in primary treatment consists of solids that are removed from the wastewater. Sludge produced in secondary treatment is a result of biological growth in the biomass as well as the collection of small particles. This sludge must be treated further before it can be safely disposed of. Methods of sludge treatment include aerobic and anaerobic stabilisation (digestion), conditioning, centrifugation, composting and drying. Anaerobic stabilisation will produce CH_4.

There are two basic types of wastewater handling systems, which generally make significant contributions to greenhouse gas emission.

i. Domestic and Commercial wastewater and

ii. Industrial wastewater.

The principal factor that determines methane generation potential of wastewater is the amount of organic material in the wastewater stream. For domestic and commercial wastewater and sludge, this is indicated by the biochemical oxygen demand. For Industrial wastewater, the chemical oxygen demand (COD) is used. The BOD indicates the amount of carbon that is aerobically biodegradable, whereas the COD indicates the total amount of carbon, biodegradable and non-biodegradable that is available for oxidation.

In Freetown, the capital of Sierra Leone, a small share of domestic and commercial wastewater is collected in a sewer system whilst the rest end in pit latrines, streams, rivers and the open drainage system. In the rural parts of the country, wastewater is managed without any formal handling system.

At national level, wastewater treatment in Freetown is limited to a small fraction of total sewage discharged in the city. In the capital, few companies have recently installed a wastewater treatment facility. Sewage emptied from septic tanks and pit latrines is discharged into two unmanaged tanks or lagoons at Kingtom. There is a sewer line system in Freetown. This system discharges sewage and other domestic wastewater types into the Sierra Leone River Estuary, giving it only primary treatment. Even there, the sludge removed by filtration mechanism, is ground and then thrown into the sea.

Until recently, all the Industrial wastewater generated in the city by the few bottling and packaging industries is discharged directly into brooks/streams and the open drainage system. These eventually empty into the Sierra Leone River Estuary without receiving any form of treatment. The sewage collection system in the city cannot adequately handle total sewage discharged in the city for the following reasons:

- Most households are not accessible by the tankers used in the system, and the number of tankers available at the Environmental Health Division is not sufficient to service the growing city population.
- Some Households cannot afford the cost of the service and so employ the services of local people who use manual labour and such people most often discharge the sewage into streams and sometimes into the open drainage system in the rainy season.

Because the wastewater generated by the few industries in Freetown is discharged into the open drainage and rivers, aerobic degradation of the organic load in the waste water do occur and therefore little or no methane emission occur in this wastewater handling system.

Industrial production, handling and/or treatments of wastewater

Mining companies are obligated to install wastewater treatment plants for their operations which are subjected to regular routine checks by EPA-SL as part of their environmental quarterly and annual audit exercises as a requirement for a renewal of an EIA license.

Waste water/sewage

Wastewater treatment is a source of NO_2 or N_2O. Where significant industrial activity exists in a country, such sector makes significant contribution to the total nitrous-oxide emission. In the case of Sierra Leone, few industries or factories exist. The few industries in the country mostly in Freetown simply discharge their wastewater into the general drainage system and this eventually runs down into the Sierra Leone River Estuary. This component of waste was therefore not regarded as significant source of NO_2 or N_2O.

Sewage network

The sewerage system is present only in the Central Business District (Wilbur Smith Associates & Davies-Techsult, 1996, p. 3-34). Three independent units were reported to be in good conditions in 1996. The outfalls at King Jimmy and Government Wharf discharge the raw sewage above sea level into the sea.

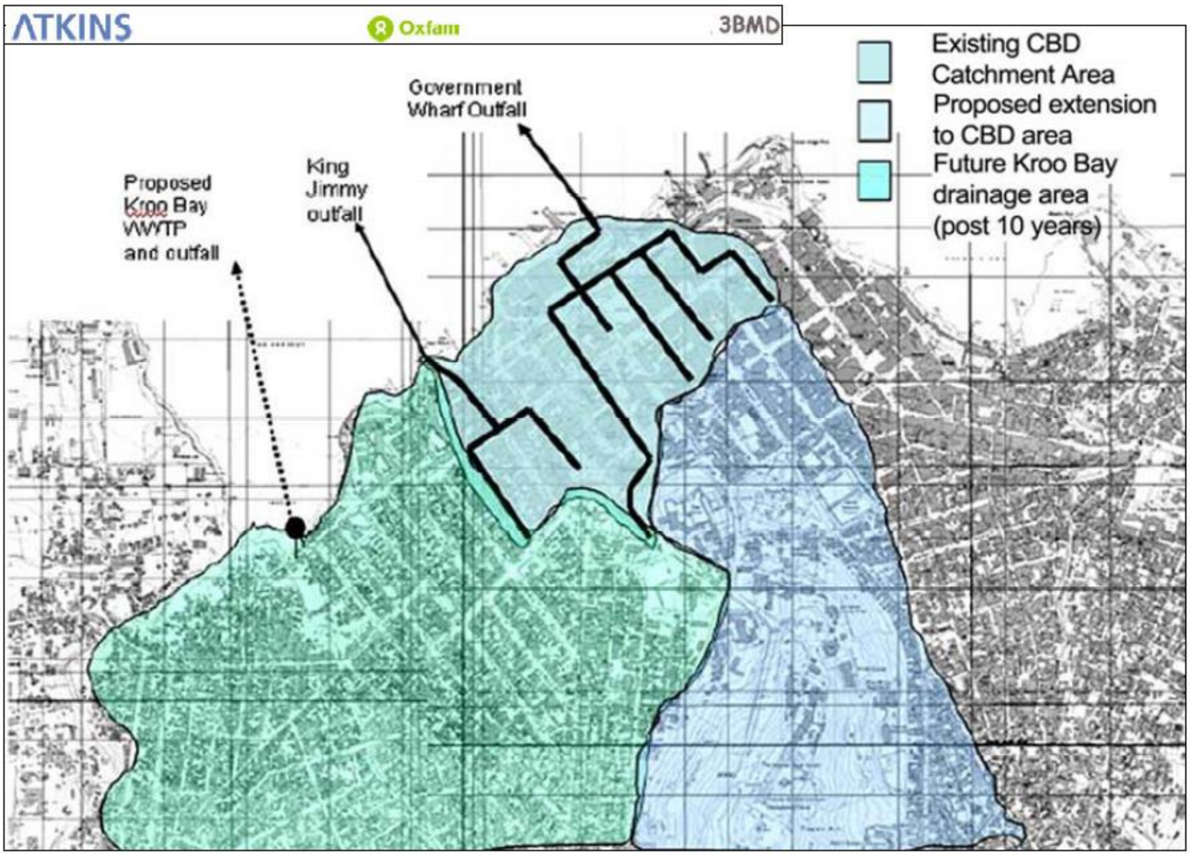


Figure 3.27 Existing and proposed sewerage catchment areas in the CBD[6]

The sewage network is extremely old and requires immediate attention. Built in 1960 and extended in 2001, it is 4 km long. The old part is constituted of decaying asbestos cement pipes and the extension is in PVC. Manholes installed for maintenance purposes often spill out waste water, especially during rainy season. These back flows are due to clogging, which are notably caused by too weak slopes, counter-slopes in the network or too small section of the pipes.

[6] Strategic Water Supply and Sanitation framework (SWSS, implemented by Atkins + Oxfam + 3BMV).

Besides this main network, a little network was built in King Jimmy Catchment area. Generally speaking, a limited amount of waste water is collected from the sewage system which discharges directly on the sea shore alongside the city.

Other (4E)

Medical (Hospital) waste Management in the Country

Hospital waste of domestic nature (organic materials, inert materials, plastic, glass, paper, metal, textiles etc) are usually collected and disposed off along with municipal waste at designated dumpsites. Of the various types of hospital wastes, normal and patient wastes accounts for almost 80% of waste generation in the city of Freetown (GOPA, 1995). The normal and patient wastes are dumped together with domestic waste and when leveled with bulldozer at the various dumpsites, parts of the hospital waste resurface on the waste hip. This is considered a high risk to health. Anatomical waste such as tissues, organs and body parts are often buried in specially lined pits in the hospital campus often after incineration. Infectious wastes are incinerated and later disposed of in specially lined pits. Wastes including syringes, drug containers, and sharps from immunization exercises are stored in safe boxes provided by UNICEF and later incinerated at the hospital. However, neither statistics of incinerated medical waste countrywide nor when such activities commenced is available. Waste from privately owned pharmacies and private practitioners are at the moment disposed off along with municipal waste. Although some treatment has started with incinerators, these would not be captured in this inventory exercise because it is out of the inventory period 2005 – 2010.

Methodology
4A Solid Waste Disposal – CH4

Three Tiers to estimate CH4 emissions from Solid Waste Disposal Sites (SWDS) are provided in the 2006 IPCC Guidelines. Tier 1: Based on the IPCC First Order Decomposition (FOD) method, using mainly default activity data and default parameters. Tier 2: Based on the IPCC FOD method, using some default parameters and good quality country-specific activity data on current and historical waste disposal at SWDS. Tier 3: Based on the use of good quality country-specific activity data and the use of either the FOD method (or country-specific method) with (1) nationally developed key parameters, or (2) measurement derived country-specific parameters.

4B. Biological Treatment of Solid Waste.

This category includes the estimation of emissions mainly from two types of treatment of solid wastes: Composting and anaerobic digestion of organic waste, such as food waste, garden (yard) and park waste and sludge.

Three tiers are provided in the 2006 IPCC Guidelines to estimate the emissions from this category: Tier 1 uses IPCC default emission factors; Tier 2 uses country-specific emission factors based on representative measurements and Tier 3 includes methods based on facility or site-specific measurements (on-line or periodic).

4C Incineration and Open Burning of Waste – CO2 and Non-CO2 Gases .

In the 2006 IPCC Guidelines, the category 4C includes two main subcategories: 4C1 Waste Incineration and 4C2 Open Burning of Waste. In the Sectoral report were estimated and declared emissions from the category 4C2.

4C1 Incineration.

Waste incineration is defined as the combustion of solid and liquid waste in controlled incineration facilities. Types of waste incinerated include municipal solid waste (MSW), industrial waste, hazardous waste, clinical waste, and sewage sludge. 100. In the 2006 IPCC Guidelines are described three tiers to be applied for the estimation of CO_2, CH_4 and N_2O emissions from incineration. The tiers differ to what extent the total amount of waste, the emission factors and parameters used are default (Tier 1), country-specific (Tier 2a, Tier 2b) or plant-specific (Tier 3).

4C2 Open Burning of Waste

Open burning of waste can be defined as the combustion of unwanted combustible materials such as paper, wood, plastics, textiles, rubber, waste oils and other debris in nature (open-air) or in open dumps, where smoke and other emissions are released directly into the air without passing through a chimney or stack. Open burning can also include incineration devices that do not control the combustion air to maintain an adequate temperature and do not provide sufficient residence time for complete combustion.

In the 2006 IPCC Guidelines are also described three tiers to be applied for the estimation of CO_2, CH_4 and N_2O emissions from open burning of waste. The tiers differ to what extent the total amount of waste, the emission factors and parameters used are default (Tier 1), country-specific (Tier 2a, Tier 2b) or plant-specific (Tier 3). Only CO_2 emissions resulting from oxidation, during open burning of carbon in waste of fossil origin are considered net emissions and should be included in the national CO_2 emissions estimate.

4D Wastewater Treatment and Discharge - CH_4 and N_2O

Wastewater can be a source of methane (CH_4) when treated or discharged anaerobically. It can also be a source of nitrous oxide (N_2O) emissions. Per the structure, activities, and source categories in the 2006 IPCC Guidelines, this category includes the following subcategories: 4D1 Domestic Wastewater Treatment and Discharge (CH_4 and N_2O) and 4D2 Industrial Wastewater Treatment and Discharge (CH_4).

4D1 Domestic Wastewater Treatment and Discharge – CH_4 and N_2O
Methane

Domestic wastewater is defined as wastewater from household water use and may be treated on site (uncollected) in pit latrines and septic systems, sewered to a centralized treatment plant (collected) or disposed of untreated in unmanaged lagoons, waterways or sea and the ground, via open or closed sewers or via an outfall. These treatment and discharge systems produce CH_4 in different degrees.

About CH_4, three methods (tier) are provided in the 2006 IPCC Guidelines to estimate the emissions from this subcategory. Tier1: This method applies default values for the emission factor and activity parameters and is considered good practice for countries with limited data. The Tier 2 method follows the same method as Tier 1 but allows for incorporation of a country specific emission factor and country specific activity data. The amount of sludge removed for incineration, landfills, and agricultural land should be taken into consideration. For a country with good data and advanced methodologies, a country specific method could be applied as a Tier 3 method. A more advanced country-specific method could be based on plant-specific data from large wastewater treatment facilities.

Methodologies used for estimating CH_4 emissions from SWDSs.

Under this category there are two methodologies for estimating CH_4 emissions from SWDSs.

i. A simple default based method which all countries can use to estimate CH_4 emissions from different types of SWDSs.

ii. A more data intensive method that countries which have adequate data can also use.

The availability and quality of data required is a source of uncertainty.
The theoretical gas yield methodology, based on mass balance approach was used. This method was considered appropriate because there is little or no industrial development in the country for the inventory period 2005 – 2010 and wastewater discharge rates and sewage treatment did not change significantly over the years.

The Theoretical gas yield methodology is based on a mass balance approach, and does not incorporate any time factors into the methodology.
Rather, the methodology assumes that all potential CH_4 is released from waste in the year that the waste is disposed off.
This gives a reasonable estimate of the current year's emissions if the amount and composition of the waste disposed of has been relatively constant over the previous several years. If, however, there have been significant changes in the rate of waste disposal, this simple method will likely not provide a good estimate of current emissions.

Notwithstanding, the simple default based method was considered appropriate because there is little or no industrial development in the country for the inventory period 2005 to 2010 (wastewater discharge rates and sewage treatment did not change significantly.

Emissions

Methane Emission from Solid Wastes Disposal Sites

Methane emissions result from the decomposition of organic landfill materials such as paper, food scraps and yard trimmings. This decomposition process is a natural process through which micro organisms derive energy. After the waste has been deposited in a landfill, aerobic bacteria initially digest organic waste. When the oxygen has been depleted, anaerobic bacteria consume the remaining waste. The anaerobic bacteria break down the organic material into substances such as cellulose, amino acids and sugars. These substances are further broken down through fermentation into gases and short chain organic compounds that form the substrates for the growth of methanogenic bacteria. Methane producing anaerobic bacteria converts these fermentation products into stabilised organic materials and biogas consisting of approximately 50% carbon dioxide (CO_2) and 50% methane (CH_4) by volume. Methane production typically begins one or two years after waste disposal in a dumpsite/landfill and may last from 10 to 60 years.

Data available is not adequate to derive the fraction of DOC, which actually degrades in our waste disposal sites. Decomposition of degradable organic matter is not always complete. Some of the potentially degradable organic material always remains in the site even over a long period of time, particularly textile materials. Also, waste materials in the solid wastes disposal sites are often seen burning. This is because methane gas emitted from the anaerobic decomposition of wastes is highly flammable and often set alight when people dispose of cigarette butts that still have fires on them into the sites. With these considerations in mind, the default value of 0.5 in the IPCC guideline was therefore considered appropriate in this estimation.

Green house gas emissions from burning of wastes (waste incineration)

Waste burning is used to manage both municipal solid wastes (MSW) and hazardous wastes in the country. The burning of either type of waste results in conversion of the organic inputs to Carbon dioxide (CO_2). According to the IPCC methodology, when the CO_2 is of fossil origin, it is counted as an anthropogenic emission in national inventories. Thus, the emissions from wastes burning are driven by estimating the quantity of waste burned, the fraction of the wastes that is carbon, and the fraction of the carbon that is of fossil origin.

Municipal solid waste is composed of garbage and non-hazardous solids. Most of the organic materials in municipal solid wastes are of biogenic origin (e.g. paper, yard trimmings), their net carbon flows are accounted for in the land use change and forestry. However, plastics, synthetic rubber, and synthetic fibre are of fossil origin. Plastics in the Sierra Leone waste stream are primarily in the form of plastic bags, containers, packaging and durable goods. Rubber is found in durable goods such as carpets and tires, and in non-durable goods such as clothing and footwear. Fibre in municipal wastes is predominantly from clothing and home furnishings. These are also considered as non-hazardous.

The latter category of waste is often disposed of by burning, because it is not biodegradable. Over the years, some residents of Freetown have found a useful method of burning worn-out tires in the construction industry. They often burn the tires on-top of rocks they want to break in the process of leveling the ground on the hillsides for construction of dwelling houses. Once the rocks are heated up, the burned-out tire materials are removed and water is poured on the rocks. This repeated expansion and contraction creates cracks on the rocks and is then easier to break with a heavy hammer operated by hand. This process emits some amount of CO_2 into the atmosphere that could not be accurately accounted for in this inventory. This is because the quantities of tires burned per annum is not documented and cannot be estimated from tire imports, because not all tires imported into the country end up been burned in rock breaking in Freetown or elsewhere in the country.

In Sierra Leone, CO_2 emissions from burning of biogenic materials are important because of the significant amount of energy derived from biomass (e.g. burning of fuel wood). The fate of biogenic materials is also important when evaluating waste management emissions (e.g. the decomposition of paper). The carbon contained in paper was originally stored in trees during photosynthesis. Under natural conditions, these materials would eventually degrade and cycle back into the atmosphere as CO_2. The quantity of carbon that these degradation process cycles through the earth's atmosphere, waters, soils and biota is much greater than the quantity added by anthropogenic greenhouse gas sources. Burning of wastes from agricultural sources is a common practice. The ash derived from such burning is believed to fertilize the soil, where crops are grown in the next growing season. This source of carbon is therefore not considered in this inventory. Although waste burning occurs, it has not been documented as a waste management option in Freetown. Sometimes the dumpsite at Granville brook burst into fires which last for several hours, especially in the dry season. The source of such fires is believed to be due to the disposal of firewood that still has fire on them, or cigarette butts thrown on the rubbish hips by scavengers. Since the methane emitted from the dumpsite is flammable, this can easily aid the waste burning process. Apart from this massive burning of wastes in the dumpsite, some people do burn their wastes (paper and plastics in their backyards), and this is not accounted for in the 30% waste that is collected and disposed off in dumpsites by the ministry of Health and sanitation.

It is therefore clear that CO_2, N_2O and CH_4 emissions estimated in this study do not include all minor contributions from waste burning, which is carried out in some homes in Freetown.

Waste water/liquid waste

Methane emission from waste water handling

The principal factor that determines methane generation potential of wastewater is the amount of organic material in the wastewater stream. For domestic and commercial wastewater and sludge, this is indicated by the biochemical oxygen demand. For Industrial wastewater, the chemical oxygen demand (COD) is used. The BOD indicates the amount of carbon that is biodegradable, whereas the COD indicates the total amount of carbon, biodegradable and non-biodegradable that is available for oxidation by a chemical oxidant (usually by potassium dichromate or potassium permanganate).

Handling of wastewater and its residual solid by-products (sludge) under anaerobic conditions results in CH_4 production. The extent of methane production depends primarily on the following factors:

- Wastewater characteristics
- Wastewater handling system
- Temperature
- The Biochemical (BOD) and/or Chemical oxygen demand (COD)

Under the same conditions, wastewater with higher BOD or COD concentrations will generally yield more CH_4 than wastewater with lower BOD or COD concentration. Systems that are suitable for anaerobic environments will generally produce CH_4 whereas systems that provide aerobic environments will normally produce very little or no methane. For example the depth of a lagoon treatment system is a critical factor in CH_4 production. Shallow lagoons, less than 1 m in depth, generally provide aerobic conditions, and little CH_4 is likely to be produced. Lagoons deeper than 2 – 3 m will generally provide anaerobic environment and significant methane production are expected. Increases in temperature will also increase the rate of methane emission. This is important in Sierra Leone and other warm countries with uncontrolled waste handling systems.

Sources of data and methodology

In the 2006 IPCC Guidelines, the Waste Sector includes five categories: 4A. Solid Waste Disposal; 4B. Biological Treatment of Solid Waste; 4C Incineration and Open Burning of Waste; 4D Wastewater Treatment and Discharge; 4E Other.

Each major category is divided into sub-categories that enable account to be taken of different waste attributes and different waste management characteristics and approaches.

Data Sources

The key sources of data are Statistics Sierra Leone(Population data), information from dumpsites (weight and types of deposited wastes) from the Freetown City and other city councils of the Ministry of Local Councils and Rural Development (MLCRD),contracted private waste collection and management companies (MASADA) etc. that could be used for the purpose of inventorying.

Table sector data source characteristics

	Sector	Data Type	Data Source	Principal Data Providers
	SolidWaste		MASADA, FCC, MOHS Environmental Health Division of the Ministry of Health and Sanitation	MASADA
4B	Biological Treatment of Solid Waste		Do	Do
4C			Industries with incinerators, Mining companies	
4D				
4E			Ministry of Health and Sanitation.	

Data on the quantity of waste incinerated were not estimated because data was not provided by some industries with incinerators for the period under review. Mining companies operate incinerators for their operations which are subjected to regular routine checks by EPA-SL as part of their environmental quarterly and annual audit exercises as a requirement for a renewal of an EIA license. Main hospitals also operate incinerators.

In the case of medical waste, data on the number of beds in hospitals and the amount of medical waste generated are not compiled by the Ministry of Health and Sanitation.

The table below shows the categories/sectors (based on available data) for which the inventory was conducted.

Category Code	Category Name	Status
4A	Solid Waste Disposal	

4B	Biological Treatment of Solid Waste	NE
4C	Incineration and Open Burning of Waste	
4D	Wastewater Treatment and Discharge	
4E	Other (Medical waste)	NO

From these sectors in 2005 were estimated emissions from the categories 4A (CH_4) and 4D (CH_4 and N_2O from domestic/commercial wastewater) and CH_4 from industrial wastewater. The emissions from the category 4C and 4E (CO_2 and non-CO_2 emissions) were not estimated.

Solid waste CH_4

Methane emission from landfill wastes occur due to man-made anaerobic conditions conducive to methane formation that exist in landfills and are therefore included in this inventory. Methane emitted in Sierra Leone was estimated using data obtained from the Environmental Health Division of the Ministry of Health and Sanitation (the Department responsible for solid wastes management in the country at the time of the inventory, Tables 4 and 5).

Table 4: Solid waste collection in Freetown

	2005	2006	2007	2008	2009	2010
Total waste generated (tons/a)	1137664	1208107	1278550	1348992	1419435	1489879
Vehicle collection by Tipper truck	27089	28766	30444	32121	33798	35474
5m3 container to transfer station	135437	143824	152210	160596	168982	177369
7m^3 container direct to station	78553	83417	88281	93145	98009	102873
7m^3 container direct to landfill	29794	31639	33484	35329	37174	39019
Hand carts and 20cm^3 containers	27089	28766	30444	32121	33798	35475
Hand carts and 7cm^3 containers	43339	46023	48706	51390	54073	56758
Subtotal tons/a collected	1478969	1570545	1662121	1753697	1845273	1936849
% of total generated waste	45	50	50	50	50	50
Waste from transfer station to landfill	149004	156670	164336	172002	179668	187334
Backyard composting	119202	125334	131467	137600	143732	149866

tons/a						
% of total generated waste						
Uncollected waste tons/a	568831	604053	639274	674495	709717	744939

Table 5: Population sizes in the country and 4 main cities of Sierra Leone used to estimate GHG gases in the various sector.

	2005	**2006**	**2007**	**2008**	**2009**	**2010**
SlL	5106402	5239168	5375387	5515147	5658541	5673335
Freetown	793098	813718.5	834875.2	856582	878853.1	902883.2
Bo	476064	488441.7	501141.1	514170.8	527539.3	541708.1
Kenema	510948	524232.6	537862.7	551847.1	566195.2	580943
Makeni	418608	429491.8	440658.6	452115.7	463870.7	476070

Reference was made to surveys conducted by (Sankoh, 1992), (Amara, 2003) in their final year dissertation projects at Fourah Bay College, University of Sierra Leone for this inventory exercise. Several Consultancy reports including the following also serve as sources of data for the inventory: GOPA (1994), Prack (1983), (FIRP, 1995), (SSL, 2004; SSL, 2008); Techsult Davies (1993).

Data obtained from these sources were fitted into the following IPCC equation (equation 1) to obtain the methane emissions using default factors and some specific factors obtained in specific studies. In cases where different values were recorded by different authors, the average was used.

$$CH_{4emission}(Gg/yr) = (MSW_T * MSW_F * MCF * DOC * DOC_F * {}^{16}\!/_{12} - R) * (1 - OX) \quad \ldots\ldots\ldots\ldots 1$$

Where:

MSW_T = Total Municipal Solid Waste generated (Gg/yr)

MSW_F = Fraction of MSW disposed to solid wastes disposal sites at Kingtom and Granville Brook

MCF = Methane correction factor

DOC = Degradable organic carbon

DOC_F = Fraction of DOC dissimilated, 0.5

F = Fraction of CH_4 in land fill sites

R = recovered CH_4 (Gg/yr), which for Sierra Leone is zero (default)

OX = Oxidation factor (fraction- default)

Percent DOC (by weight was calculated from equation 2:

$$DOC = 0.4A + 0.17B + 0.15C + 0.30D \quad \ldots\ldots 2$$

Where:

A = *percent MSW that is paper and textiles*

B = *Percent MSW that is garden wastes, park wastes or other non-food organic petrucibles*

C = *Percent MSW that is food waste*

D = *Percent MSW that is wood or straw*

It was recorded that only 30% of the total solid wastes generated in the greater Freetown is actually collected by the Environmental Health Division of the Ministry of Health and Sanitation and deposited in the two main solid wastes disposal sites (GOPA 1995). 20% of the total wastes generated is utilised in backyard composting. The remaining 50% is not collected at all and end up in the gutters, streams and eventually into the Sierra Leone River Estuary. Over the year however, the EHD recorded that collection rose from 30 to 50% (Table 4, although estimated), and this new percentage was used in this inventory. Unlike previous inventory in the first and second Communications, for this (third) inventory, estimates of emission was calculated for the provinces. Hence, although official data from the provincial towns were not obtained, a proportion (fraction) of the population as a function of the waste calculated for Freetown was used to calculate emission from the major town (Bo, Kenema and Makeni).

Carbon-dioxide (CO_2) emitted from municipal solid waste in Sierra Leone

Carbon-dioxide emitted from municipal solid waste in Sierra Leone was estimated based on open burning of waste. Data for this computation included population data obtained from the Environmental Health Division of the Ministry of Health and Sanitation (the Department responsible for solid wastes management in the country at the time of the inventory), per capita waste generation and according to equation 3 below:

$$MWS_B = P*P_{frac}*MSWp*B_{frac}*E*10^{-6} \quad \ldots\ldots 3$$

Where

P = Population (Capita)

P_{frac} = Fraction of Population Burning Waste (fraction). According to data from EHD, 50% of waste goes to the dumpsites and 20% is burnt in backyards. This gives a total percent of 70 and a fraction of 0.70 used in the above equation.

MSWp = Per Capita Waste Generation (0.45 kg waste/capita/day for Sierra Leone)

B_{frac} = Fraction of the waste amount burned relative to the total amount of waste treated (fraction). Default value = 0.6

E = Number of days by year 365 (day)

MSW_B = Total Amount of MSW Open-burned, Gg/yr

6.2 Domestic and Commercial Wastewater Methane Emission

Domestic and commercial wastewater methane emission was estimated using the default IPCC methodology (IPCC 2006) equation 4. The Total Population of Freetown, Bo, Kenema and Makeni (Table 5) for each year was multiplied by a per capita wastewater BOD_5 production rate to determine total wastewater BOD_5 produced 0.037kg, BOD/person was used.

$$WM = P * D * SBF * EF * FTA * 365 * 10^{-12} \quad \text{...} 4$$

Industrial Wastewater Methane Emission

During the period under review, as in the case of previous reviews, wastewater from industries (with the exception of some mining companies) is discharged untreated into the open drainage system, brooks and streams. These eventually empty into the Sierra Leone River Estuary, which is considered as a sink, hence emissions from this category of wastewater are not considered in this inventory and no separate calculation for the industrial wastewater was done. This is because although limited industries exist countrywide, none have a formal wastewater treatment plant(with the exception of some mining companies). Only until recently after the establishment of the Environment Protection Agency – Sierra Leone (EPA-SL) industries were asked to install wastewater treatment plants as a condition for the issuance of an Environment Impact Assessment (EIA) license. Consequently, prior to the operationalization of EPA-SL, industries were not treating their wastewater and no documented information exists on the quantity of wastewater they produced.

Sewage treatment

Sewage after treatment in a septic system or wastewater treatment facility is disposed off on land or discharged into aquatic environments such as rivers and estuaries. Nitrous oxide (N_2O) may be generated during treatment and disposal through nitrification and denitrification of the nitrogen that is present in sewage.

Nitrification occurs aerobically and converts ammonium (NH_4^+) into nitrate (NO_3^-, while denitrification occurs anaerobically, and converts nitrate into dinitrogen gas (N_2). Nitrous oxide can be an intermediate product of both processes. In general, temperature, pH, biochemical oxygen demand (BOD) and nitrogen concentration affect N_2O generation from human sewage. The amount of protein consumed by humans determines the quantity of nitrogen contained in sewage.

Nitrous oxide emissions from human sewage were estimated using the IPCC default methodology (IPCC/UNEP/OECD/IAEA 1997) as follows:

$$N_2O_{emission} = N_{effluent} * EF_{effluent} * (44/28) \quad \text{..............5}$$

Where

$N_2O_{emissions} =$ N_2O emissions in inventory year, kg N_2O/yr

$EF_{effluent} = 0.005$, emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N,
The factor 44/28 is the conversion of kg N_2O-N into kg N_2O

$N_{effluent}$ = nitrogen in the effluent discharged to aquatic environments, kg N/yr and is given as

$$N_{effluent} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{Sludge} \quad \text{...6}$$

$N_{EFFLUENT}$ = total annual amount of nitrogen in the wastewater effluent, kg N/yr
P = human population
Protein = annual per capita protein consumption, kg/person/yr
F_{NPR} = fraction of nitrogen in protein, default = 0.16, kg N/kg protein
$F_{NON-CON}$ = factor for non-consumed protein added to the wastewater
$F_{IND-COM}$ = factor for industrial and commercial co-discharged protein into the sewer system
N_{SLUDGE} = nitrogen removed with sludge (default = zero), kg N/yr

Inventory Results and discussion

Results of the inventory exercise on waste for the inventory period 2005 – 2010 is presented (Tables 6 and 7). Generally, GHG emissions increase continuously throughout the inventory period. This is because population increased correspondingly for the period under review.

Methane and carbon dioxide are the two important gases released from our solid waste whilst methane and nitrous oxide are the two important gases released from wastewater (Table 6). Nitrous oxide emission is however significantly smaller compared to methane and carbon dioxide.

Table 6: Summary of Green House Gas emission from Solid Waste Disposal in Sierra Leone

			2005	2006	2007	2008	2009	2010	***Total***
Solid waste disposal on land	Unmanaged waste on disposal sites	CO_2	151.68	155.63	159.67	163.84	168.08	172.60	**971.49**
		CH_4	87.77	103.56	109.60	115.64	121.68	127.64	**665.90**
		N_2O	-	-	-	-	-	-	-
Waste water handling	Domestic & commercial wastewater	CO_2	-	-	-	-	-	-	-
		CH_4	7.13	7.31	7.50	7.70	7.90	8.11	**45.64**
		N_2O(*10^{-6})	167.23	171.58	176.04	180.61	185.31	190.27	**1071.04**

Table 7: Total emissions (Gg/yr) from the waste sector in Sierra Leone

GHG's	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**Total**
CO_2	151.68	155.63	159.67	163.84	168.08	172.60	**971.49**
CH_4	94.9	110.87	117.1	123.34	129.58	135.71	**711.54**
N_2O (*10^{-6})	167.23	171.58	176.04	180.61	185.31	190.27	**1071.04**

Recommendation

Biological Treatment of Solid Waste

The use of bio digesters to process solid waste and recover energy for use is being promoted by many countries. Bio digesters produce biogas, an alternative source of fuel. They are appropriate technologies that take advantage of the energy that is naturally present in animal waste and kitchen trash. As these wastes break down, whether in the ground, a compost heap or landfill, bio digesters release CH_4.

In contrast to the other waste storage and disposal methods mentioned, a bio digester traps the CH_4 and stores it for heating, cooking, or lighting. In this way, bio digesters can provide a sustainable substitute for the propane, kerosene, and firewood that many rural families in developing countries use to serve these needs.

For those families that have to buy their fuel, a bio digester can save them significant sums of money every year. For those that cut trees down for firewood, a bio digester will save them time and help to prevent the deforestation that is becoming prevalent in places where large numbers of people still gather their own firewood.

Rehabilitation and Expansion of Drainage Systems

The sewerage and drainage system in the country especially in the capital Freetown needs urgent rehabilitation and extension. The existing sewerage system is only present in the Central Business District. The system is extremely old, (dating back to pre-colonial days) characterised by decayed asbestos cement pipes. Manholes installed for maintenance purposes often spill out waste water, especially during rainy season due to frequent clogging of the pipes. Because the system is only present in the central business district, only limited volume of wa stewater is collected from sewage system in Freetown. Furthermore, no formal treatment is done on collected wastewater. Wastewater collected is discharged directly into the Rokel river.

As for the sewerage system, the Freetown drainage system also requires upgrade and expansion. Upgrade because some original drainage network had decayed. Expansion because increased settlement in slopes and hills had resulted in greater amount of run-offs from the hills during the rainy season resulting in flooding of almost anytime the city experience heavy downpour of rain.

Uncertainties and further improvement

Some uncertainty exists in the population and waste data used to calculate emissions. With regards the population, the last official population data of the country is that from the 2004 census. This inventory period spans 2005 – 2010 for which only projected population data exists.

Uncertainty is inherent in the waste data from EHD. The last official and holistic study on waste was conducted in 1994. After this period, lots of changes had occurred with regard waste types/composition, amount etc. Furthermore, national circumstances such as the lack of any study/research in the waste sector from government, agencies and other institutions that would have provided much needed country specific waste emission factors makes it impossible for emissions to have been calculated based on the 2006 higher tiered (2 and above) approach. Consequently, only the mass balance method is applicable using the IPCC default values. This method is the least accurate but where country-specific data is unavailable as is virtually entirely the case for the Sierra Leone waste sector, it provides a way of knowing the country's estimated status with regard emission of GHG.

It is highly recommended for government, public and private sectors to sponsor studies in the waste sector, so as to prevent a repeat of the difficulty encountered in obtaining data during this inventory period. Data obtained from such studies would benefit the country in developmental efforts as well.

Quality Control by third party reviewers

A review of the draft National Greenhouse Gas (GHG) Inventory of Sierra Leone (hereinafter referred to as 'the Inventory') corresponding to the period 2005 – 2010 with 2005 selected as base year was conducted. Emission estimates presented in the Inventory have been generated as part of the Third National Communication (TNC) to the United Nations Framework Convention on Climate Change (UNFCCC).

The review was coordinated by the UNDP-UNEP Global Support Programme (GSP) and was conducted from January 05 to January 07, 2017 (Sectoral Reports) and February 2-3, 2017 (Synthesis Report) by Dr. Carlos López, consultant in national GHG emissions inventories. In it, is examined mainly the adherence of the draft Inventory to the requirements indicated in the UNFCCC Decision 17/CP.8 Annex, the UNFCCC Decision 2/CP.17 Annex III, and also to the advice of the IPCC Guidelines and Guidance indicated in these decisions for the preparation of the inventories to be included in the Second and Third National Communications and Biennial Update Reports (BUR) from non-Annex I Parties under the UNFCCC.

Difficulties specific to the waste sector

Absence of data on:

- official and well-constructed and protected dump sites in towns and cities
- disaggregated waste in Sierra Leone:
- the amount and weight (daily) deposited at dump sites;
- the production and characteristics of urban wastes of other towns in Sierra Leone (apart from Freetown)
- Non-availability of weighing machines at dump sites
- conduct a survey to know the composition of urban wastes;
- conduct surveys to have:
    a) the total amount of soda used in the country; (b) data on activities relating to the consumption of halocarbons (HFC and PFC) and sulphur hexafluoride;

General recommendations to improve the inventory

The following general recommendations are proposed with a view to improving the next inventories:

- integrate the collection of data necessary for the inventory in the routine work of MDAs;
- reinforce information and training of MDAs on issues related to GHG inventories;
- take into account data necessary for the inventory in preparing a progress report of forest services;
- propose a data reporting guide for data holders;
- provide additional support to enable the conduct of studies/surveys so as to generate information necessary for the establishment of better quality inventories;
- set up a databank to be provide regular inputs through an annual transmission system of activity data by holders (the institution most recommended to implement is Statistic Sierra Leone while drawing on data providers);
- define the type of data to be collected concerning formal holders and conduct an awareness campaigns to persuade them to integrate the collection of these data in their activities;
- organize specialized training sessions particularly for public and private policy-makers results on the inventory and expanding the range of experts;
- build on the successes of institutions specialized in data collection such as and Statistics Sierra Leone to perpetuate a reliable database; systematically archive available and already processed data after defining a template which is in line with the requirements of the IPCC software.

Consolidate initiative taken in the second national communication. These initiatives are: set up an inventory multidisciplinary team made up of experts from main institutions holding data:

- organize information and sensitization sessions for data holders;
- train experts in charge of the inventory;
- provide all the means and mechanisms likely to serve in complementary surveys during the inventory to check data or to have solid grounds for expert judgments;
- set up a permanent national team in charge of carrying out the inventories;
- organize workshops with the goal of showing to institutions the importance of data used in inventories so as to motivate them to integrate it in their reports.

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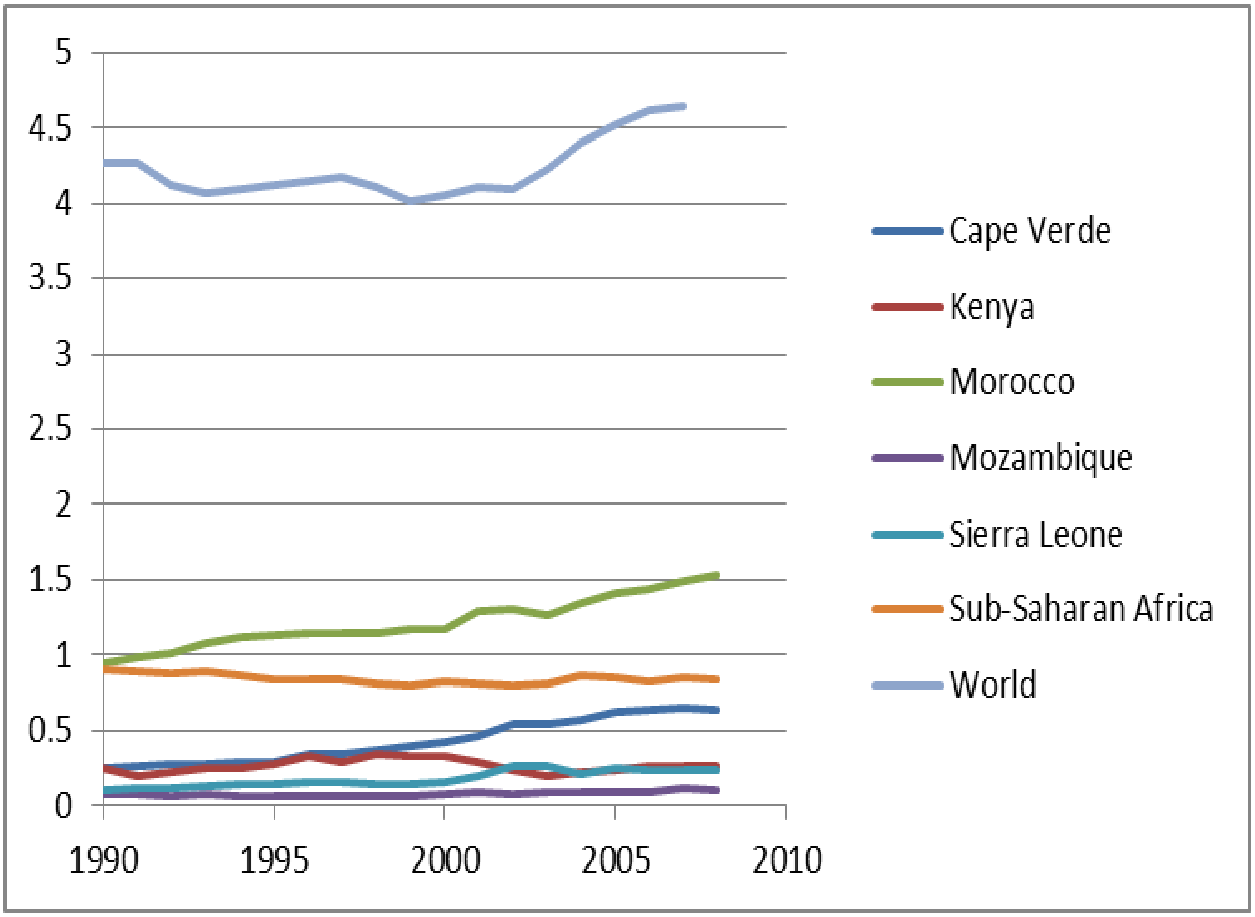
Chapter 4: Programmes Containing Measures to Mitigate Climate Change

Introduction

According to the compilation by the World Resources Institute (WRI) , Sierra Leone's per capita GHG emissions in 2000 was only 4.2tCO_2e (with LULUCF) and 1.2tCO2e (without LULUCF), and this was expected to drop to as low as 0.2tCO2e in 2005[7].

Compared to the global average of 6.7tCO_2e/person (including LULUCF) in 2005, Sierra Leone has one of the lowest emissions per capita in the world.

Fig. 4.1Emissions per capita (metric tons) of selected countries



Though Sierra Leone's emissions are negligible, in a bid to significantly contribute towards the reduction of the sources and potential sources of GHG emissions or enhancing carbon sinks, Sierra Leone, following previous mitigation assessments (INC,SNC), and drawing upon the strategic direction of Vision 2035, proposed to undertake the following appropriate mitigation actions which were it's

[7]**Available at *en.wikipedia.org/.../List_of_countries_by_greenhouse_gas_e...***

Internationally communicated pre-2020 GHG emissions reduction plans under the Copenhagen Accord (GoSL, 2012):

- ✓ Establishment of the national secretariat for climate change (NSCC) Setting/developing air, water and soil quality standards, and ensure regular assessments and monitoring through control programs.
- ✓ Expanding clean energy utilization (e.g. solar, mini-hydro electric power, LPG, biomass stoves etc).
- ✓ Development of energy efficiency programmes through sensitization and awareness raising campaigns. Sustainable production of charcoal to reduce dependence on firewood.
- ✓ Development of alternative energy sources such as bio-fuels from sugarcane, corn, rice husk, etc.
- ✓ Developing agricultural and urban waste incineration programmes for energy production.
- ✓ Improved waste management through composting and recycling of waste.
- ✓ Development and enforcement of regulations on regular maintenance of vehicles (vehicle emission testing): formulation of transport plans.
- ✓ Improving and promoting use of public transport (e.g. road and water) for passengers and cargo to reduce traffic congestion and GHG's emissions.
- ✓ Setting/developing air, water and soil quality standards, and ensure regular assessments and monitoring through control programs.

Within the overall national context for the TNC, greenhouse gas mitigation affects socio-economic policies and choices involving development, sustainability and equity. It is against this backdrop that Sierra Leone's policies to limit net emissions to promote sustainable development are consistent with broader societal objectives. The co-benefits of the country's mitigation options following this assessment, can promote benefits far beyond immediate climate change concerns such as reducing health problems, increasing local employment, minimizing air pollution, protecting and enhancing forest and water sheds, minimizing certain subsidies and taxes and accelerating the development and diffusion of energy-efficient technologies.

Current mitigation activities

The purpose of this information is to identify current actions/ efforts that this TNC can build upon.

The sources of this information include, REDD+ strategies, technology needs assessments, climate change plans, economic development plans. Sierra Leone has only one Clean Development Mechanism (CDM) project, and has recently developed it's nationally appropriate mitigation actions (NAMAs).

Examples of actions/efforts already taken by Sierra Leone include:

- Reduction of fossil fuel subsidies
- Feed-in tariffs or minimum requirements for renewable energy generation
- Reduction in incentives for urban sprawl and increase in incentives for compact urban development
- Sustainable management of forests and lands
- Reduced deforestation and forest degradation (REDD+); GOLA forest
- Restoration of degraded agricultural lands, forests, and other lands
- Programs to reduce emissions in industry sectors (e.g., cement)
- Low emissions development strategies (LEDS)

This mitigation assessment provides a national sector -level analysis of the potential costs and impacts of various policies, technologies and practices that have the capacity to reduce greenhouse gas (GHG) emissions. The assessment presented here was part of the climate change project to develop this TNC initiated in July 2014. The scope of the assessment did not cover projections of GHGs for a given time period. No scenarios were developed to project emissions.
The assessment draws upon the overarching strategic direction that will guide Sierra Leone's development to 2035, as articulated in *it's vision to become a middle income country by 2035*.

The national strategies will be implemented through sector level programs, plans and activities for the social, governance, economic, and environmental aspiration of Vision 2035. The Plan will be supported by five -year poverty reduction, strategy papers (PRSPs) documents.

PRSP 2008 -12 was the first such document, which includes one outcome on energy efficiency and conservation.
PRSP 2013 -2018 was the second, which includes one outcome on mainstreaming inclusive green growth.

Focus of the Assessment
Sierra Leone's assessment focuses primarily on energy related emissions, non -energy sector activities (agriculture, forestry, waste etc,) are also included. As noted in Chapter 3(GHG Inventory), carbon dioxide (CO2) emissions for the country (characterized by the energy sector) have been trending up over 2000 -05 – increasing from 529,28 Gigagrams (Gg) in 2000 to 20340,20 Gg in 2005 even though the 1996 guidelines were used for the year 2000, and the 2006 guidelines for the year 2005. As Sierra Leone is a net importer of fuel to meet it's energy demands, the energy sector accounted for nearly 90 per cent of the 2005 CO2 emissions.

4.1Background Information

Sierra Leone is one of the poorest countries in the world; consistently appearing near the bottom of the UNDP Human Development Index[8]. The country is classified as least developed ranked 177 out of 187 based on 2012 data (UNDP HD1 report 2014). The HDI combines measures of life expectancy, literacy, school enrolment and per capita GDP into a single index to measure relative human development among nations. This index value reflects that Sierra Leone is characterized by weak economic development, as evidenced by low GDP growth rates, high debt load, high unemployment, weak export performance and energy dependence Sierra Leone currently has a population of ~7 million (2016 SSL census result) with a growth rate of 2.5% per annum (SSL, 2010). The 2014 census which should have occurred in December was postponed due to the ebola pandemic. Population distribution in the country is uneven with the Western Area being the most densely populated. Presently, the capital Freetown is hosting close to 2 million people (2016 SSL census result).

Sierra Leone at Glance:

Population (millions)	6.0
Urban population (% of total population)	38.8
Average annual growth (%)	2.1
Human Development Index (HDI)	0.336
Gross Domestic Product (GDP) per capita (PPP$)	808
Gross National Income (GNI) per capita (constant 2005 PPP$)	737
Population in severe poverty (%)	53.2
Population vulnerable to poverty (%)	13.1
Population below the income national poverty line (%)	66.4
Life expectancy at birth (years)	47.8
Environmental performance index (0-100)	32.1 (2010)
Natural resources depletion (% of GNI)	2.1
Death due to water pollution (per million people)	3.271 (2004)
Adult literacy rate (% ages 15 and older)	40.9(2005-2010)
Primary Education gross enrollment ratio (%)	85.1(2001-2010)

[8] http://www.nationsencyclopedia.com/Africa/Sierra-Leone-INDUSTRY.html(accessed 30th December 2015)

Secondary Education gross enrollment ratio (%)	26.5(2001-2010)
Tertiary Education gross enrollment ratio (%)	2.0 (2001-2010)
Source: UNDP.(2011).“Human Development Report 2011”.	

4.1.1 *Sierra Leone’s Energy Sector Profile*

Sierra Leone has no known primary petroleum reserves and imports all of its petroleum requirements. Domestic energy needs are met by burning petroleum products and renewable fuel biomass (i.e., bagasse, fuel wood, and charcoal) and from using other renewable resources (e.g., solar, wind and hydro).

Analysis of the sector

4.1.2 Revised Institutional Framework

The country now has in place energy policy and Public Utility Regulation Commission and National Electricity Act, 2011. The National Electricity Act 2011 called for the unbundling of the National Power Authority into the Electricity, Distribution and Supply Authority (EDSA), and Electricity, Generation and Transmission Company (EGTC). EDSA will be responsible for the distribution and supply of electricity, while EGTC will be responsible for the generation and transmission of electricity. These two companies will be in full operation as separate entities on 31st December, 2014, with the view to improving efficiency in the provision of electricity supply in the country.
A small amount of electricity is generated by industrial, commercial or residential operators for their own use. There is no petroleum refinery in Sierra Leone. The petroleum product market is open and the Petroleum Agency of the Ministry of Trade and Industry, along with multinational petroleum marketing companies, imports refined petroleum products. Heavy fuel oil needed by the mining industry is pooled directly from the imported refined petroleum products.

The mining industry is assumed to have the largest percentage end use, followed by electricity generation , transportation and then the sugar industry . The majority of the fuel used in bioenergy projects /sugar industry is bagasse, with much smaller amounts of heavy fuel oil and wood and while the other sectors use petroleum products nearly exclusively. The exceptions are charcoal in the domestic sector. In making the sectoral assumptions from the data provided by ME, it was assumed that all gasoline consumption was for transportation. Small quantities of gasoline are used for domestic marine vessels but it was not feasible to allocate fuel consumption for domestic marine purposes. Initially all of the turbo and aviation gasoline was attributed to international bunkers.

Estimates of charcoal use (included in the “Other” sector are subject to considerable uncertainty since the production and distribution of charcoal is in the informal economy.

Regarding the energy sector, poor access to electricity is recognized as a binding constraint to long-term economic growth in Sierra Leone. Energy was a major focus of the PRSP 2's Agenda for Change, which included a goal of "cheap, affordable energy for all". Overall, access to modern energy has increased from 3% of the population in 2000 to 9% in 2011, but biomass from fuel wood and charcoal still accounts for more than 85% of total energy use. There is scope for efficiency gains from all sources of energy, and transmission losses remain high at over 40%. The target is to increase billing and collection rates to 90%. Fuel prices (USD 0.94 per liter for both gasoline and diesel in 2010)[9]. Sierra Leone currently has only 90 MW of installed capacity, of which 86% is for Freetown; electricity generated from the hydro-electric facility at Bumbuna, completed in 2009, accounts for 62% of power generated and oil-powered facilities the remainder.

With private sector support, Sierra Leone has invested in hydroelectric power generation, building the Bumbuna hydro-electric plant.

Mitigation Efforts

The Ministry is also working together with UNDP for the implementation of the "Energy Efficient Production and utilization of Charcoal through Innovative Technologies and Private sector Involvement" Project. The project aims to:

- Create an enabling environment for the production and use of sustainable, energy efficient kilns and improved cook stoves
- Support a first large scale deployment of these technologies and
- Ensure that the subsequent national transformational and diffusion of these technologies will be ensured by setting up sustainable financial mechanisms and tools for investment

Already the Ministry is in the process of formulating both renewable energy and energy efficiency policies. The formulation of these policies will provide a platform to create awareness on the country's vast renewable energy potentials. Plans are under way to carry out feasibility studies in various potential investment locations across the country.

CRITICAL CHALLENGES

While the country had suffered from inadequate power generation capacity for many years, the transmission and distribution of the power generated had also been a major challenge. Hence, improvements to the transmission and distribution systems remain a critical component of efforts to increase the supply of electricity. The poor transmission and distribution system has in high line losses estimated at about 40 percent of units of electricity generated;

[9] World Development Indicators, 2012.

To date, only about 13 percent of the population is estimated to have access to electricity from the national power grid. Moreover, there is high seasonal variability in hydroelectric power production.

- There is need to make EGTC and EDSA self- sustaining.
- Provide electricity to the District Headquarter towns including Kabala, Magburaka, Lunsar, Kono, Pujehun, Port Loko, Moyamba, Bonthe and Kailahun.
- Intensify rural electrification by rolling out the Solar strategy to all districts.

The World Bank has provided funding support in order to overcome the monumental challenges of improving access and quality of power supply for enhancing economic transformation in the country. The project aims at

- Reducing losses in electricity supply in Freetown by investments in the rehabilitation of critical components of EDSA's network, which is the most urgent step to enable expanded and more reliable electricity supply
- Improving the commercial performance of the EDSA through the supply and installation of a business information system and metering equipment at EDSA which will help raise collection rates and overall commercial performance of the utility and
- Improving access to electricity in rural areas through a pilot program for installing solar PV systems in schools and hospitals in one village in each of the 14 administrative districts in the country

Energy Supply situation

The energy supply consists of electricity, petroleum products and renewable energy, including hydropower. In these sub-sectors, the focus is on increasing the supply of modern energy supplies for Sierra Leone. Table 4.1 shows the total primary energy supply and Table 4.2 represents the Energy supply in Sierra Leone.

Table 4 1: Total primary energy supply

Year	Total Primary Energy Supply (GWh)	Total Primary Energy Supply (ktoe)
2013	47123	3926.8
2012	43718	3643
2011	17580	1464.9
2010 (base year)	17479	1456.5

Table 4 2: Trend of energy supply in Sierra Leone (2006 – 2013)

Year	Biomass Consumption (000 toe)	Petroleum Products Consumption (000 toe)	Electricity (Grid Connected) Consumption (000 toe)	Final Energy Consumption (000 toe)
2006	1,154	195.7	3.4	**1,353.1**
2007	1,175	166.0	3.1	**1,344.2**
2008	1,197	192.4	12.8	**1,402.2**
2009	1,218	164.5	12.3	**1,394.8**
2010	1,241	199.3	16.2	**1,456.5**
2011	1,262	187.8	16.1	**1,464.9**
2012	3393.8	232.5	16.8	**3643**
2013	3622	289.9	14.9	**3926.8**

Source: Ministry of Agriculture and Food Security (2013), PU (2013), MoE and NPA-BKPS.

Energy demand situation

Biomass energy comprises at least 83% of all energy used in the country.[10] It provides the bulk of the energy supplied in both the household and the commercial and service sectors of the economy[11]. The structure of the energy supply and demand in Sierra Leone by sectors and energy carriers as reported by the National Energy Policy and Strategic Plan (2009) is presented in Table 4.3. It should be noticed that figures for the year 2006 and 2013 have been extrapolated from original figures given in a study by the World Bank for the year 1986. As can be seen, fuel wood still represents the main energy carrier in the country. The bulk of fire wood consumption takes place in the household sector, mainly for cooking in rural areas (Table 4.4). Charcoal is also consumed in the residential sector, mainly for cooking purposes in urban areas. Still, there is some consumption of fire wood and charcoal in the industrial sector as well as electricity, LPG and kerosene. Table 4.3 shows the Structure of energy supply and demand pattern in 2013.

Table 4 3: Structure of energy supply and demand pattern in 2013

[10] MEWR. 2009a. "2009 National Energy Plan", September 2009; UNDP. 2012. "National Energy Profile of Sierra Leone", June, 2012. GoSL. 2012. The Agenda for Prosperity: Road to Middle Income Status - Sierra Leone's Third Generation Poverty Reduction Strategy Paper (2013 – 2018).

[11] MEWR. 2009b. "National Energy Policy and Strategic Plan: Energy for Poverty Alleviation and Socio-Economic Development: Part II Energy Strategy Plan", September 2009

	Biomass		Petroleum Products	Electricity (Grid	
Sector	Firewood	Charcoal		Connected)	Total %
Agriculture, Forestry, Fishing	1%	-	5%	2%	2%
Mining	-	-	9%	1%	2%
Industry/Commercial	3%	9%	13%	60%	21%
Transport	-	-	48%	1%	12%
Household/Residents	96%	91%	25%	36%	63%
Total	100%	100%	100%	100%	100%

Source: Ministry of Agriculture and Food Security (2014), PU (2014), MoE and EDSA (2014).

Table 4 4: Household energy consumption in Sierra Leone (Energy Directorate Statistics, 2013)

Year 2012 District	Total Population	Area (Sq. km)	Population Density	Number of households	Annual Fuel wood consumption (t/yr)*	TOE	tCO2-eq/yr
Sierra Leone	**6,037,660**	**71,500**	**83.3**	**1,006,475**	**3,122,589**	**3,393,825**	**4,660,056**
Bo	624,389	5,249	118.9	103,859	322,223	350,212	480,875
Moyamba	262,725	6,922	37.9	50,607	157,008	170,646	234,314
Pujehun	320,686	4,135	77.5	45,797	142,085	154,427	212,044
Bonthe	160,114	3,528	45.4	29,812	92,492	100,526	138,032
Kenema	621,750	6,093	102.0	112,027	347,564	377,754	518,694
Kono	305,952	5,681	53.9	54,676	169,632	184,367	253,154
Kailahun	442,454	3,899	113.5	81,445	252,683	274,632	377,097
Bombali	469,064	7,985	58.7	72,640	225,366	244,941	336,329
Port Loko	529,831	5,719	92.6	76,787	238,232	258,925	355,530

Kambia	324,769	3,108	104.5	45,489	141,130	153,389	210,618
Tonkolili	413,273	7,003	59.0	62,617	194,269	211,144	289,921
Koinadugu	318,849	11,621	27.4	53,270	165,270	179,626	246,644
Western Area	1,243,804	557	2233.0	217,449	674,636	733,236	1,006,805

* Based on 83% fuelwood used for cooking and 10 kg fuelwood per day.

The biomass energy situation has transformed dramatically over the past decade. Since the end of the civil war there has been a significant increase in charcoal production nationally and in charcoal consumption in urban areas – most notably in Freetown. The vast majority of production now occurs in the provinces.[12] A number of villagers have given up farming to become full-time charcoal and commercial fuel wood (firewood) producers, illustrating the new vitality of the trade and its importance for rural livelihoods."[13]

As Table 5 shows, Freetown biomass energy consumption, until recently, was primarily firewood (50.7% in 2004). Today, roughly one quarter (26%) of households use firewood as their primary cooking and heating fuel in Freetown, while charcoal constitutes almost three quarters.[14] However, wood remains the major source of cooking energy in other urban areas (SLIHS, 2003, SLIHS, 2013), which has important implications for household cooking efficiency improvement options. Wood fuel and charcoal currently account for over 98% of all household cooking energy in Sierra Leone (SLIHS, 2013).

Table 5: Freetown Population & Primary Cooking Energy, 1963 to 2013

[12] Primarily in Western Region, with limited amounts still produced on the Peninsula and in Western Rural. Project Rapid Rural Appraisal and, Schultz, M. 2011. Land and Forest-Cover Change Analysis, Western Area Peninsula Forest Reserve (WAPFR), Sierra Leone. 2nd Report of Activities. OBf 2011.

[13] Munro, Paul & Greg van der Horst. 2012b, The Domestic Trade in Timber and Fuel wood: Products in Sierra Leone: Current Dynamics and Issues. FAO, EFO/FLEGT, Freetown, 2012.

[14] Note the SLIHS of 2003 and 2011 did not measure actual quantities of household energy consumed. They simply asked for "primary energy source for cooking". However, interviews with all three major petroleum product distribution companies (National Petroleum, Total, Afrigas), showed kerosene imports were down to a fraction of 2004 levels, while only Afrigas is trying to expand LPG sales. While statistics on quantify of electricity used for cooking by households are not available, NPA (National Power Authority), MoE and consumer interviews indicate that very little electricity is used for cooking and water heating.

			Freetown as %	% Freetown Households Primary Cooking Source					
Year	Freeown Population	National Population	National Pop	Charcoal	Wood	Kerosene	LPG	Electricity	Other
1963	127,917	2,180,355	5.9%	1.0%	91.0%	7.0%	n/a	n/a	n/a
1975	276,247	2,735,159	10.1%	18.0%	68.0%	12.0%	n/a	n/a	n/a
1989	469,776	3,515,812	13.4%	30.0%	60.0%	8.8%	n/a	n/a	n/a
2004	764,484	4,976,871	15.4%	32.2%	50.7%	10.8%	1.0%	0.1%	5.2%
2013 (est)	1,019,744	5,989,623	17.0%	72.7%	26.0%	0.6%	0.2%	<.05%	0.5%

Source: Various Census, Sierra Leone Integrated Household Surveys (SLIHS, 2003, and SLIHS, 2013) and other data from Statistics Sierra Leone.

Tables 4 and 4 show the energy consumption by sector and energy carrier in GWh for 2010 and 2013.

Table 4 Energy consumption by sector and energy carrier in GWh for the year 2010

2010	Petroleum products	Electricity	Firewood*	Charcoal	Coal	Others	Total per sector
Transport sector	1166	-	-	-	-	-	1166
Industrial sector	194	68.1	138.7	20.4	-	-	421.2
Tertiary sector (commercial and services)	96.4	48.6	277.4	81.6	-	-	504
Agriculture and fisheries sector	119	3.8	138.8	-	-	-	261.6
Residential sector	602.1	72	13317.7	918	-	-	14909.8
Other sectors/ Mining	214.2	1.9	-	-	-	-	216.1
Non-energy use	-	-	-	-	-	-	-
Total	2391.7	194.4	13872.6	1020	-	-	17478.7

Table 4: Energy consumption by sector and energy carrier in GWh for the year 2013

2013	Petroleum products	Electricity	Firewood*	Charcoal	Coal	Others	Total per sector
Transport sector	1870	0.5	-	-	-	-	**1870.5**
Industrial sector	367	86.3	287	104	-	-	**844.3**
Tertiary sector	85	21.8	861	366	-	-	**1333.8**

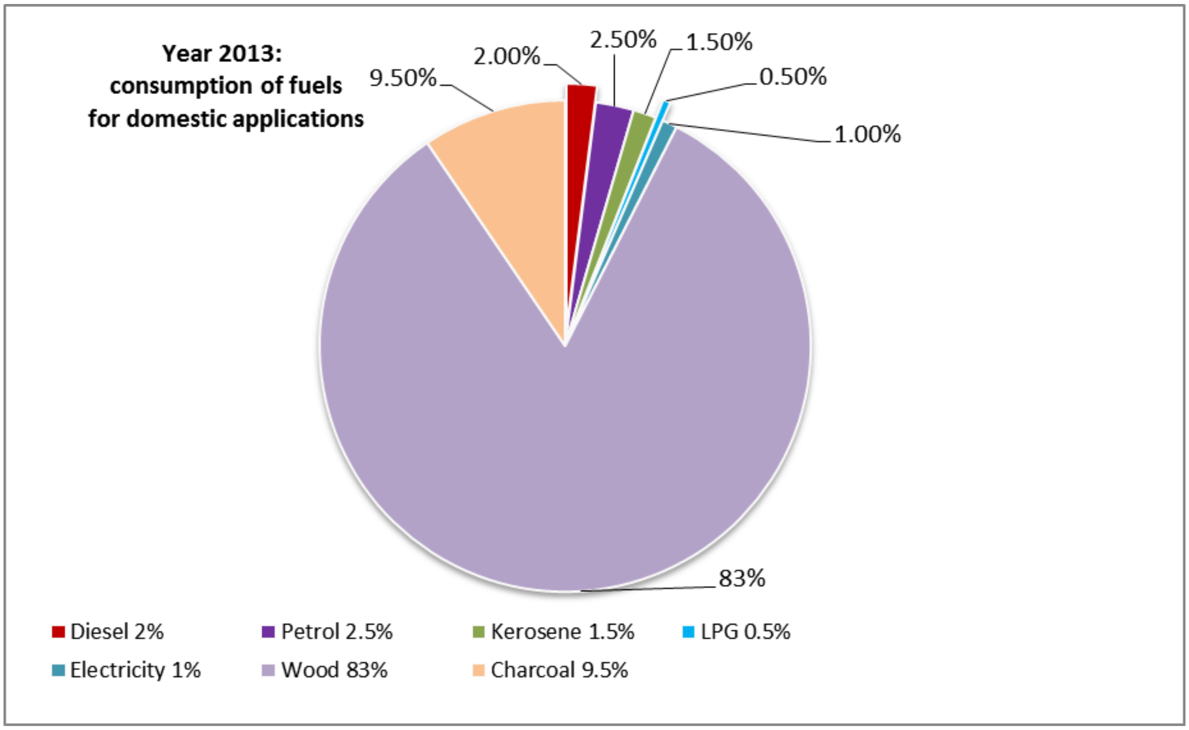
(commercial and services)							
Agriculture and fisheries sector	174	3.6	382	-	-	-	**559.6**
Residential sector	670	65	36715	4750	-	-	**42200**
Other sectors/ Mining	313	1.8	-	-	-	-	**314.8**
Non-energy use	-	-	-	-	-	-	
Total	3479	179	38245	5220	-	-	**47123**

Consumption of fuels for domestic applications

Table 9: Residential Sector Consumption of Fuels in 2013.

Typte of Fuel	Petrol	Diesel	Kerosene	LPG	Electricity	Firewood	Charcoal	Total
No. of Households (HH) 2013	31506	2048	46268	15033	36268	735517	165074	**1031714**
Fuel consumed (GWh) 2013	437	121	96	16	65	36715	4750	**42200**

Figure 4.2 Consumption of Fuels for domestic applications



Electricity Sector

Table 4 10: Current and expected demand in GWh

Year	Residential sector GWh	Industrial sector GWh	Other sectors GWh	TOTAL GWh
2013	52.11	98.84	28.75	179.7
2010 (base year)	56.41	106.98	31.13	192.48
Expected for 2020	2415	3086	1208	6709
Expected for 2030	3658	4675	1829	10162

Table 4 11: GRID GENERATED ELECTRICITY CONSUMPTION IN SIERRA LEONE (2006 – 2013) '000'toe

POWER STATION	2006	2007	2008	2009	2010	2011	2012	2013
KINGTOM	2.75	2.6	10.2	6.6	3.5	1.14	7.2	6.5
BLACKHALL ROAD	Nil	Nil	1.8	1.4	Nil	0.81	3.4	3.1
BUMBUNA	Nil	Nil	Nil	3.5	11.8	13.5	5.05	4.03
BKPS	0.65	0.61	0.79	0.78	0.91	0.69	1.15	1.27
Total '000'toe	**3.4**	**3.21**	**12.79**	**12.28**	**16.21**	**16.14**	**16.8**	**14.9**

Source: MoE, NPA, BKPS and BHP (2013)

Table 4 12: INSTALLED POWER CAPACITY IN SIERRA LEONE AS OF MAY, 2012

Type of power plant	Installed Capacity in MW	Number of Plants	State Owned, Private, Mixed	Grid Connected or Decentralized Plant
Thermal Oil Plant	37	7	State Owned	Grid Connected
Large Hydropower plants (>10MW)	50	2	State Owned	Grid Connected
Small Hydropower Plants (< 10MW)	6.75	4	State Owned	Grid Connected
Auto-Generators (135MW) plus two years import (39MW)	135+39 = 174	33,000	Private	Isolated
Mining Company Gen.	88.5	Unknown	Private	Isolated
Photovoltaic	0.025	Unknown	Mixed	Isolated
TOTAL MW	**356.3**			

Source: MEWR, NPA, NRA and SPU (2012)

- **Grid systems for electricity transmission and distribution (national grid, isolated grids, mini-grids, etc.), including regional interconnections to other countries**.

There are only two electricity grid systems in the country namely, i) 161KV, 202km line between Bumbuna Hydro station and Freetown via Makeni Town. ii) 33KV, 30km line between Bo, Kenema and Dodo Hydro site.

There is a proposed WAPP (CLSG) regional interconnection between Ivory Coast, Liberia, Sierra Leone and Guinea.

There is non-existence of a national grid in Sierra Leone.

- **Off-grid systems used for consumers with no grid service (e.g. domestic individual diesel generators)**

Over 80 per cent of the Sierra Leone population use diesel generators off-grid systems in rural communities.

- **Difficulties faced by the sector (energy losses, infrastructure quality, regulatory barriers, etc.)**

Definitely the energy sector is faced with several difficulties such as over 40% electricity losses being experience, aged and weak T&D network including limited energy regulatory barriers.

- **Access to energy: electrification rate, urban and rural cases.**

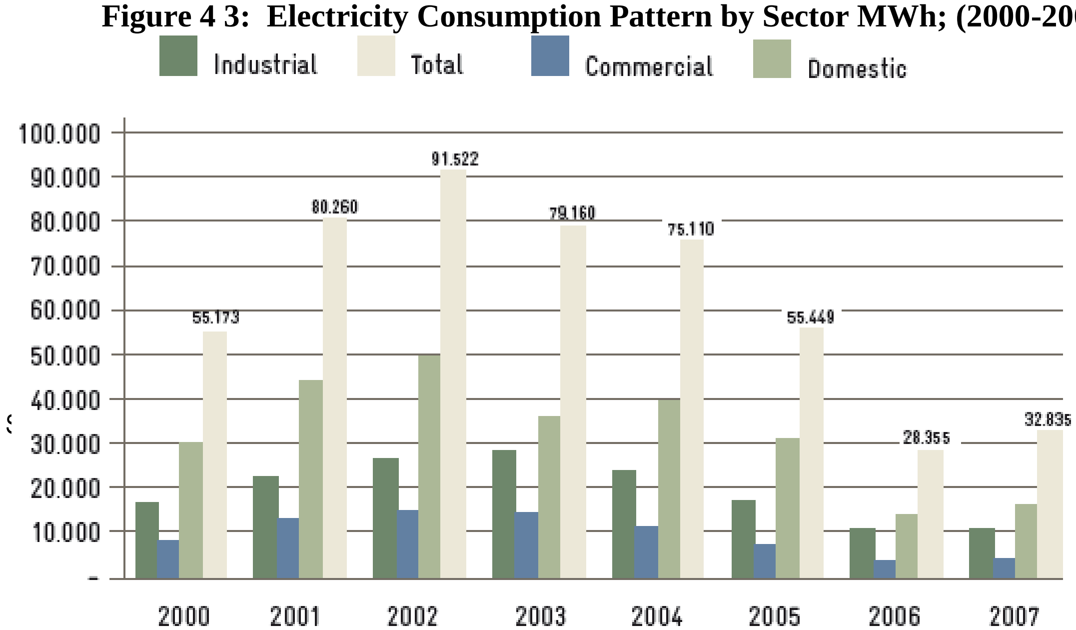
Below table shows the electrification rate in the country.

Table 4 13: ACCESS TO GRID CONNECTED ELECTRICITY IN SIERRA LEONE (2006 – 2013)

POPULATION	2006	2007	2008	2009	2010	2011	2012	2013
Freetown	38,362	47,281	53,126	64,306	67,422	73,551	86,200	93,755
BO-Kenema	8,762	9,078	9,455	10,180	11,302	12,593	17,553	24,331
Makeni	305	430	521	596	602	1,040	3, 490	9,104
Lungi	-	-	-	-	-	-	-	1,758
Kono	-	-	-	-	-	-	-	377
Total Customer	**47,429**	**56,789**	**63,102**	**75,082**	**79,326**	**87,184**	**107,243**	**129,325**

Population with Grid connection	284,574	340,734	378,612	450,492	475,956	523,104	643,458	775,950
Population without Grid connection	4,937,426	5,009,266	5,106,388	5,173,508	5,294,644	5,478,896	5,394,202	5,414,330
Urban	1,982,418	2,030416	2,079,941	2,131,013	2,183,784	2,238,230	2,294,311	2,414,209
Rural	3,234,472	3,312784	3,393,589	3,476,917	3,563,016	3,651,850	3,743,349	3,776,071
Access to Electricity %	**5.5**	**6.4**	**7.4**	**8.7**	**8.2**	**8.7~9**	**10.7**	**12.5**

Figure 4 3: Electricity Consumption Pattern by Sector MWh; (2000-2007)



Generation costs, tariffs for different type of consumers, subsidies

The Tables 14 and 15 below show the tariffs of different type of consumers from the Electricity Distribution and Supply Authority and GoSL subsidies.

Table 4 14: Tariff of Electricity Supply to consumers

Tariff Structure	Energy Consumption (kWh)	Energy Charge (LE/kWh)						
		1996	1998	2000	2003	2005	2008	2014
Tariff 1	Domestic							
	0-30	90	117	205	287	373		Average 1,224
	31-150	110	143	293	410	533		
	Above 150	130	169	389	545	709	989	
	Min. Charge	2.500	3.250	6.143	8.600	11.180		
Tariff 2	Non-domestic (commercial)							
	0-30	100	130	358	501	651		
	31-150	120	156	429	601	781		
	Above 150	130	169	465	651	846	1,290	
	Min. Charge	3.000	3.900	10.725	15.015	19.520		
Tariff 3	State-run institutions							
	All units	100	130	429	601	781		
	Min. Charge	5.000	2.600	17.875	25.025	32.533	1,161	
Tariff 3A	Others							
	All units	120	156					
	Min. Charge	5.000	6.500				1,161	
Tariff 4	Industry							
	All units	150	195	517	724	941		
	Min. Charge	5.000	65.000	65.000	91.000	118.300	1,376	
Tariff 5	Street lighting							
	All units	120	156	435	609	792		
	Min. Charge	7.500	9.750	796	20.475	26.618	1,161	

Tariff Structure	Energy Consumption (kWh)	Energy Charge (LE/kWh)						
		1996	1998	2000	2003	2005	2008	2014
Tariff 6	Temporary supplies							
	All units	200	260	-	700	910		
	Min. Charge	5.000	6.500	-	8.680	11.284		
Tariff 7	Welders							
	All units	200	260	546	764	993		
	Min. Charge	10.000	13.000	19.500	27.300	35.490		

Source: EDSA Management, 2014

Transport sector

Table 4 16: Transport sector energy consumption for the base year 2010

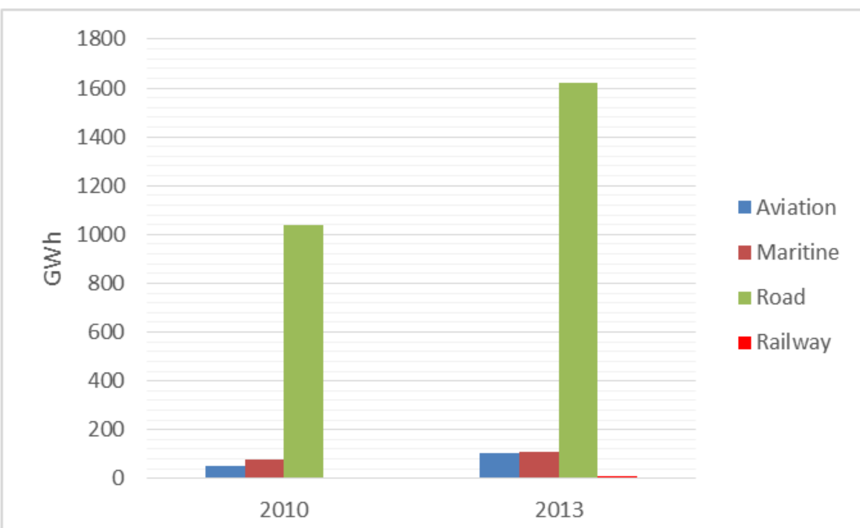
Year 2010	**Energy Consumption by type of transport (GWh)**				**Total (GWh)**
	Aviation	**Maritime/River**	**Land**		
			Road	Railway	
Gasoline	4	8	597	-	**609**
Aviation fuels (ATK, etc.)	41	-	-	-	**41**
Gas Oil (Diesel fuel)	3	65	443	-	**511**
Natural Compressed Gas	2	3	-	-	**5**
Electricity	-	-	-		**-**
Others…	-	-	-		**-**
					1166

ATK: Aviation Turbine Kerosene

Table 4 17: Transport sector energy consumption for 2013

Year 2013	Energy Consumption by type of transport (GWh)				Total (GWh)
	Aviation	Maritime/River	Land		
			Road	Railway	
Gasoline	7	12	920	0.2	**939.2**
Aviation fuels (ATK, etc.)	85	-	-		**85**
Gas Oil (Diesel fuel)	6	91	702	11	**810**
Natural Compressed Gas	4.2	6	-	0.8	**11**
Electricity	0.25	0.2	0.05		**0.5**
Others…	-	-	-		**-**
					1845.7

Figure 4.3 Transport sector energy consumption 2010 and 2013



The above Tables 16, 17 and figure 4 are energy consumption for 2010 and 2013 in the transport sector Table 4.18 below shows the total primary energy supply trajectory from 2014 to 2030.

Table 4.18: Total Primary Energy Supply Trajectory from 2014 to 2030 in ktoe

Energy (ktoe)	2014	2015	2016	2017	2018	2019	2020	2021	2022
Biomass	3843	3969	4152	4343	4507	4549	4703	5095	5489
Electricity	75	222	275	328	380	538	555	573	608
Petroleum Products	335	382	436	490	541	589	647	699	749
Total (ktoe)	**4253**	**4573**	**4863**	**5161**	**5428**	**5676**	**5905**	**6367**	**6846**

cont. Table 4. 18.

Energy (ktoe)	2023	2024	2025	2026	2027	2028	2029	2030
Biomass	5803	6197	6574	6978	7437	7824	8175	8755
Electricity	625	660	695	713	750	798	815	853
Petroleum Products	789	832	884	937	989	1032	1079	1123
Total (ktoe)	**7217**	**7689**	**8153**	**8628**	**9176**	**9654**	**10069**	**10731**

4.1.2National Institutions and Agencies Related to Implementation of Mitigation Actions

The key institutions involved in the implementation of Sierra Leone's National Energy Policy, are the same as those that are involved in climate change mitigation. The Energy Policy speaks to Sierra Leone having well-defined and established governance, institutional, legal and regulatory framework for the energy sector that facilitates stakeholder involvement and engagement. The policy also plans to ensure that the (energy sector) institutional framework includes mechanisms for improved coordination and organization between and within energy agencies and capacity building to meet the human resource needs.

Since climate change and mitigation issues affect nearly all public and private sector institutions and every facet of life, it will be necessary to focus on those institutions and their policies and legislation under whose portfolios there are highest GHG emissions and opportunities for mitigation.

The highest GHG emissions occur in the transport, transformation (electricity generation), and the mineral extractive industries (rutile, bauxite etc.) sectors. Implementation of mitigation activities invariably will need facilitating and supporting roles from other institutions to provide suitable financial incentives, assessment and analysis of outcomes, public relations and public education. These institutions and the existing policies and legislation are described below in order to identify issues that could present barriers and/or facilitate implementation of GHG mitigation activities.

4.1.3 Key Ministries/Institutions Directly Involved In GHG Mitigation

Ministry of Energy

This ministry is responsible for the development of the energy sector and generation of electricity. It is expected to develop the energy resources and provide adequate energy(mainly electricity) supply to the nation. It enhances the improvement of energy supply and delivery facilities and maintenance of existing ones.

The MoE dealt mainly with issues related to electricity. But, in recent years, the Ministry's focus has been extended and other energy issues are being addressed. Directorate of Energy (DoE) was established by an act in 2010 under the Ministry of Energy. The DoE was set up to conduct strategic planning on energy security and access issues and was mandated to introduce new energy resources and ensure efficient utilization of energy resources. To further implement its objective, the DoE formed the Renewable Energy and Energy Efficiency and rural electrification units in 2012 to address the issues of renewable energy as alternatives to fossil based energy and energy efficiency and rural electrification. The units of this ministry are charged with the responsibilities of organizing and conducting research and development in energy and energy efficiency and rural electrification. In 2014 the Ministry also established the National Energy Task Force, which is meeting on a daily basis, to address energy issues. This task force, has recently completed national energy strategic plan for the next three years. In which it is the desire of the ministry to generate a 1,000 MW of electricity, by 2017/2018.

The Ministry is responsible for establishing the legislative and policy framework to facilitate the achievement of Sierra Leone's national energy goals, which have implications for the mitigation activities and projections outlined in this assessment. It also provides the necessary guidelines for general medium and long -term energy strategy planning. ME, in collaboration with other Government entities as well as other partners and stakeholders in the public and private sectors, is also leading the development of a carbon trading policy. The Designated National Authority for the Clean Development Mechanism (CDM) is also within the ME.

ME, in setting indicators and targets for the energy sector, will also be mindful of the mitigation activities as well as the projections and take into account key issues such as need for the use of cleaner technologies in industry as well as enabling a more efficient energy sector in general as well as leading various initiatives for the diversification of energy.

Electricity generating companies:

Sierra Leone's electricity is generated by Electricity Distribution Supply Authority (EDSA) of Sierra Leone.

EDSA is the sole distributor of electricity to a customer base of over 600,000. While EDSA has the exclusive right under its License to distribute and supply electricity throughout Sierra Leone, effective January 2014.

Electricity Generation Transmission Company (EGTC) is responsible for the generation and transmission of electricity.

The Ministry of Transport and Aviation (MTA):

This ministry is mandated to deal with issues related to transport on land, air and sea as well as local and international communications. The SLRA maintains the database with registration information for the licensed motor vehicle fleet.

MTA's primary responsibility is for Sierra Leone's land, marine, and air transport, as well as the main road network, including bridges, drains, gullies, embankments and other such infrastructure. MTA has regulatory responsibility for the safety of all publicly or privately operated modes of transportation. This includes airports, airline operators, sea ports, shipping traffic, and public land transportation, as well as road infrastructure and road safety. The infrastructure includes a 15,394 km road network, 330km of rail track, a small fleet of public passenger buses, one international airport, three specialized sea ports and one public deep -water port.

There are 21 reporting entities that assist MTA in fulfilling its mandate. Among them are the Transport Authority (SLRTA), the Civil Aviation Authority (CAA), and Airports Authority of Sierra Leone (SLAA) and the Port Authority of Sierra Leone's (SLPA).

The Transport Authority regulates licensing of all public and commercial vehicles and the regulating and monitoring of public transportation. It also administers the provisions of the Road Traffic Act, and is responsible for the testing of vehicles to ensure fitness, road -worthiness and general compliance with standards of safety. It holds vehicle registration information for the entire vehicle fleet.

The Meteorological Department

The Meteorological Department is the Focal Point for climate change in Sierra Leone and is responsible for providing local weather forecasts.

Sierra Leone Maritime Administration

This organization is responsible for the administration of maritime affairs including shipping activities, safety of marine transportation, pollution and vessel registration.

Ministry of Trade and Industry (MTI)
The Petroleum Agency of Sierra Leone (PA):

The Petroleum Act of 1979 established the PA as a Statutory Corporation under the Ministry of Trade and Industry, with the exclusive right to explore for oil, to develop Sierra Leone's petroleum resources, and to enter all stages of the petroleum industry. The only oil refinery in Sierra Leone is not working.

The Sierra Leone Standards Bureau (SLSB)

The Sierra Leone Standards Bureau is a statutory body established by the Standards Act of 1988. Its main functions are formulating, promoting and implementing standards for goods, services and processes. The Bureau develops and enforces technical regulations for those commodities and practices which affect health and safety. It is the agency that sets fuels specifications.

Statistics Sierra Leone

Statistics Sierra Leone main functions are to:

- collect, compile, analyse, abstract and publish statistical information relating to the commercial, industrial, social, economic and general activities and condition of the people;

- collaborate with public agencies in the collection, compilation and publication of statistical information including statistical information derived from the activities of such agencies;
- take any census Sierra Leone; and generally promote and develop integrated social and economic statistics pertaining to Sierra Leone and to co-ordinate programmes for the integration of such statistics.

The Ministry of Finance and Economic Development:

The MOFED has responsibility for the macro-economy which includes implementing tax related incentives/disincentives for the development of all sectors including the energy sector.

Ministry of Agriculture, Forestry and Food Security

This ministry if mandated to preserve and conserve, as well as through managed commercial exploitation to provide for sustainable and permanent regenerating forest resources. It is responsible for issuing licences to exploit and maintain all forests types on public lands to monitor their harvesting so that they are sustainable and ecologically stable.

The Agriculture Division

The Forestry Division:

The Forestry Department is a department of the Ministry of Agriculture, Forestry and Food Security and is the lead agency responsible for the management and conservation of Sierra Leone's forests. Its functions are mandated by the Forest Act, 1996, and are aimed at managing forests on a sustainable basis to maintain and increase the environmental services and economic benefits that forests provide. A National Forest Conservation and Management Plan and the Strategic Forest Management Plan 2009-13, among other things, describe the Department's policy and legal framework, forest management constraints, forest values, the current state of Sierra Leone's forests and establish goals and a wide range of implementation forest management strategies and activities.

The National Protected Area Authority (NPAA)

THE NATIONAL PROTECTED AREA AUTHORITY AND CONSERVATION TRUST FUND ACT, 2012 provides for the establishment of the National Protected Area Authority and Conservation Trust Fund, to promote biodiversity conservation, wildlife management, research, to provide for the sale of ecosystems services in the National Protected Areas and to provide for other related matters. The object for

which the Authority is established is to exercise oversight authority over National Parks and Protected Areas designated for conservation purposes so as to protect the fauna and flora in its natural state, promote sustainable land use practices and environmental management developing a national REDD+ Strategy and promoting REDD+ Projects in Sierra Leone as a source of sustainable financing for Protected Area Management; develop and implement wildlife conservation education and training programmes throughout Sierra Leone;
(h) promote biodiversity research;
(i) formulate and implement awareness raising activities amongst others.

Ministry of Lands Country Planning and the Environment

This Ministry is charged with the responsibility of land country planning and also for articulating and implementing the country's land policy and managing the environment.

Ministry of Fisheries and Marine Resources

It is responsible for the management of fisheries resources and related habitats in a manner which would maximize benefit in terms of fish catch now and in the future. It is expected to develop fisheries resources and to devise methods of enhancing current production and more effective exploitation. The ministry issue license for offshore trawling and monitors small-scale inshore and offshore large-scale fishing. It is also responsible for enforcing laws on fishing activities and concerns itself with pollution and other environmental problems which affect water quality and fisheries resources.

Ministry of Mineral Resources

This ministry is charged with the responsibility to supervise mining operations in the country. It issues licences for all mining operations, enforces laws and provisions contained in the Mining Act and its amendments. It is responsible for enforcing provisions in the new mining act relating to the rehabilitation of mined out areas.

The Minerals Agency (MA)

The Minerals Agency (MA) was established in 2005 as an arm of the Ministry of Mineral Resources, to deal mainly with the sovereign aspects of the Government's participation in the mining industry. MA's functions include:

- Monitoring and studying the mining industry;
- Providing technical advice;
- Undertaking research and development activities;
- Assessing and ensuring rationalization in the use of Sierra Leone's mineral reserves and

- Monitoring and making recommendations on pollution control and other environmental concerns in the industry. The MA also manages the Mining Community Development Programme, which involves implementation of development projects within the vicinity of mining operations, to foster harmony between the community and the companies. The MA works in collaboration with other agencies, and is proactive in attaining compatibility between the industry's operations (processes, activities and products) and the environment by:
- Ensuring that the operations are conducted with minimal or no adverse impact on the environment; ensuring compliance with all local standards and regulations through maintaining a regular and effective monitoring programme;
- Conducting regular reviews on the environmental performance of the industry and instituting the necessary corrective actions;
- Promoting research and development aimed at identifying new technologies for a cleaner, more efficient production process and waste minimization; and
- Fostering and maintaining a harmonious relationship with communities in the areas of mining operations.

The main institutional conflicts are (1) the extent to which the Ministry has jurisdiction over marine areas with respect to marine based mineral resource, offshore dredging and its impact on marine resources and (2) the overlap of water quality monitoring with the interest of the Ministry of Marine Resources.

Ministry of Tourism

This ministry is responsible to promote and develop the country's tourist industry and culture. It is also charged with duty of protecting the country's heritage, monuments, and cultural and historical sites

The Office of the President (OP):

The Office of the President provides an oversight for the environment and the Environment Protection Agency is established under the Office of the President by the amendment of the 2008 Act in 2010.

Sierra Leone Environment Protection Agency

The Government of Sierra Leone has also established the Environmental Protection Agency (EPA-SL) in July 2008. This Agency is responsible to coordinate and monitor the implementation of all environmental policies, programmes and projects. To ensure the enforcement of the strategic environmental assessment (SEA) and Environmental Impact Assessment (EIA) as well as related legislation to promote sustainable environmental development, human wellbeing and poverty reduction in the country. EPA- SL is the agency entrusted with managing Sierra Leone's natural and the man -made environment and is the lead government agency responsible for environmental management. The climate change secretariat has also been established within the EPA-SL.

Disaster Management Department

The Government of Sierra Leone established the Disaster Management Department in the Office of National Security. As a first step in dealing with the problem of climate change, the Department together with key stakeholders embarked on the development of a national hazard profile, national disaster management policy, national disaster management preparedness and response plan, vulnerability and capacity assessment and contingency plans on health related problems, population movement, floods, water shortage etc,.

Local Government Councils

Are responsible for the administration of local government including and implementation of the devolved responsibilities from centra government ministries, departments and agencies.

4.1.3 Key Policies and Legislation Related to Implementation of Mitigation Actions

Vision 2035 Sierra Leone:

Vision 2035 articulates, "Mitigation, through reducing greenhouse gas emissions, will be addressed through greater energy conservation. Energy conservation in Sierra Leone will put us in a "win -win" situation as it provides other substantial positive economic, social and environmental benefits. It is assumed that, energy conservation efforts, use of cleaner technologies and development of alternate energy will result in lower spending on imported oil, less pollution and reduction in pollution -related illnesses. We will engage in reforestation to increase the amount of greenhouse gases removed from the atmosphere, provide improved watersheds and waterways and reduce landslides and soil erosion. These measures (energy conservation and reforestation), if pursued on a global scale, will mitigate and reduce the global rate of climate change".

National Energy Policy 2009 -30

In December 2009, the government tabled a National Energy Policy 2009 -30 in Parliament that will lead toward developing: A modern, efficient, diversified and environmentally sustainable energy sector providing affordable and accessible energy supplies with long -term energy security and supported by informed public behaviour on energy issues and an appropriate policy, regulatory and institutional framework.

This vision will be realized by translating the policy into strategies and specific areas of action, such as diversification of the country's existing fuel sources, development of renewable sources of energy, biofuels, and waste -to -energy programmes, to name a few. These strategies and actions are being administered through the corporate and operational plans in a range of organizations, starting with the Ministry of Energy and Mining (MEM) and its agencies, and also including other Ministries, agencies and departments such as those ministries with responsibilities for transport, agriculture, and environment.

The policy places priority attention on seven key areas:

1. Security of energy supply through diversification of fuels as well as development of renewable energy sources;
2. Modernizing the country's energy infrastructure;
3. Development of renewable energy sources such as solar and hydro;
4. Energy security and efficiency;
5. Development of a comprehensive governance/regulatory framework;
6. Enabling government ministries, departments and agencies to be model/leader for the rest of
7. society in terms of energy management; and
8. Eco -efficiency in industries.

Each of these seven priority areas, when implemented, will reduce Jamaica's GHG emissions and they have been included in the scenarios in this mitigation assessment. Other policies to be developed that will also help in the reduction of GHG emissions include the Renewable Energy Policy, the Biofuels Policy, and the Energy Conservation and Efficiency Protocol (ECE) for the management and use of energy in the public sector. The ECE speaks to the operation of public sector facilities and entities.

The National Transport Policy

The National Transport Policy drafted in 2007 is guided by the vision to create a "sustainable, competitive, safe, accessible, and environmentally friendly transport network providing world class air, land, rail, and marine facilities contributing to a vibrant import, export and trans -shipment trade for Sierra Leone and the world." The transport policy is designed to encourage energy conservation measures (e.g., efficient traffic management; carpooling; park and ride; use of clean fuels to minimize pollution; flexi -work hours and tele -commuting; an efficient public/urban mass transit transport system; and use of non -motorized transport) and promotion of vehicle and road maintenance programmes. Supporting legislation for use of biofuels will be put in place.

The transport policy also will encourage more efficient modes of transport such as barges especially for bulky materials like aggregates. The possibility of enhanced coastal and rail transport will be kept under constant review. The policy foresees that once natural gas is introduced into Sierra Leone's energy supply mix, the transport fleets, where applicable, will be converted to CNG. In the longer term, a CNG supply network will be developed to enable private motorists to convert to natural gas based motor vehicles.

The Forestry Department's Strategic Forest Management Plan: 2009 - 13 will enable it to fulfil its mission to manage, protect and conserve the country's forest resources. The Forest Management Plan specifically refers to the mandate to maintain and measure the role of forests as carbon sinks as part of Sierra Leone's commitments under the UN Framework Convention on Climate Change (UNFCCC).

The environmental policy and environmental assessment (EA) legislation and procedures of Sierra Leone which are relevant to the climate change, are the following:

The National Environmental Policy (NEP)
As the first national policy concerning the environment the NEP, which was approved in 1990 and revised in both 1994 and 2002, is a milestone document for environmental management with enormous implications for climate change. This policy highlights the general principles to be considered by all activities that have potential implications for the environment, in particular outlining the main environmental goals and objectives that underlie Sierra Leone's aspiration for sustainable development. Its relevance to climate change can be viewed in terms of the restraints that it poses to the uncontrolled use of forests, along with their natural resources.

The National Environmental Action Plan (2002)
Unlike the NEP, this plan (NEAP) sought to identify the specific activities that needed to be undertaken in order to protect Sierra Leone's environment. Most of these activities, which were intended to be integrated into any future national development plan for the country, relate to such issues as environmental education and training, environmental information systems (EIS), and the integration of NEAPs into national development plans. Because this plan also ranks and prioritizes environmental actions with a strong emphasis on protecting security of tenure, it arguably has serious implications for climate change.

The National Biodiversity Strategy and Action Plan (2003)
Developed in 2003, the BSAP was formulated based on the NEAP. Its relevance to climate change is the highlighting of the state of Sierra Leone's biological and ecological resources and the threats posed to their existence. This plan specifically identifies a range of cross-sectoral actions needed to ensure the effective protection and sustainable use of the country's resources. Several of these priority actions relating mainly to such thematic issues as forest management, land degradation, and soil and water management have also been outlined among the key priority activities of the National Adaptation Plan of Action (NAPA).

The National Land Policy and Land Commission Act (2004)
On the other hand, the National Land Policy was formulated in response to the prevalence of land encroachment and haphazard development which has led to the

intensification of vulnerability in many areas. Its major influence on climate change is the power to minimize "the social and environmental implications" of the various types of land uses in the country (Government of Sierra Leone, 2005).

The Environmental Protection Agency Act (2008)

The Environmental Protection Agency- Sierra Leone Act is an improved version of the Environmental Protection Act (EPA) (2000) acting as the environmental focal point for the country, to ensure that Sierra Leone complies with the relevant Multilateral Environmental Agreements (MEA's) that it has committed itself to. Prominent among these MEAs are the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol, the United Nations Convention to Combat Desertification (UNCCD), and the United Nations Convention on Biological Diversity (UNCBD).

The Environmental Protection Agency Act, 2008 and Environmental Protection Agency (Amendment) Act, 2010

The Environmental Protection Agency Act, 2008 established the Environmental Protection Agency Sierra Leone - (EPA-SL), to provide for the effective protection of the environment and for other related matters. This Act mandates the EPA-SL among others to: Advise the President on the formulation of policies on all aspects of the environment and in particular make recommendations for the protection of the environment.

The National Security and Central Intelligence Act No. 10 of 2002

This Act established the Office of National Security (ONS) which serves as the central coordinating body for the security sector and intelligence organ of the state at the policy level. The Disaster Management Department is one of seven departments within the ONS created by this Act and this department has the mandate to coordinate all issues related to both natural and man-made disasters. It also brings together all stakeholders from governments, NGOs, United Nations specialized agencies, and community based organizations, the private sector, media and local communities. In other words, it is the central agency responsible for disaster management.

The National Disaster Management Policy (Draft)

The Policy recognizes that disaster management and risk reduction are a multidisciplinary endeavor, and while it indicates the ONS as the lead agency in this process, it stipulates that this Office is to collaborate with the decentralized government institutions, the public and private sector, UN agencies and NGOs. Importantly gives strategic directives to the government on steps to be taken before, during and after disasters. The objectives of the Draft Disaster Management Policy are to:

- Ensure the integration of disaster risk management into sustainable development programmes and policies to ensure a holistic approach to disaster management;

- Ensure priority and requisite institutional capacities for disaster risk reduction at all levels;
- Enhance the use of knowledge, education, training, innovation and information sharing to build safe and resilient societies;
- Improve the identification, assessment, monitoring and early warning of risks.

Conclusion

The ministries, departments, agencies and institutions described above all have enabling legislation that empowers them to undertake their functions. Implementing the various mitigation measures and assessing the current and future mitigation options requires institutions and agencies with the institutional and legislative frameworks to facilitate the construction and operation of mitigation projects and activities as well as the collection and analysis of relevant information that will monitor their implementation and assess new development possibilities.

However some crucial pieces of legislation tends to be lacking for example:

- The Electricity Survey Act which can allow for the collection, compilation and analysis of information relating to the generation, distribution and use of electricity, and the quantities and types of electrical apparatus in use.

- The Petroleum Quality Control Act includes regulations that require reporting of fuel sales information by petroleum marketing companies.

4.2 Methodological Approach

Description of Leap data requirements and constraints

This section is meant to give an insight as to the constraints in using the above model.

LEAP Approach in the Mitigation Assessment

The Long -Range Energy Alternatives Planning System (LEAP) model11 was planned to be used for the mitigation assessment to examine the demand, transformation, resources, and non -energy sector emissions and effects. LEAP is a scenario -based, energy -environment modelling tool based on a comprehensive accounting of how energy is consumed, converted and produced in a given region or economy under a range of alternative assumptions.

The input data for the LEAP model are grouped into five categories:

1. *Key assumptions*, i.e., macroeconomic, demographic and other time -series variables used in other categories;
2. *Demand*: Overall energy consumption of households, industry, government, road transport, and various JPS electricity customer rate classes;

3. *Transformation*, i.e., petroleum refining, electricity distribution and generation, charcoal production;
4. *Resources*: indigenous energy resources; and
5. *Non energy sector effects*, i.e., GHG emissions from cement and lime manufacturing, GHG emissions from agriculture, forestry and industry.

Detailed data was to be obtained for the sub-categories listed in Table 4.4. Additional information about these sub-categories follows. However the comprehensive structured data required for the efficient working of the software was unavailable as shown below.

Table 4.4: LEAP Model Input Data

Key Assumptions	• **Population**	**A**
	• **Household Size**	**A**
	• **GDP in $**	**NA**
	• **Population growth rate**	**A**
	• **GDP Growth Rate**	**NA**
	• **Transportation Emission factors (for 11 pollutants in 8 vehicle classes)**	**NA**
Demand Module	• Household (Refrigeration, Lighting, Cooking, Fans, Stereo, Air conditioners,	NA
	• Computer equipment, Washing machines, Clothes ironing, Television, All other	NA
	• Industry (Cement & Clinker, cement mills, Rutile and Bauxite mining#, Lime kilns, Sugar)	NA
	• Government (Hospitals, NWC, Other Government)	NA
	• Municipal (Rate 60)	
	• Rate 20, Rate 40A##, Rate 50	
	• Road Transport (8 vehicle classes)	NA
	• Commercial charcoal	
Transformation Module	• Transmission & Distribution	NA
	• Electricity Generation	NA
	• Charcoal making	NA
Natural Resources	• Primary (Wind, Hydro, Wood, Bagasse, Municipal Waste)	NA
	• Secondary (Output fuels)	NA
Non-Energy Sector Effects	• Landfill emissions	NA
	• Agriculture (Animals, Soils, Rice	NA

	Production, Forestry) • Industry (Lime kilns, Cement, limestone)	NA	

Sectors	Required data	Possible source	Possible data providers	Available(A)/Not Available (NA)
Key Assumptions	As stated above	Statistics Sierra Leone, ME, MTA	Bank of Sierra Leone, ME, MTA, Statistics Sierra Leone	
Demand Module	As stated above	Statistics Sierra Leone	Statistics Sierra Leone ME,MTI, MOHS	
Transformation Module	As stated above	ME, EDSA, EGTC	ME,MAFFS,MTI	

4.2.1 LEAP Model Information Sources

Key Assumptions
This module contains macroeconomic (GDP and GDP growth rate), demographic (population, population growth rate, household size) and other time -series variables (for example, emission factors for the on -road fleet) that are used in the other modules.
Historical and projected GDP data were not available from the Bank of Sierra Leone publications.

Demand
The demand module requires activity and energy intensity data such that the product of the two gives the energy consumption. The demand module was broken down into various “branches” namely, household, industry, government, road transport, and various electricity customer rate classes used by EDSA. These branches were selected because fuel and electricity end -use and other activity data may be available for them and/or subcategories within them. However these data sets were unavailable.

Transformation
The transformation module comprises petroleum refining (which is absent in Sierra Leone), electricity distribution and generation (information should be obtained from EDSA) and charcoal production branches. Electricity transmission and generation

data should be obtained primarily from the publicly available Tariff Rate Application available on the web site of the Office of EDSA and from historical reports provided.

4.2.2 Constraints, Gaps and Challenges that the country has faced while elaborating this Chapter

The major gap is a comprehensive economic analysis of mitigation options and identification of viable technological options. The major challenge is in terms of quantitative and qualitative data for the mitigation software's (LEAP,COMAP ,COPATH etc.),

Reduction Potential

It has been difficult to calculate the emission reduction options for each sector. It has been also is difficult to calculate the emission potential of each sector or for each one of the identified mitigation measures however we would try to provide this kind of information since this it is one of the most important elements of the mitigation analysis in the next NC Report.

This year like the previous, saw other challenges for the conduct of the mitigation studies these include but not limited to:

a) Lack of comprehensive and software (LEAP,COMAP ,COPATH etc.), compatible data;
b) Shortage of qualified professionals;
c) The Project has not been able to benefit from UNFCCC/UNDP Workshops, Seminars and Conferences as recommended in the Project Document;

4.2.3 Development priorities and national context

Previous and planned initiatives, policies and legislation national and regional.

The development priorities have been articulated in chapter one. Beyond the reporting period, Sierra Leone has developed the second PRSP dubbed Agenda for Change for the period 2008 -2 focused on **inclusive green growth**.

Defining the main sources of emissions

As Sierra Leone does not have any source of primary fuel, the country imports fossil refined based fuel to meet 85% of its energy needs mainly in the electricity, transportation and mining sectors. Hence these are the main sources of emission. Other sources include the AFOLU sector with minimal emissions from waste and cottage industries.

4.2.4 Mitigation Assessment Approach

Based on the constraints in using the LEAP software as outlined earlier this chapter, nationwide stakeholder consultations with synergies drawn from the NDC, NAMA and PRSP green growth documents were employed.

The first approach to this mitigation assessment was to conduct a scoping workshop, which involved collecting data and information through stakeholder consultations and desk review of literature on mitigation options of GHGs from the source categories identified in the inventory chapter. The outcome was the development of a comprehensive list of mitigation options for the relevant categories, which were then screened for prioritization.

Assessment and prioritization of mitigation opportunities of Sierra Leone in the key sectors

In this section, an attempt is made to assess and prioritize mitigation opportunities of Sierra Leone in the key sectors (source categories) for which the Green House gas inventory was done. Reference to other potential sectors to avoid carbon dioxide emission was also made.

Residential sector

The characteristics of the residential sectors below as represented by the rural and urban areas give some insight into the mitigation opportunities existing in the sector.

Rural Areas

Food preparation in rural areas is done almost exclusively from biofuels (fuel wood and various residues). As reported in the SNC, the current dominant technology makes use of “three stones stoves” with very low energy yield (about 4 to 5%). As rural populations make up about 83% of the total population of the country, the economic potential of fuel is very high there. This economy could be obtained by combining two technologies namely the popularization of metallic improved stoves with a better output (between 12 and 30%) and substitution with fuel more appropriate to current uses.

In Sierra Leone, fuel-wood and kerosene account for about 96.8% and 2.7% respectively as the main sources of energy used for domestic cooking.
The LPG and other petroleum by-products technology is less appropriate in this environment for issues of cost and security. Lighting is dominated by kerosene, oils and gas as well as battery powered torches and agricultural residues.

Possible Technological Resources for the rural areas.

The Economically Profitable Technologies (EPT) potential, as envisaged in this case, is the extension of rural electrification.

Another EPT consists of using portable PV solar lamps. It is a unit made up of a fluorescent tube, 6 to 12 V battery and an amorphous panel of 10 Wc. The major obstacles are high cost, unavailability of spare parts and inexistence of skilled staff for the maintenance of this equipment.

Urban Areas

However, in urban areas, the Electricity Distribution Supply Authority (EDSA) plans to electrify over 60% of households through an electrical grid extension policy. Cooking stoves notably coal stoves and the LPG are being promoted in order to cover the needs of the mixed populace. The major obstacles here are the cost of new equipment, price of gas sales, maintenance and especially the high level of risk associated with the low level of education.

Economic Sectors

The economic sectors considered in the table below are also consistent with the source categories of GHGs identified in the inventory. For each of these sectors mitigation options have been listed which can help to reduce emissions.

Sector/Source Category	Options/Opportunities
Energy / Industrial Sector	Hydro Electric Power (HEP), switching and promotion of other forms of renewable energy (Solar Energy & wind), use of other fuels such as Ethanol, Oxygen, development of alternative energy sources such as Bio-fuels (from corn, sugarcane, rice husk etc).
Transport Sector:	Designing and improvement of provincial and feeder roads, use of lead-free petrol, Mass transportation (road and water) for passengers and cargo, Quality control for spare parts for all types of vehicles, enforcement of regular maintenance regulations for vehicles, regulations / policies on fuel use and consumptions.
Agricultural sector	Water management in rice cultivation and maintenance of soils, use of rice-

	straw, compost and biogas residues, mineral fertilizers, fallow incorporation and mulching.
Forestry sector	Forest protection, conservation and increased efficiency in forest management. Reforestation, afforestation and agroforestry, urban and community forestry.
Waste sector	Waste incineration, composting, recycling, landfills and open-dumps.

Screening
A screening exercise was undertaken in order to reduce suggested options to a small amount of viable ones.

National and project screening criteria and indicators

In screening this long list of mitigation measures the following criteria were applied. The criteria included the following:

- availability and ease of collecting the data needed for project development and implementation,
- the benefits and costs of the projects,
- the economic and social importance of the project in the country, and
- reduction of the concentrations of GHGs in the atmosphere.

The additional national indicators used include:

- National development benefits and policy priority;
- How well the projects span the range of GHG mitigation opportunities in the country;
- How representative these projects are of GHG mitigation opportunities in the country sub-region as a whole; and
- The availability of information to assess these projects;

Outcome of the screening

The outcome of the screening was the reduction of the options in the various sectors above to manageable options that were then subjected to some general analysis.

Energy

- ✓ Rural electrification using Solar Home Systems to compliment the Hydro Power Plant;
- ✓ Greenhouse gas reduction through the use of Improved Cooking Stoves;
- ✓ Large scale introduction of Liquefied Petroleum Gas to displace fuel wood;

Transport

- ✓ Improvement of the road ,rail and water transport system

Forestry

- ✓ Carbon sequestration through reforestation and protection of existing forests; Managing a multi-product forest for cashew nuts, honey-bee-keeping, etc;

Agriculture

- ✓ Integrated crop and livestock farming – utilizing rice straw (treated with urea) as cattle feed;

Waste

- ✓ Utilizing waste to generate landfill gas for bottling: Waste management using composting;

4.2.5 Analysis of Mitigation options and project ideas by sectors

A comprehensive economic analysis of mitigation options and identification of viable technological options and a calculation of the emission reduction options for each sector were not carried out.

Methodology Utilized for prioritization

The method for prioritizing the mitigation options was based on the "Mitigation Option Weighting" method, which is itself based on the following criteria:

Mitigation benefits, Financial Viability, Implementation/Organizational viability, Technological viability, Size, Acceptability, and Political Willingness.

Energy Sector

Analysis of the sector

The National Energy Profile also makes the case for increased solar and hydro power generation and a range of biomass sources. It also highlights knowledge and capacity constraints. With private sector support, Sierra Leone has invested in hydroelectric power generation, building the Bumbuna hydro-electric plant.

The Ministry of Energy has prepared an ambitious new Energy Strategy has been outlined in this chapter. [15]
Its vision builds on the three pillars of access, efficiency and renewable energy[16], with specific, time bound targets for each pillar.

Sierra Leone, a water-abundant country and has potential for bio-energy production, especially from sugar-cane, so long as environmental and social safeguards are respected.

The use of palm nut shells as fuel for thermal generators of electricity was also viewed as a viable mitigation option. These shells are being produced in huge quantities during the harvesting period of palm oil in the provinces. They can be used as a source of fuel as they have high calorific value. Though this option results in reducing emissions, it can be controlled as it is from a single source. Its benefits are that rural communities will have electricity and have the opportunity to use electric stoves. This will result in fuel wood savings, less time spent collecting wood, forest preservation and income generation through the selling of the nuts since these nuts are annually produced in large quantities in the provinces.

Sierra Leone has over 20 hydro potential sites of which the Bumbuna Dam is the only one that has been tapped. This dam, which has been completed, has a capacity of 50MW. This was considered as the most viable mitigation option for the electricity sector. If five of these hydro potentials including Bumbuna are utilized, it will result in almost zero emission from the electricity sector.

Production of petroleum products

All the petroleum products consumed in Sierra Leone are imported basically from international markets. Recently the country has proved to have oil reserved. At present this is at an exploratory stage. A development of this resource is envisaged in the future; therefore emission from this sector may consequently be enhanced.

Results of prioritization

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[15] "Sustainable Energy for all": MEWR Government of Sierra Leone June 2012.
[16] The pillars are consistent with the UN 2012 Energy for All goals, which aim to double energy access, double the rate of improvements in energy efficiency and double the proportion of renewable energy in the energy mix by …?

Proposed mitigation options

Energy and Water Sector	
Possible Mitigation Options to be Considered	**Priority**
Hydro Electric Power (HEP),	High
switching and promotion for renewable energy (Solar Energy & LPG)	High
development of alternative energy sources such as Bio-fuels (from corn, sugarcane, rice husk etc)	Moderate

Potential of the mitigation options

For the different activities considered for which fossil fuels and fuel-wood are the sources of energy, the following mitigation options were considered and weighted (Table 3.1).

Table 3.1: Mitigation Options and their weightings

Activity	Mitigation Option	Weighting
Electricity	Steam generators using Nut shell	21.8
Cooking	Efficient Biomass stove using Rice husk	18.7
	Efficient Biomass stove using Wood shavings & saw dust	16.1
Road and River Transportation	Mass transportation – Railway	20.5
	Mass transportation – Bus	18.7
	Mass transportation – Water (Boats or Ferry)	18.7

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Information regarding Projects on bioenergy:
http://www.afdb.org/fileadmin/uploads/afdb/Documents/Environmental-and-Social-Assessments/Addax%20Bioenergy%20-%20ESHIA%20summary%20-%20Final%20EN.pdf

Transport Sector

Analysis of the sector

Since 2000, there has been a steady increase in the number of vehicles plying the roads. No data exists on the consumption rates of motor vehicular transport in the country.

In 2000, the transport sector had some 16,763 constituent units for about $^2/_3$ of the passenger vehicles including motorcycles and remaining 1/3 for transportation of goods. Its growth rate is quite high especially since the advent of low cost second-hand car, which increases CO_2 emission potential in the sector.

The ERT potential envisaged in the NTS is the promoting of alternative means of transportation, the modernization of number of motor vehicles and especially the construction of 2000 km of railway lines.

Table 1

Vehicle Population By Region	
East	9826
North	6770
South	7452
West	38560
Total	62608

As presented in the table above, the vehicle population of the country, found by the census is 62.608. The Western region takes 38,560 of this total, followed far behind by the Eastern region with 9,826, then the South with 7,452 and the North in the fourth position with 6,770.

This shows that on the basis of percentage, the Western region takes 61%, Eastern region 16%, Southern region 12% and Northern region 11% as seen in pie chart below.

Results of prioritization

The Results of the prioritization exercise are shown below.

Table 2 Summary of Analysis of Mitigation Options for GHG Emission in Transport

Mitigation Options	Priority
Designing and improvement of provincial and feeder roads	High
Mass transportation (road and water) for passengers and cargo	High
Improvement of the water transport system	Moderate

Quality control for spare parts for all types of vehicles	High

Analysis of options and project ideas

Description of the potential of mitigation options

That most mitigation efforts from private vehicles would need to be carried out in the Western region given that they concentrate more than 61% of the emissions. Improvement of feeder roads in the city for instance would significantly reduce congestion and engine idling.
Improvement of conditions in the provinces will encourage vehicle owners to use their vehicle in those areas rather than the Western area where there is a high vehicle population concentration.

Other strategies can be envisaged which basically make use of energy conservation through the users capacity building. The promotion of urban transport and the technical control of means of transportation. Costs are also major constraint here both for the renewal of the car fleet and for the promotion of transit in urban centers. The promotion of less pollutant alternative fuels, such as LPG, biofuels or battery-powered vehicles, is other Energy Profitable Technology alternatives, though the same obstacles remain.

Possible Technological Resources to implement the measures

In the urban areas of Sierra Leone particularly, more roads can be designed and constructed at strategic places to ease congestion and idling of vehicle engine. In the case of new vehicle imports, vehicles used for more than ten years should not be allowed for import. The importation of Lead-free petrol should be encouraged.
Another Economically Profitable Technologies (EPT) potential, as envisaged in this case, is the extension of the railway.

Mitigation Capacity in the Agricultural Sector

Analysis of the sector

A recent inventory on GHG emissions from the Agricultural sector in Sierra Leone identified a number of gases such as methane (CH_4), carbon dioxide (CO_2), Carbon monoxide (CO), Nitrous oxide (N_2O) and NOx (Consultancy Report 2010). The period of inventory was ten years, 1995-2005, with 2000 as the base year.

The agricultural sector, contributed in 2006 to approximately 46% of gross domestic product (GDP) and employing over 65% of the labor force. Increase in food

production and security is another government's top priority on its national agenda. Mechanisms have now been put in place to ensure that higher crop yields are obtained in order to reduce on food imports to save more foreign exchange earnings that could be used for other development programs and projects.
Government is also making strides to provide agro-meteorological information to avoid crop failure in the country

Crop production in the country is very sensitive to climate and climate variation. Agriculture is the largest economic sector in Sierra Leone, contributing (in 2006) to approximately 46% of GDP[1] and employing over 65% of the labor force. Rice is the main agricultural production and it is mainly cultivated for subsistence purposes. The fluctuation in yearly crop yields is mostly due to weather effects and climate variability. The impact of climate change is already tangible in the country. Indeed, Sierra Leone is experiencing climatic hazards such as seasonal drought, strong winds, thunderstorms, landslides, heat waves, floods and changed rainfall patterns.

As reported in the Sierra Leone's National Adaptation Programmme of Action (NAPA), poor communities have suffered the most from climate change impacts, as floods destroyed their crops and increased droughts caused water shortages in some areas of the country. In particular crop production, being highly vulnerable to climatic change, has been affected by prolonged period of dry days even during the rainy season (July/September) and heavy rains in March that prevented farmers to burn their fields resulting in weeds expansion. As an example of predicted climate change impact on crop production, for temperature above 25° C rice production is expected to retard and yields to decrease[2]. Other production such as maize, millet and cocoa are projected to be negatively affected by climate change. Considering that food production depends entirely on subsistence farming, a decline in agricultural productivity – coupled with the increasing trend of food prices – is expected to ultimately worsen current food insecurity problems.

The rainfall in the country is increasingly becoming sporadic and in the last two years rains have fallen in March which is the driest month of the year than the last three decades. Furthermore, the country is now experiencing prolong period of dry days even in the months of July/august and September which are supposed to receive the highest precipitation. The erratic rains now falling in March have prevented farmers from properly burning their farms which leads to early emergence of weeds resulting in poor yield of crops.

The Comprehensive list of mitigation options outlined earlier in the chapter were then screened for further analysis:

Potential Agricultural Mitigation Options

With regards to mitigation, many options have been identified as follows:

- improved rice cultivation practices,
- improved animal husbandry practices,

- improved manure management practices,
- improved fertilizer management practices,
- application of zero tillage or conservation farming and
- application of agro-forestry practices, which include crop rotations, mixed cropping and intercropping systems.

Results of prioritization
Summary of prioritized mitigation options for GHG Emission in Agriculture

Mitigations options for irrigated rain fed and deepwater rice cultivation.		
No.	**Mitigation option**	**Weight /30/priority**
1	Water regime modification	23
2	Organic residue management	23
3	Use of mineral fertilizer	18
4	Straw management	21
5	Crop establishment	24
LIVESTOCK: ENTERIC FERMENTATION AND MANURE MANAGEMENT		
1	Creation of cattle ranches, stables, pig pens and poultry houses	22
2	Improved intensive/semi-intensive ducks and chicken management	21
3	Animal manure management – use of manure in lowland and upland rice fertilization	21

Potential of the mitigation options
References

http://www.gafspfund.org/gafsp/sites/gafspfund.org/files/Documents/sierra.pdf

Mitigation Capacity in the Forestry Sector

Analysis of the sector

The forest sector plays a key role in a number of areas. It provides for environmental management such as provision of clean water sources, sustainable livelihoods of both urban and rural population, aesthetic values and cultural values and acts as carbon sinks. Despite the important roles above, their use for livelihoods and development results in forest deforestation and degradation.
Forest conversion causes deforestation through land use whereby forests are converted into cropland or rangeland, settlements etc. Deforestation is a major concern presently growing at 2.5% annually translating into an estimated loss of 40,

0000 hectares of forest per year. Other activities such as roads, rail and dam construction in addition to settlement also contribute to deforestation.
In addition weather events such as high temperatures and high wind velocity and low relative humidity during dry season negatively exacerbates bush fires that destroy plantations and natural forests.
Consequently, the bush fires, increased use of firewood and charcoal, increased seasonal burning are identified as major sources of CO_2 emissions.

Sierra Leone has responded to the concerns above in the forest sector by developing a national forest policy and Forest Act (1997) and Community Based Forest Management supplement to the policy. The Forestry Act, provides for participatory forestry, forest management, research, education, forest industries and protection and rehabilitation of environmentally fragile areas.

The act among other issues seeks to protect trees and other resources in forest reserves, conserve and enhance biodiversity, protect and facilitate management of trees on customary land, promote community involvement in the conservation of trees, promote sustainable utilization of timber and other forest produce and protect fragile areas such as river banks and water catchment. The forest policy was set out to introduce the concept of participation and to promote Community Based Forestry Management in the forest sector. It recognizes local communities tenurial rights over natural resources by assigning to them authority and responsibility. Due to this local communities are highly involved in conservation of natural forests within customary lands.

This is possibly contributing to the increased forest land cover in Sierra Leone. In addition local communities are engaged in afforestation and reforestation which reduces pressure on forest energy needs and helps in reclamation of forest degraded areas. The forests also act as carbon sinks for mitigation measures to climate change.

The destruction of forests through burning and the decaying of woody biomass results directly into significant contribution of **CO_2** to the atmosphere. However, the expansion of forests and the maintenance of existing stands can capture a lot of **CO_2** from the atmosphere and maintain it on land over decades. During 2000, the GHG emissions from the forestry and land-use sector was mainly through changes in forest and woody biomass, forest conversion and soil out-gassing.

Summary of prioritized of Mitigation Options for GHG Emission from Forestry

Mitigation Options	Prioritizing Measures
Reducing the demand for fuel wood (reducing deforestation)	High
Preserving forested lands as national Parks, Sanctuaries, Aboreta etc	High
Afforestation /plantation establishment	Moderate
Community Forestry	Moderate
Forest Conservation	High
Forest Protection	High
Agro-forestry cropping system	High
Reforestation/Rehabilitation of degraded lands	High
Increasing efficiency of wood recovery/use	Moderate
Substitution of timber for high energy construction material	moderate
Substitution of wood and other bio fuel for fossil fuels	moderate
Integrating trees into existing land use patterns-shelter belts	High
Residential shade trees/roadside vegetation	Moderate

Forestry protection and conservation, reforestation and afforestation have the desired potential to significantly reduce GHG emissions through various tree planting programmes that enhance carbon storage, which may increase the carbon pool to 756 million t C by 2050.

On-going changes in international policies in forestry are creating new opportunities which Sierra Leone could benefit from. These include the Reducing Emissions from Deforestation and forest Degradation (REDD) and Clean Development Mechanism (CDM) architectures. Such changes will help Sierra Leone demonstrate the role of its forestry policy in the co-generation of livelihoods, biodiversity, and carbon benefits from forests.

Private finance through carbon markets can play a major part in funding mitigation**.** The existing carbon offset markets will likely remain a major source of climate finance for Sierra Leone; making use of these markets should be of a high priority for Sierra Leone . However there is a proliferation of opportunities in Sierra Leone stemming from the REDD and CDM, which are not currently regulated by any policy framework. The challenge is to ensure that these opportunities benefit local communities who are affected most by the burden of Climate Change and have a low adaptive capacity.

Public Awareness

The mounting of a public-awareness campaign using the various public media, and the provision of incentives to aid awareness of the importance of sustainable management of forest resources and the value of forests. The major thrust in this regard will be the development of education packages for schools, media, and communities to increase awareness about issues in the forest sector.

Forestry Education, Training and Research

The main objectives here are the development of a forest sense. The vital element in the achievement of this policy objective is a well-planned and well-coordinated educational and training policy. Very high priority will be given to educating a cross-section of the community in the value of forests in national development.

Government's main strategy will involve grassroots education by promoting the formation of nature clubs and forestry cooperatives, so that the benefits of forestry can be discerned easily, and by gradually introducing forest conservation into school curricula. Another important strategy will involve intensifying national Tree Planting Day activities so that there is more widespread involvement, and encouraging youth participation in nursing and planting tree seedlings, for example, schools and clubs will be encouraged to establish their own nurseries.

Mitigation policies in the Forestry Sector

The following Polices may be necessary to implement the mitigation options and can be used to maintain carbon stocks and/or expand carbon sinks:

- Polices and local laws protecting cultivation of steep slopes and protecting other vulnerable areas/ecosystems such as PA and Forest Reserve.
- Policies on shared responsibility for managing such PA between local communities and central government.
- Control of logging and harvesting of forest and non-forest products.
- Planned and aggressive afforestation and reforestation polices by private individuals local communities, Forestry Department and Environmental NGOs.
- Land tenure policies that encourage private ownership of some lands with an expressed mandate to sustainable development by planting and retaining trees on their land i.e. parties involving Agro-forestry cropping systems.

Possible Technological Resources to implement the measures

Waste Sector

Analysis of the sector

Domestic, agricultural and industrial waste is generated in the form of solid and liquid. There is no form of waste management or separation in Sierra Leone. Solid waste is collected from residential properties and commercial services, markets, recreational areas, government offices and institutions (schools and Hospitals), fish and poultry processing plants, industries, hotels, etc. the waste constitutes the following: leftover food, paper, grasses, construction waste and other cutting.

In Sierra Leone, waste management analysis is only conducted in the Freetown municipality, which is located in the Western area. As such, much of the data used is based solely on data provided for this area by the Ministry of Health and Sanitation. No data exist on waste management for both the rural and the provincial areas, which is about 90% of the country. The focus therefore has been more on Freetown, the capital of the country with the following characteristics: It is;

- the most densely populated area in the country
- the seat of government, commercial and economic centre of the country. where the harbour; the entry point of all imported goods is located and
- the point of attraction of most food stuffs produced in the country.

According to the information in the inventory chapter, the following waste categories are present in Sierra Leone.

Waste source Categories Present in Sierra Leone

Category Code	Category Name	Present in Sierra Leone
6A	Solid Waste Disposal on Land – CH_4	Y
6B1	Industrial Wastewater	Y
6B2	Domestic and Commercial Wastewater-N_2O	Y
6 C	Waste Incineration – CO_2, CH_4 and N_2O	Y
	Medical waste	Y

Estimates of Emissions from Waste Management Sector

Five main sources were considered: solid waste disposal on land – CH4, industrial wastewater – CH4 , domestic and commercial wastewater – CH4, domestic and commercial wastewater – N2O, waste incineration – CO2, CH4 and N2O

The estimated emissions from these source categories show minimal results. Hence the proposed mitigation measures are in the areas of stronger policies and legislations and strengthening of public and private waste management infrastructure and repair of moribund ones.

The Comprehensive list of mitigation options outlined earlier in the chapter were then screened for further analysis:

Proposed mitigation options

Waste Sector	
Waste Management Practices	**Possible Mitigation Options to be Considered**
Solid Waste Disposal On Land	Composting
Industrial Wastewater	Recycling
Domestic And Commercial Wastewater	Recycling and treatment plants for industries and mining companies
Waste Incineration	Conversion to biogas

Mitigation options in the waste management sector

The method used to arrive at the mitigation options proposed by the stakeholders was the "Mitigation Option Weighting" method. The following options listed in table 3.21 were prioritized:

Results of prioritization

Table 3.21: Weighted Mitigation Options

Mitigation options	Weighting / 30/priority
Waste incineration	**15**
Policy and Legislation	**29**
Landfills and open-dumps	**19**
Composting	**28**
Recycling	**25**
Repair of moribund Structures (municipal sewage treatment system)	**30**

The weighting method identified transforming organic wastes to manure as the most suitable mitigation option, using composting. This method, though considered as the best alternative, has its constraints with respect to the manner in which garbage waste is collected. As such, for the manure option to be successful, initial separation of garbage wastes must first be done. For separation of garbage wastes to be achieved, the following should be done:

- Effective education of the populace on separation of garbage wastes.
- Separated garbage wastes should be sold.
- Recycling and manure producing (controlled anaerobic digestion) small-scale industry should be encouraged.

Potential of the mitigation options

Crops and animal wastes are known to provide significant amounts of energy. It is estimated, for example, that about 110MT of dung and crop residues can be used as fuel, coming second only to wood as the dominant biomass fuel world-wide.

Operations such as thinning of plantations and trimming of felled trees can generate large volumes of forestry residues. At present in Sierra Leone, these are often left to rot on site. They can be collected, dried and used as fuel by nearby rural industries and domestic consumers.

Timber processing is another source of wood residues. Dry sawdust and off-cuts produced during the processing of cut timber make very good fuel. The sawdust and off-cuts can be collected countrywide from furniture industries and processed to produce fuel.

Over 90% of domestic waste in Sierra Leone is currently land-filled and most of the remainder is incinerated. The presence of plastics, metals, bottles and toxins create pollution problems, but landfill and incineration sites can be subjected to operating conditions laid down by appropriate regulatory authorities and designed in such a way to ensure that GHG emissions are reduced to acceptable levels.

Again, large scale plans for waste separation, recycling and composting remains elusive in Sierra Leone. Energy from wastes is an attractive option but the shortage of suitable landfill sites within the city and the high costs of transporting the wastes to distant sites are constraints.

Possible Technological Resources to implement the measures

In the urban areas of Sierra Leone particularly, landfill sites can be designed at strategic places were domestic refuse (MSW) can be safely deposited after sorting, to allow anaerobic digestion. The gas (LPG), produced can be collected by an array of interconnected perforated pipes buried at depths of up to 20m in the refuse. In the case of new landfill sites, the pipe system is constructed before the wastes are deposited. The gas collected can be used for electric power generation or heat as required

The potential technology options for the different mitigation options are identified below:

Potential technology options
Waste incineration Landfills and open-dumps Composting Recycling

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http://www.sierraleonetransformation.org/sites/default/files/Recommendations%20for%20Waste%20Management%20Strategy%20in%20the%20Urgan%20areas%20of%20SL.pdf http://www.jofamericanscience.org/journals/am-sci/am0605/20_2026_Situational_am0605_124_135.pdf

4.2.6 Assessment of the institutional capacity-building requirements to sustain mitigation work and the related legal and institutional frameworks

Sierra Leone has very low institutional capacity to sustain or to undertake the mitigation work. This is because the country has very high level of poverty, low level of trained and qualified personnel at all levels in the sectors were mitigation can occur.

3.3 Implementation of Mitigation Actions

This section:

- Indicates the main requirements for implementing mitigation measures;
- Identifies regulatory and policy gaps; and
- Provides specific recommendations for implementing priority mitigation measures.

3.3.1 Main Requirements for Implementation of Mitigation Actions

Successful implementation of the mitigation measures will *inter alia* depend on:

- Provision of incentives/disincentives for the development and use of innovative technologies that improve/worsen efficiency;

- Implementation of energy related policies that support the goals of the national energy policy, namely, the biofuels, waste -to -energy, and carbon emissions trading policies;
- Creation of relevant legislation to support investments in efficiency in energy -intensive sectors such as transport and mining;
- A review of previous and existing demand side management programmes for performance,

Strengths and Lessons Learned;

- Stronger institutional capacities in the energy and environment sectors;
- Development of programmes designed to influence market behaviour towards more efficient use in energy across all sectors;
- Development of mechanisms to efficiently share energy related information and for public and private sector entities to collaborate on energy related projects;
- Establishment of a system to identify and replace old inefficient electricity equipment and (especially) generating units/plants with more fuel efficient and cost efficient technologies and plants;
- Promotion of strategic partnerships between the public and private sectors to finance and develop energy diversification projects; and
- Introduction of national vehicle emission standards and regulations to reduce vehicular emissions and promote introduction of cleaner transportation fuels (especially CNG).

The Energy Policy presents a range of options and strategies for energy conservation to which the government is committed to pursue over the short, medium and longer term. It also identifies fuel diversification (with explicit targets) among the key goals to improve energy security and reduce energy costs.

Some of the specific strategies included in the Energy Policy that will facilitate the mitigation measures are as follows.

- finalizing the energy efficiency and conservation policy;
- creating relevant legislation to support required investments in energy efficiency;
- infusing energy conservation issues into relevant sectoral policy development (e.g. tourism, health, and water policies);
- implementing a public education programme to encourage energy conservation;
- providing incentives/disincentives for the use of innovative/clean technologies in power generation, mining, and manufacturing to improve energy efficiencies;
- promulgating the energy efficient building code;
- introducing national vehicle emission standards;
- promoting greater vehicle fuel efficiency;

- promoting imports of more fuel efficient vehicles;
- levying taxes on petrol at appropriate levels to encourage conservation;
- providing adequate infrastructure for transition to alternative energy vehicles;
- improving infrastructure and enforcing maximum axel weight standards;
- Increasing mass transit opportunities and utilization; and introducing financial incentives for solar technologies in the public and private sectors.
- SLIEPA to facilitate private sector involvement to implement projects in the areas of hydropower, wind, solar, biomass and waste -to -energy.

4.3.2 Identification of Regulatory and Policy Gaps
Barriers and opportunities for mitigation

A lot of barriers and opportunities for implementation of the different identified measures exist. These include both institutional and those related to capacity and inter –agency coordination.

Institutional and Policy Gaps Affecting Implementation of Mitigation Actions

Various regulatory, policy and coordination gaps exist in the energy sector. The Energy Policy clearly articulates these gaps and includes strategies to fill most of them. Some of the critical gaps that affect implementation of mitigation measures are highlighted below.

Carbon Trading:

The Carbon Trading Policy is absent. A draft of this policy can include a proposal to name the designation of the Designated National Authority (DNA) and to "s*ecure a sustained source of funding to support the provision of DNA related activities and services". T*he policy can recognise the absence of an institution/agency and a Clean Development Mechanism (CDM) governance structure, it can also clearly articulate the nature of the institution or agency that will house the DNA and its activities, e.g., whether or not any legislation will be needed; how the DNA office would be staffed; a timeline for its establishment; and the governance structure surrounding the DNA office.

As of 2009, the ADDAX bioenergy project is the only project in Sierra Leone that is engaged in carbon trading. The draft policy should recognise that additional capacity is needed to successfully take advantage of CDM opportunities. Since there were several potential projects in 2009 that could benefit from carbon trading, it is considered essential that this policy be drafted with great urgency.

Other Policy and Regulatory Gaps:

Some of challenges in the energy sector include legislation that lacks adequate enforcement provisions and clearly articulated policies or protocols to address: the pricing of electricity and petroleum products; decision making about retiring or mothballing old inefficient electricity generation plants; tax and pricing structures for road users; how to (better) address electricity system losses; and the development of renewable generation capacity. This has resulted in incremental decisions and has limited the introduction of diverse sources of energy and providing integrated monitoring and enforcement of regulations. As of 2009, there were also no legislative provisions for the net metering, carbon trading (as discussed above) or energy efficiency standards, although it is envisaged that these will be addressed as the 2009 National Energy Policy is implemented.

Coordination among energy sector stakeholders:

The stakeholders involved in the implementation of mitigation measures span the gamut of public and private sector agencies and institutions as well as the general public. Coordination of mitigation activities and communication of vital information to and among these stakeholders will be vital.

As of 2009, there is a formal interagency body (Climate Change Secretariat of EPA-SL) that coordinates mitigation activities between various agencies and now facilitates information flow.

Data collection and information:

In general, various pieces of legislation include provisions that require reporting of fuel sales, electricity generation parameters and emissions and for acquisition of production and other “activity data” that are needed for estimating emissions and for planning purposes. Data on historical electrical energy use and fuel consumption are collected by various entities, including the petroleum unit, statistics SL, ME, EPA -SL.

Enhancement of the survey approach is needed so that energy intensity data can be obtained on a routine basis. Specific examples include the enhancement of the surveys to include collection of information on the age ranges and numbers in each household of selected high energy consuming appliances (e.g., refrigerators, television sets, and air conditioners). Since nearly all electrical appliances and equipment are imported, enhancement of the import classification would be useful to clearly distinguish between various categories of appliances (based on technology and ranges of energy use).

Examples are as follows:

- Motor vehicles – to distinguish fuel used (i.e., diesel, gasoline, CNG, hybrid, electricity, etc.);
- Refrigerators (range in SEER value, refrigerant (HC or HFC));
- TVs (based on technology and/or energy intensity).

While various energy sector projects and programmes have been planned over the years, few were undertaken and there has been limited coordination of activities and timeliness in implementation of projects. Additionally, over the years, while some emphasis has been placed on the promotion of energy conservation in commercial sectors and industries such as tourism, the emphasis was not sustained and pilot projects (such as the Environmental Audits for Sustainable Tourism) were not effectively institutionalized across other sectors.

In the case of electricity generation, the forecasting of electricity consumption among various rate categories was based on macroeconomic data rather than on knowledge of end use equipment. It is to be noted that information on more immediate or shorter term energy requirements is sometimes included in environmental impact assessments and could also be included in the EPA's permit applications. Low levels of research in the energy sector can also be identified as a gap, resulting in low levels of adoption and adaptation of new and emerging energy technologies, improvements in energy infrastructure, and appropriate legislation.

There is also a lack of a comprehensive and sustained public education programme that would encourage Sierra Leoneans to use energy wisely and to aggressively pursue opportunities for conservation and efficiency. As a result of this, the Sierra Leonean public has a relatively low level of awareness of the importance of energy and its use in their daily lives and the contribution that each person can make to the responsible and efficient use of this vital resource. This low level of awareness also could explain the low intensity of use of solar energy for water heating in Sierra Leonean households.

4.3.3 Capacity -Building Needs

Capacity building in energy sector institutions will be required if mitigation measures are to be effectively implemented. Capacity building needs in the public sector centres on institutional arrangements for the collection, compilation, reporting and analysis of energy information and for public education. Implementation of private sector measures requires increased private sector technology awareness and capability and an environment that facilitates and encourages investment for implementation of mitigation measures. Public sector agencies with regulatory or other responsibility for the energy and environment must also be aware of the technologies, be able to assess them and to develop policies that are responsive to private sector and national needs.

The following specific capacity building needs have been identified:

- Enhanced capacity to compile GHG (and other) emission inventories and the capacity to perform energy and GHG emissions forecasting/modelling;
- Development of an energy information clearing house;
- Staff trained to perform functions of the DNA and the supporting institutions (e.g,National Carbon Trading Promotional organization);
- DNA institutions identified and/or established and any necessary legislation enacted(e.g., to enable certification or licensing of trading modalities);
- Role of the Energy Efficiency Unit within the Petroleum Unit of Sierra Leone expanded to provide technical assistance in the public and private sectors;
- Regulatory agencies provided with enforcement powers to improve the efficiency of the system and comply with established benchmarks, procedures and standards;
- Stronger links with the energy sector and academic institutions developed to drive the adoption and adaptation of new technologies in the energy sector;
- Capacity of local companies developed to improve their processes and energy efficiencies and to take advantage of carbon trading opportunities.

Adoption of Clean and Energy Efficient Technologies

- The identified renewable energy projects for electricity generation as of 2009 must meet the targets for renewables set in the 2009 -30 Energy Policy.
- Develop capacity to facilitate greater energy efficiency in the mining industry and the manufacturing sector;
- Engage in research towards adoption and adaptation of new and emerging technologies and improvements in energy infrastructure;
- Implement incentives/disincentives to enable the development and use of innovative technologies to improve energy efficiencies in all sectors and in households;
- Research and develop alternative fuels for the transport sector, including the use of biofuels and CNG when it becomes available;
- Encourage the use of solar powered water pumping by the GVWC and SALWACO; mandate that all new hot water installations be solar in all public buildings; and promote more widespread use of solar water heating in hotels;
- Promote the adoption of solar powered cooling/air conditioning, especially in the hotel/tourism sector;
- Implement demand -side energy management programmes, including the use of energy efficient appliances, equipment, and building designs; setting and enforcing standards for public sector organizations; and public awareness and educational programmes.

Address Data and Information Gaps

- Improve the motor vehicle fleet database (e.g., ensure correct assignment of fuel type; add off road categories, weight units; clearly distinguish between non-motorised trailers and motorised trailers; add allowance (categories) for future hybrid and CNG vehicles. This could be achieved by quality assurance checks during data entry and use of databases with manufacturers' specifications);
- Compile statistics for annual vehicle kilometres travelled (VKMT) through periodic surveys or routinely collect and record odometer readings during vehicle inspections for certificates of fitness;
- Develop mechanisms that would facilitate or require fleet management companies to report VKMT and other general non-confidential vehicle data; This type of information will inform the design of appropriate end use surveys in the commercial/manufacturing sectors and in planning/forecasting demand;
- Survey industrial and commercial customers for end use equipment;
- Conduct periodic surveys for charcoal and wood use;
- Conduct proper residential energy use survey in conjunction with data from EDSA smart meters;
- Compile data on appliance imports or sales for refrigerators;
- Develop and sustain public education on energy efficiency and conservation;
- Review the sustainable development and energy conservation curriculum needs throughout the (primary, secondary and tertiary levels) in the educational system and enhance the curriculum accordingly.

4.4 Recommendations

For some countries, particularly developed countries with emission reduction targets, energy policy is linked to or framed within the context of climate change mitigation and the move towards a low carbon economy. Although developing countries, including Sierra Leone, do not have emission reduction targets, mitigation actions such as energy conservation and development of renewable energy sources are having positive impacts in terms of economic, social, and environmental considerations.

The recommendations below are focused on improving the enabling environment and building institutional and technical capacities to encourage adoption of suitable energy conservation/GHG mitigation technologies and to fill data gaps that will facilitate cost-effective energy use and implementation of GHG mitigation measures.

These include the following:

- Improving the enabling environment within which GHG mitigation and other energy sector activities take place. This could entail streamlining some legislation or policies and in some cases additional legislation.
- Strengthen regulations so there are adequate enforcement provisions and clearly articulated policies that: address the pricing of electricity and petroleum products; improve decision making about retiring or mothballing inefficient electricity generation plants; (better) address electricity system losses; and develop renewable generation capacity;
- Develop and implement a regulatory framework to allow carbon trading to take place. This should include legislation establishing the DNA and associated entities, and specification of the trading modalities for local and international entities (e.g., licensing, certification or regulation of such entities, owning Certified Emission Reductions and Verifiable Emissions Reductions, etc.);
- *Establish an enabling environment to encourage local and foreign financing of innovative energy projects, especially in renewables*. This could entail developing policies and programmes that will encourage use of biogas and solar heaters as well as other alternate energy sources such as photovoltaic systems. These could, for example, entail revolving loans and/or import duty concessions and incentives for energy efficiency improvements;
- Implement incentives that will encourage tertiary level institutions to develop research programmes for the application and implementation of renewable energy projects;
- Adapt/adopt or develop energy efficiency standards for consumer and industrial electrical equipment and base import duties for such equipment in part on energy efficiency standards;
- Introduce national motor vehicle emission standards and regulations;
- Develop regulations and safety standards in anticipation of the introduction of CNG infrastructure and CNG use in industry and in vehicles;
- *Revise the bases for tax/customs duties* so that they are based on vehicle weight class and fuel type (not cc rating);
- Make use of the energy efficiency fund to increase energy projects, such as those related to renewable energy;
- Implement the building code.

The achievement of these objectives should be a national priority for a country with a low human development index which should lead to a high mobilization of the international community.

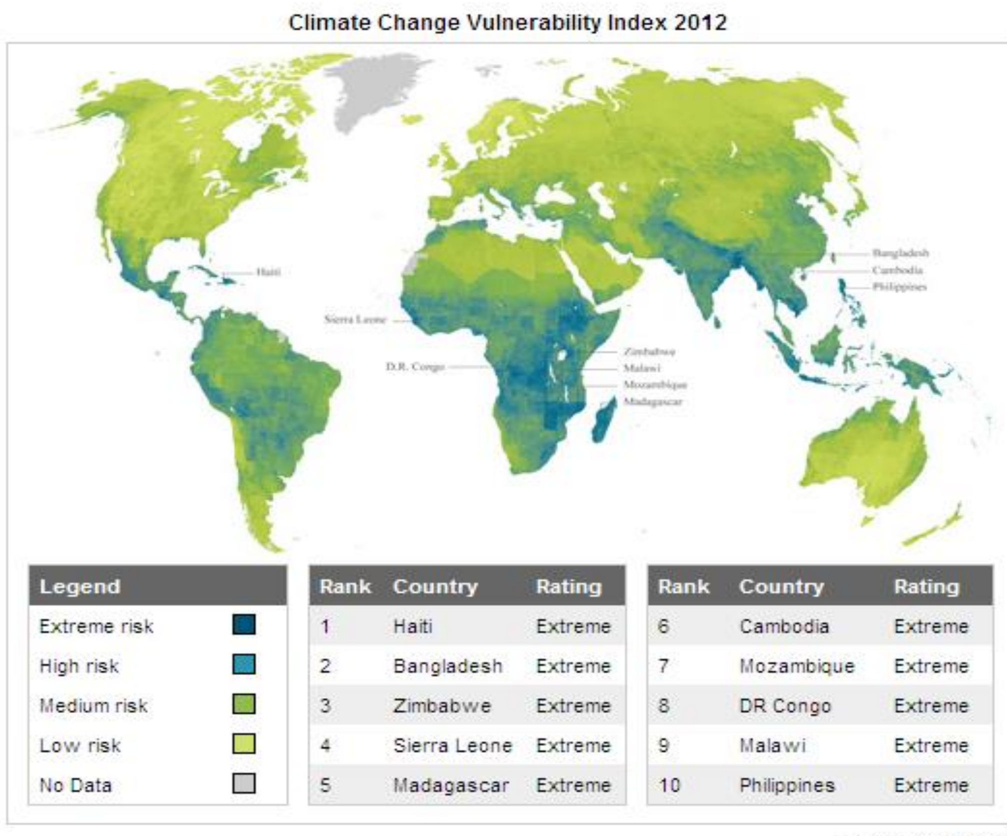
Chapter 4 References

UNFCCC website http//unfccc.int/national reports non-annnex1 natcom items 2979 php

Chapter 5: Programmes Containing Measures to Facilitate Adequate Adaptation to Climate Change.

5.1 Introduction

According to the Maplecroft climate change vulnerability index in 2012, Sierra Leone has been rated as the fourth most vulnerable country to climate change having extreme risk as revealed in figure 5.1.



Rank	Country	Rating	Rank	Country	Rating
1	Haiti	Extreme	6	Cambodia	Extreme
2	Bangladesh	Extreme	7	Mozambique	Extreme
3	Zimbabwe	Extreme	8	DR Congo	Extreme
4	Sierra Leone	Extreme	9	Malawi	Extreme
5	Madagascar	Extreme	10	Philippines	Extreme

Figure 5.1: Maplecroft's CC Vulnerability index for 2012

According to Maplecroft, population growth combines with poor government effectiveness, corruption, poverty and other socio-economic factors to increase the risks of climate change to residents and businesses of vulnerable countries. Infrastructures, which cannot cope with the expanding population levels, will therefore struggle to adapt in the future, making disaster responses less effective, whilst at the same time these disasters themselves may become more frequent. This

has implications on buildings, transportation routes, water and energy supply and the health of the residents. The common climate related hazards in Freetown are floods, heavy storms, extreme dryness and water shortage and landslides.
Sierra Leone is currently ranked as the third most vulnerable after Bangladesh and Guinea Bissau to adverse effects of climate change. Our vulnerable population has low capacity to adapt to climate change and the rural populations will be the most affected because of their high dependence on rain-fed agriculture and natural resource-based livelihoods. Over the years and quite recently, Sierra Leone has witnessed the loss of life and property as a result of landslides and surface flooding in our towns, city, islands, and low-lying areas are gradually sinking due to climate variability and change. Climate change also affect our socio-economic sectors and the need for climate change mainstreaming at the national, sector and local levels is vital to move the country toward a low emission and climate resilient development pathway.

5.1.1 Methodological Approach

The Climate change impacts for the years 2005 to 2035 and 2050, were considered as part of the vulnerability and adaptation (V&A) assessments undertaken for four priority sectors: agriculture, water resources, human health and coastal zones.

The UNDP Adaptation Policy Framework methodology provided the overarching approach for the V&A assessments, coupled with the most appropriate existing analytical tools. Stakeholder engagement and relevant consultations were priorities for the sectoral assessments, to the extent possible under the timeframe and funding circumstances. These included various workshops in various parts of the country throughout the process to invite technical inputs on the V&A assessments and the resulting policies and measures recommended.

Future climate scenarios were developed using those presented in the IPCC Special Report on Emission Scenarios (IPCC, 2000), which are driven by demographic changes, GDP growth, energy and technology change, as well as land use change.

Climate modeling results were produced by the Meteorological Agency combined with IFRI….. Climate Modeling across the A1B, A2, B1 and B2 scenarios of the IPCC and using GCM output from the HADCM2, UKTR, CSIRO-TR and ECHAM4 models.

Modelling Approach	Model Name	Scenarios			
		A1B	A2	B1	B2
AOGCM	HAD	✓	✓	✓	
	MRI	✓	✓	✓	
	ECH	✓	✓	✓	
RCM	PRECIS		✓		✓
Statistical Downscaling	Mo'Bay + Worthy Park		✓		✓

5.1.2 Construction of Climate Change Scenarios in Sierra Leone

For the construction of the baseline scenario country data for the years 1960-2015 (55years) for the various parameters of Rainfall, Temperature and Solar Radiation/Sunshine data etc. and information on the country's present climate were used. These input data were used to run the various climate models to give the climate change scenarios. The current climate change scenarios for Sierra Leone were accomplished through the use of MAGICC version 5.3 (Model for the Assessment of Greenhouse-gas Induced Climate Change). The models used by MAGICC have been developed in the Climatic Research Unit and the climate model is a standard upwelling-diffusion, energy- balance model of the form originally developed by Hoffert et al. (1980) and described by Wigley and Raper (1987, 1992, 1993) and by Raper et al. (1996). The GCM output from the HADCM2, UKTR, CSIRO-TR and ECHAM4 models were also used to construct the climate change scenarios.

5.1.3 Model Description

UKTR

UKTR is a transient experiment in which the year-by-year greenhouse gas forcing is a 1% per annum compounded increase over a 75-year period. The experiment was performed in the Hadley Centre in the UK during the winter of 1991/92 using the UK Met. Office's 11-layer high resolution atmospheric GCM, coupled to a 17-layer ocean model and it is reported in Gates et al. (1992) and Murphy and Mitchell (1995). The horizontal resolution of the atmospheric and ocean models is 2.5 deg. latitude by 3.75 deg. longitude. The climate sensitivity of the same atmospheric model, coupled to a mixed-layer ocean, was estimated to be 2.7deg C. Mean monthly precipitation pattern correlation coefficient is 0.76

HADCM2

This experiment was performed at the Hadley Centre during 1995 and 1996 using the Second Version of the UK Met. Office's Unified Model (HadCM2), consisting of an 19-layer high resolution atmospheric GCM, coupled to a 20-layer ocean model. The horizontal resolution of the atmospheric and ocean models was 2.5 degrees Latitude by 3.75 degrees Longitude. The greenhouse gas only integrations (which are used in SCENGEN) used the combined forcing of all the greenhouse gases as an equivalent CO2 concentration. The scenario forcing consisted of a 1% per annum increase in equivalent CO2 concentration through to 2100. The first ensemble member of the experiment is reported in Kattenburg et al. (1996) and Mitchell and Johns (1997), while the full ensemble of four simulations is reported in Mitchell et al. (1999). The ensemble-mean response is used in SCENGEN Version 2.4 (earlier versions of SCENGEN used the first member only). The global warming by 2071-2100, with respect to 1961-2010, averaged 3.2deg C and the increase in global precipitation was 5.01%, yielding a global precipitation sensitivity of 1.6% per degree Celsius warming. The climate sensitivity of the same atmospheric model, coupled to a mixed-layer ocean, was estimated to be 2.5deg C. Mean monthly precipitation pattern correlation coefficient is 0.73

ECHAM4

ECHAM4 is the current generation in the line of ECHAM models (Roeckner, et al., 1992). The ECHAM climate model was developed from the ECMWF atmospheric model and a comprehensive parameterization package developed at Hamburg which allows the model to be used for climate simulations. The model is a spectral transform model with 19 atmospheric layers and the results used here derive from experiments performed with spatial resolution that approximates to about 2.8° longitude/latitude resolution. A summary of developments regarding model physics in ECHAM4 and a description of the simulated climate obtained with the uncoupled ECHAM4 model is given in Roeckner et al. (1996). The experiments from which results are used here consist of a climate change simulation in which historical greenhouse gas forcing from 1860 to 1990 is followed by a 1% per annum increase in radiative forcing (CO2 equivalent concentration) from 1990 to 2099. The greenhouse gas only change fields used in SCENGEN are calculated as the difference in climate between the 50-year means of years 2051-2100 and 1961-2010 in the greenhouse gas only forced simulation. The global warming by 2051-2100, with respect to 1961-2010, was 3.0deg C and the increase in global precipitation was 1.97%, yielding a global precipitation sensitivity of 0.7% per degree Celsius warming. The climate sensitivity of the same atmospheric model, coupled to a mixed-layer ocean, was estimated to be 2.6deg C. Mean monthly precipitation pattern correlation coefficient = 0.75

CSIRO-TR

The CSIRO Atmospheric Research Mark 2b climate model (Hirst et al., 1996, 1999) has recently been used for a number of climate change simulations. This version of the CSIRO model has 9 levels in the vertical and horizontal resolution of approximately 5.6 degrees longitude by 3.2 degrees latitude. In the basic greenhouse gas experiment (the one used in SCENGEN) the model combines the effect of all radiatively active trace gases into an "equivalent CO_2" concentration. Observed concentrations are used from 1880 to 1990 and the IS92a projections into the future. This gives close to a 1%/year compounding increase of equivalent CO2. The greenhouse gas only change fields used in SCENGEN are calculated as the difference in climate between the 30-year means of years 2020-2050 and 1961-2015 in the greenhouse gas only forced simulation. The global warming by 2020-2050, with respect to 1961-2015, was 3.3deg C and the increase in global precipitation was 6.95%, yielding a global precipitation sensitivity of 2.1% per degree Celsius warming. The climate sensitivity of the same atmospheric model, coupled to a mixed-layer ocean, was estimated to be 4.3deg C. Mean monthly precipitate on pattern correlation coefficient = 0.74

The models as used in MAGICC/SCENGEM run on the Climatic Research Unit (CRU) Global Climate Dataset which contains gridded monthly surface climate variables for the period 1901-2000. The dataset can be used to examine climate variability over the twentieth century, to evaluate the simulations of various GCMs over the period 1961-2015 and to combine observed 1961-2015 global land fields with a user-defined GCM change field to generate a future climate field for any time slice and variable.

5.1.4 The reference year

The reference year 2015 has been used for climate model output and so it is assumed to be the baseline year against which future changes in the various climate and socio-economic variables are calculated. This year is assumed to represent the period 1961-2015, exceeding the thirty-year period used to define the baseline climatology used in SCENGEN. The year 2125 is the assumed end-year of simulations.

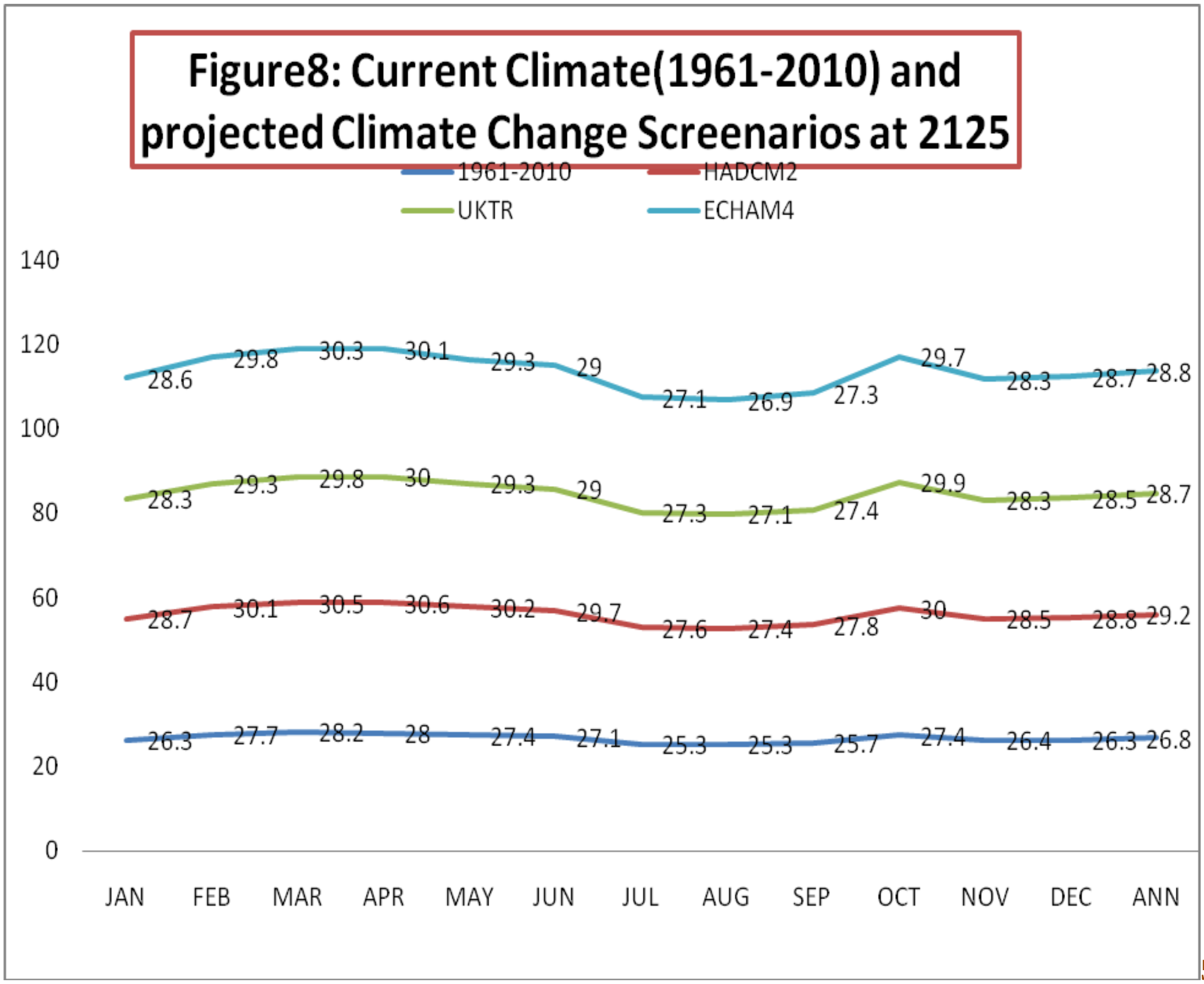
5.1.5 Model outputs

Temperature Scenarios

The average annual temperature of Sierra Leone for the period 1961 to 2015 and based on observed data from meteorological stations is about 26.9^{O}C. Combining this average annual temperature with the 2*CO2 output from the GCMs, the average annual temperature for Sierra Leone for the period 1961-2015 is projected to increase by about 7 to 9.5 per cent above this average temperature at 2125. Figures 5a (8), Figure 8b and Table 2 below show the variation of this projected increase in the annual average temperatures at 2125.

The current Climate Scenarios projected for 2050 are given in the Chart below for HADCM, UKTR and ECHAM4 model runs.

Figure 5.2 Current Climate (1961-2019)



55

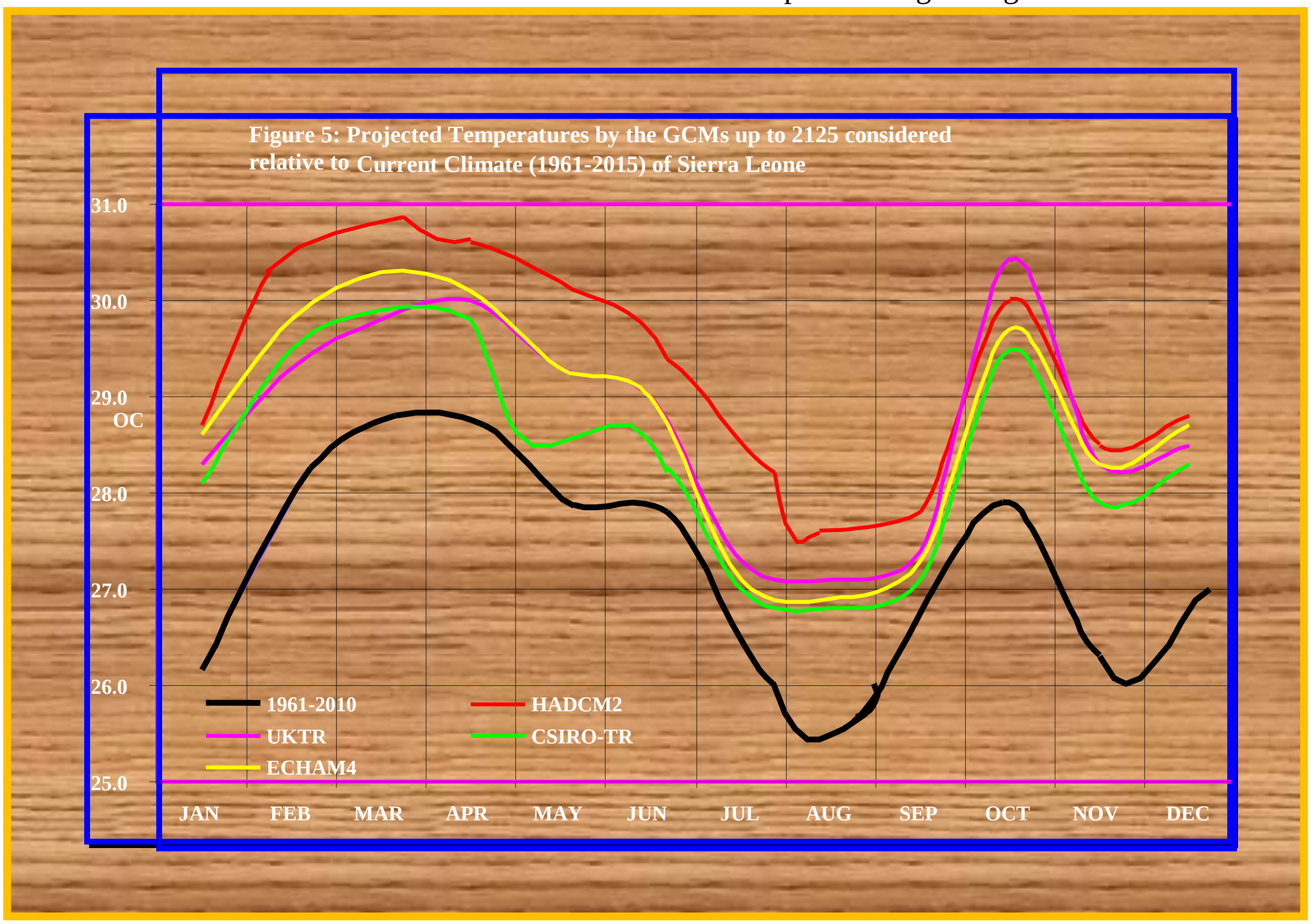
Figure 5a: Current Climate (1961-2015) and three projected Climate Scenarios at 2125

Similar work with the CCSIRO-TR model only gave the projection for 2120 using the same country data of 1961-2015 as tabulated below.

Table 5: Current climate (1961-2015) and projected climate change temperature scenarios at 2125													
Years/Monthly	**JA**	**FE**	**MA**	**AP**	**MA**	**JU**	**JU**	**AU**	**SEP**	**OC**	**NO**	**DE**	**AN**

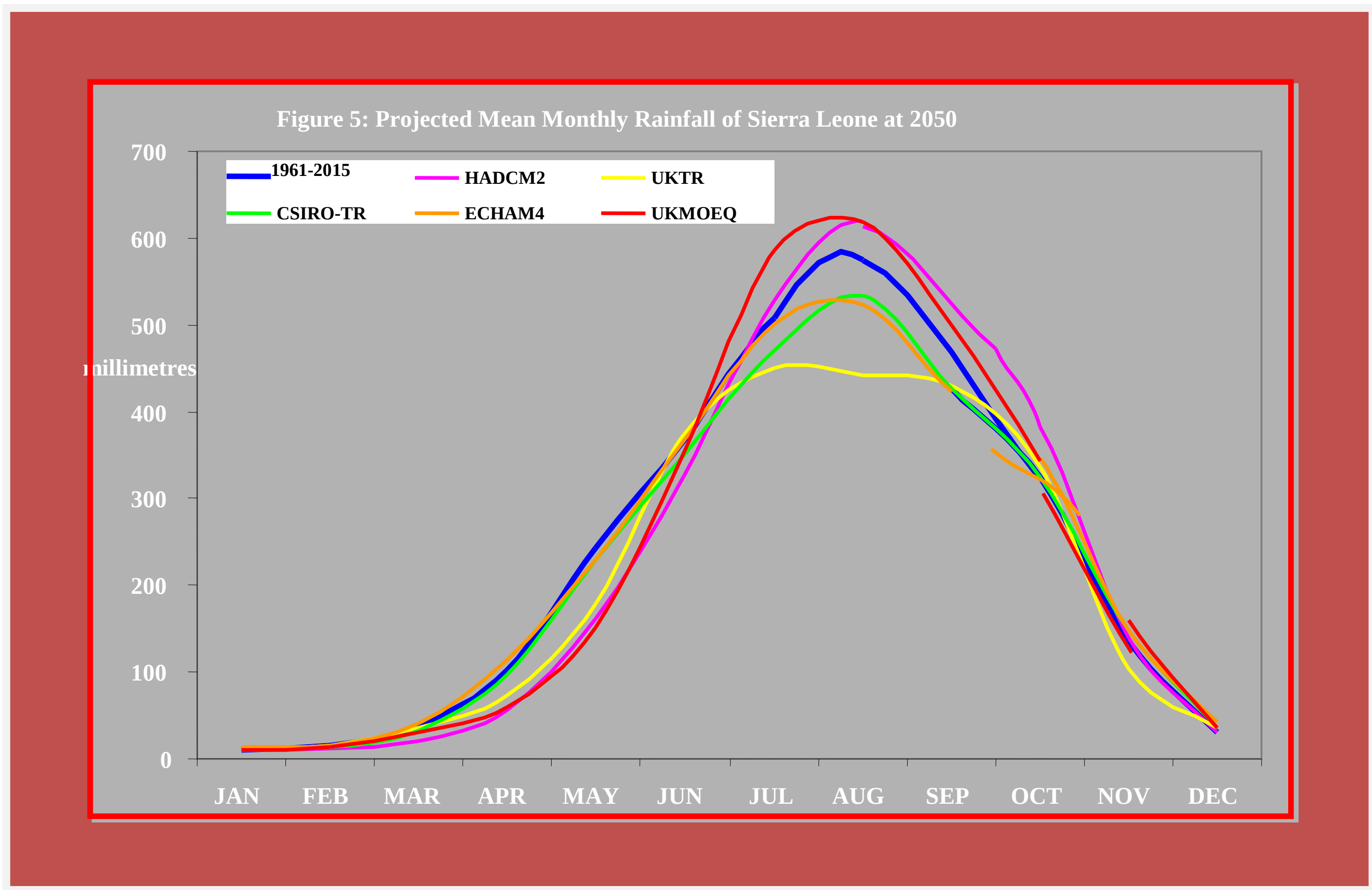
1961-2015	N	B	R	R	Y	N	L	G		T	V	C	N
CSIRO-TR Scenario For Average Temperature	28.1	29.5	29.9	29.8	28.9	28.8	27.0	26.8	27.1	29.5	27.9	28.3	28.5

However the GCMs were considered where the later was extrapolated to give Figure 5.3

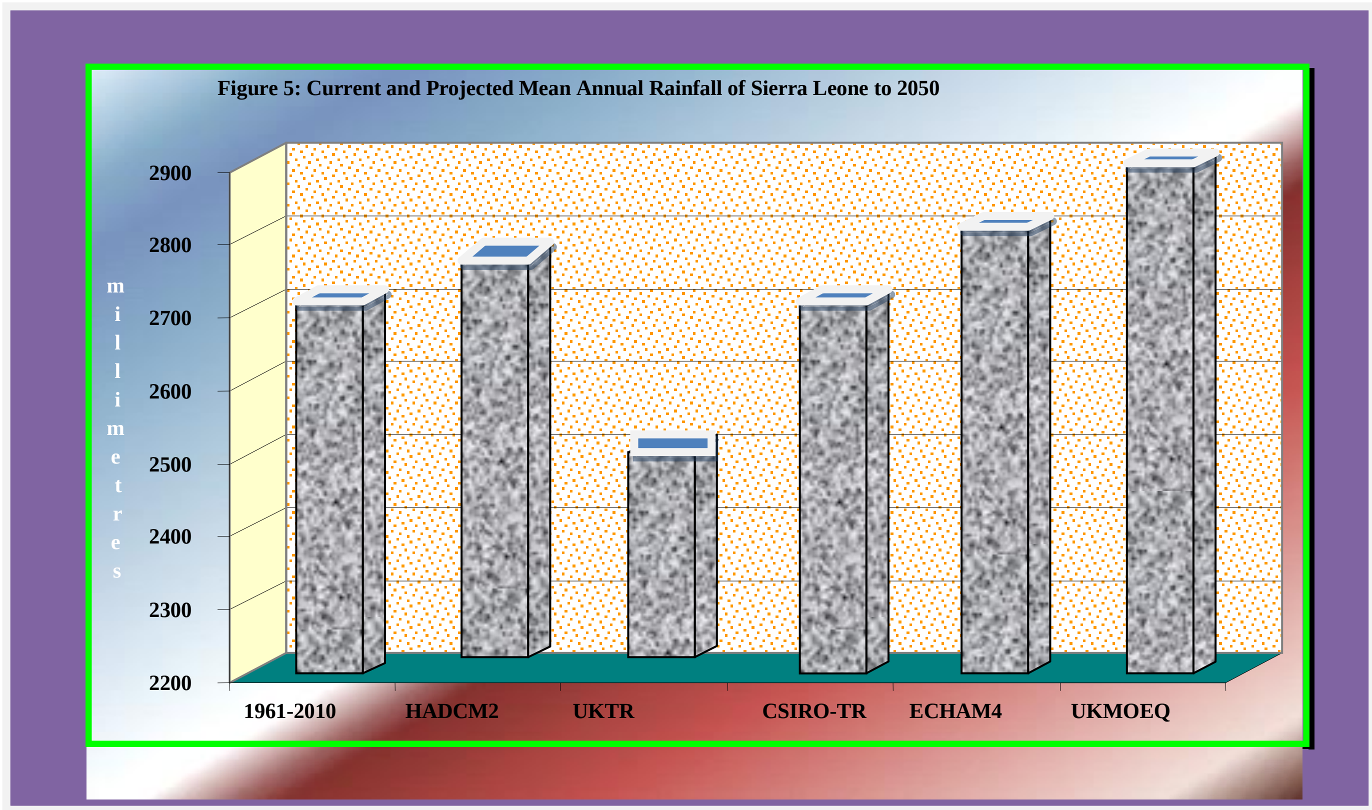


Precipitation Scenarios

Figures 5,5 and 5.6 show current (1961 -2015) and projected rainfall to 2050. Both figures show that monthly (Figure 6) and annual (Figure 7) rainfall values at 2050 under the ECHAM4 and HADCM2 models are similar to current climate rainfall values.

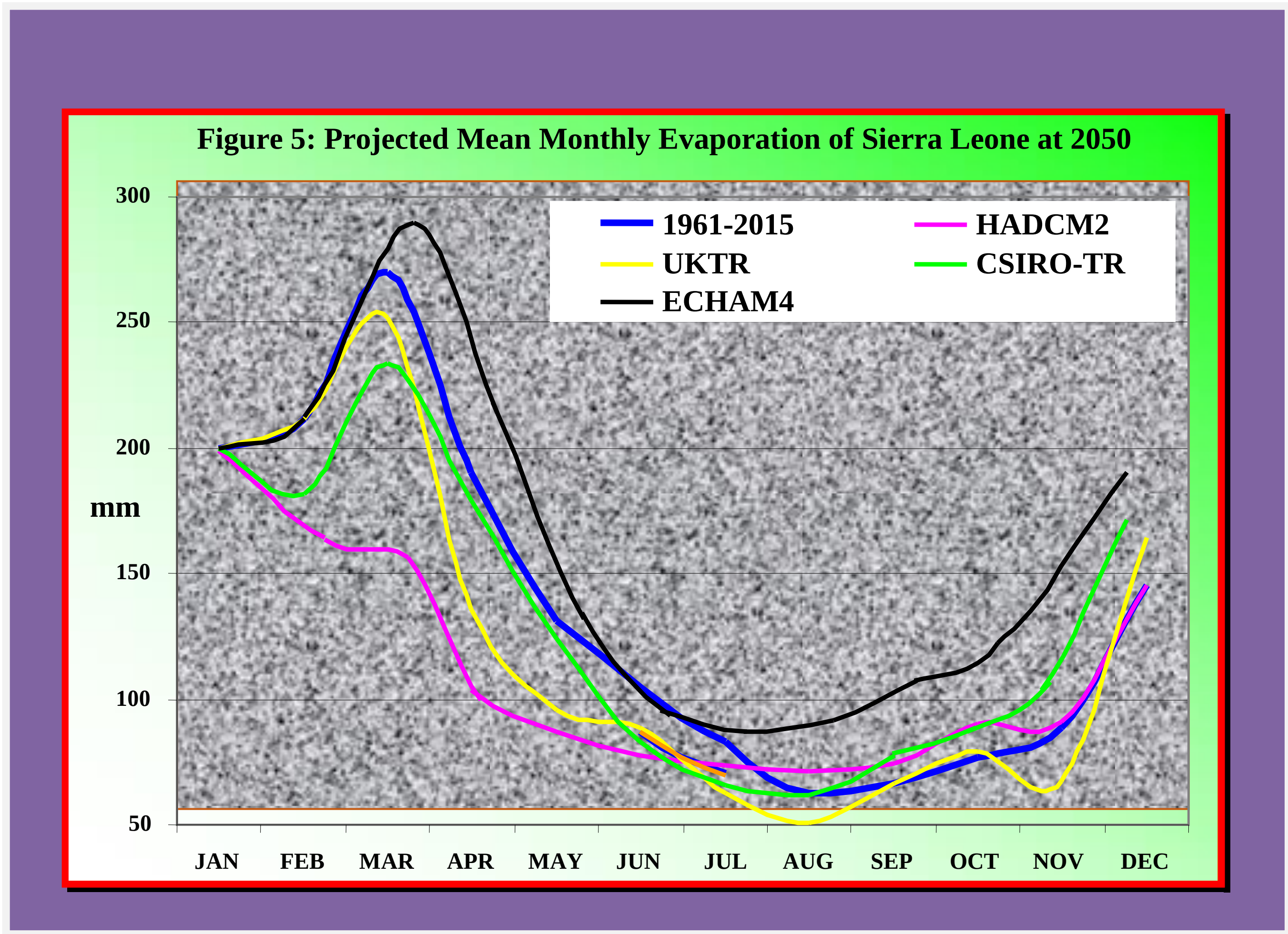


. However, the CSIRO-TR and UKTR models show a decrease in rainfall by about 3.5% and 9% respectively below current monthly and annual rainfall values.



Evaporation

Mean monthly evaporation for current climate (1961-2015) and projected values at 2050 by GCMs are illustrated in Figure 5.1 During the period from January to May monthly evaporation values under current climate are higher than all projects to 2125 by the GCMs except for the ECHAM4 model whose projection is higher than current climate values and projects by all other GCMs used in this study.



The monthly variations in evaporation shown in Figure 11 above are markedly reflected in the mean annual evaporation values illustrated in Figure 12 below. Variations about the mean annual evaporation of 1690 mm under current climate (1961-2015) show an increase of about 6.5% under the ECHAM4 model but a decrease of about 20% under the HADCM2, 8.5% under the UKTR and 5% under the CSIRO-TR models.

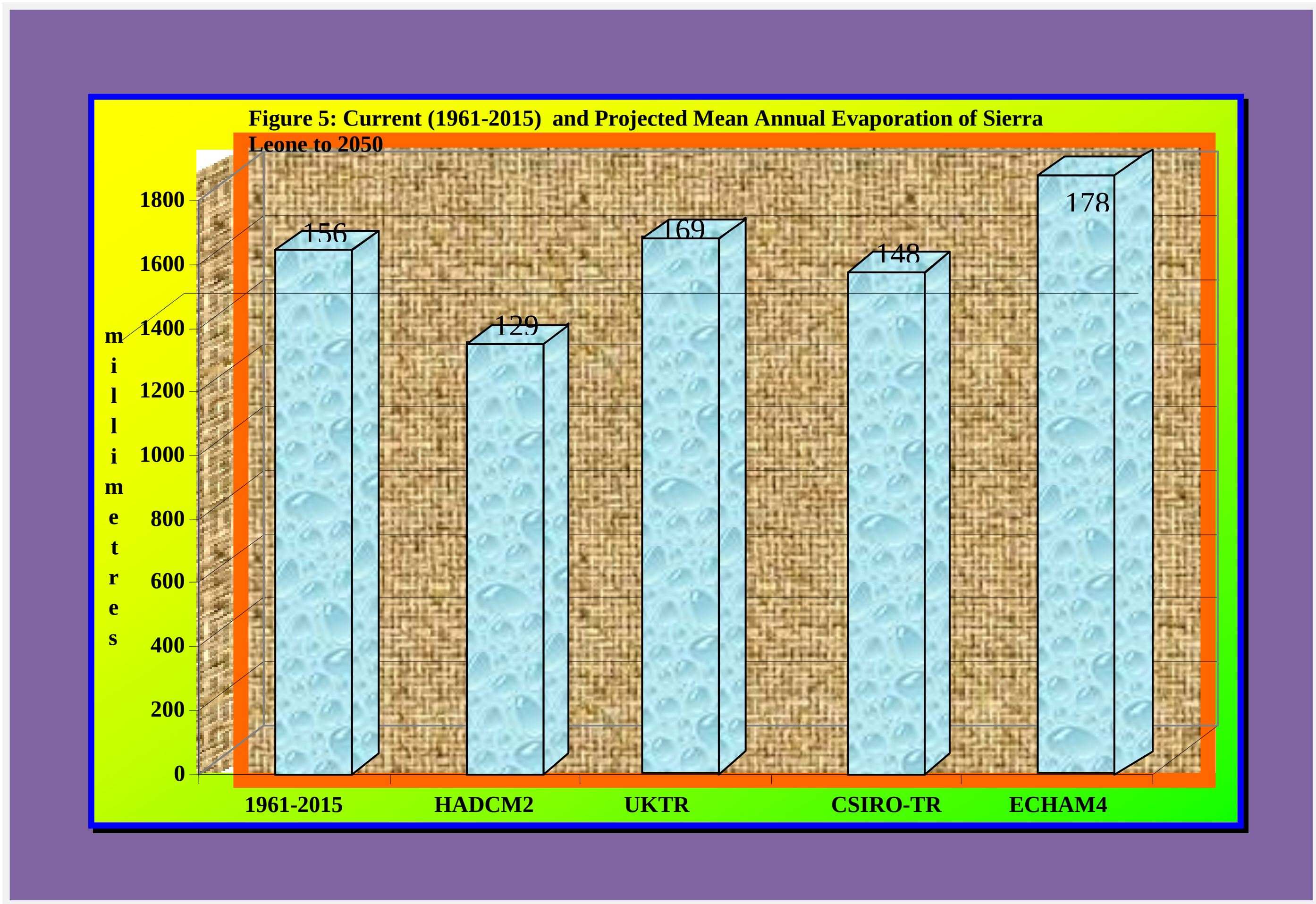


Figure 5: Current (1961-2015) and Projected Mean Annual Evaporation of Sierra Leone to 2050

Solar Radiation

From Table 3 the estimated average annual solar radiation received at the surface is about 6021 MJ/m^2/year for the period 1961 to 2015. Based on projects using GCM outputs this is expected to decrease by 12% under the HADCM2, 9% under the UKTR, and 3% under the CSIRO-TR models but increase by 5% under the ECHAM4 model.

Table 5: Current (1961-2015) and Projected (to 2050) Solar Radiation (MJ/m^2/month) for Sierra Leone

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
1961-2010	530	412	601	567	552	486	446	422	465	530	498	512
HADCM2	530	292	319	306	364	433	464	481	521	626	513	512
UKTR	530	412	559	403	403	496	397	341	470	546	378	578
CSIRO-TR	530	354	523	533	519	462	415	413	465	530	543	578
ECHAM	530	412	641	632	521	486	440	406	462	565	542	703

CO_2 levels and Sea Level Rise Scenarios:

The country is yet to develop a fully functional Marine Meteorological Station which is very vital for the assessment of sea level. For the accompanying analysis the regional projection is used with the model outlook. Based on the best reference MAGICC/SCENGEN projects CO2 concentration of about 350 parts per million (ppm) for the 1990s. Double CO2 concentration levels of about 580 ppm are likely to be achieved by 2075 and about 700 ppm by 2100 and to about 950 ppm by 2025. Sea level rise (SLR) scenarios adopted in this study are 0.2 m as baseline, and 0.5 m, 1.0 m, and 2.0 m by 2100 and by 3.5 m (IPCC, 1990).

Table : Atmospheric CO_2 concentrations and sea level rise scenarios

Year	CO_2 Concentrations (ppm)	Sea level rise	
1990	350		
2000	370		
2025	425	**Baseline**	0.2 m by 2100
2050	510	**ASLR1**	0.5 m by 2100
2075	580	**ASLR2**	1.0 m by 2100
2100	700	**ASLR3**	2.0 m by 2100
2125	950	**ASLR4**	3.5m by 2025

ASLR is Accelerated Sea Level Rise

Uncertainties

The climate outcomes outlined above are by no means certain. They should be viewed on a scale of probabilities and on the projected emission scenarios. The vulnerabilities described will largely depend on social conditions and the ability of the government and International donors to finance adaptation measures.

The probability of sea level rising over the next century is greater than 66 percent, but the magnitude of the rise is uncertain because of the large deviation among sea level rise models, and the absence of regional models. The possibility of increased storms is unclear.

5.1.6 Future climate projections

The mean annual temperature is projected to increase by 1.0–2.6°C by the 2060s and 1.5–4.6°C by the 2090s. The projected rate of warming is most rapid in the northern inland regions of western Africa than the coastal regions.

According to the NAPA, the projected rainfall from 1961–1990 to 2100 under the General Circulation Models (GCM) outputs show an increase in rainfall by about 3% and 10% below current monthly and annual rainfall values respectively.

The NAPA's results indicate that because the maximum temperatures have increased (by about 0.67°C and 0.18°C respectively) with a corresponding interesting trend in the decrease in precipitation levels by 50.28mm, it is projected that Sierra Leone will continue to experience an increase in temperature as well as drought/dry spells.

The climate models (HADCM2, UKTR, CSIRO, ECHAM and UKMOEQ) indicate a steady increase in temperature for Sierra Leone with little inter-model variance. With regards to rainfall an increase or decrease under climate change scenario is a critical factor in estimating how climate change will affect Sierra Leone, given the country's extreme vulnerability to water related problems.

Various General Circulation Models (GCMs) have been used in developing climate change scenarios for Sierra Leone. The models predict an increase in temperature of of about 5 °C by 2100. The increase in temperature will increase the amount and intensity of precipitation. An increase in rainfall could lead to an increase in surface runoff, resulting in flooding and landslides. On the other hand a decrease in the amount and intensity of rainfall may lead to drought.

Climatic risks pose a serious challenge to Sierra Leone's Natural and economic sectors, sectors which already faces several challenges.

5.1.7 RECENT CLIMATE TRENDS: Recent assessment of the long-term (1960 – 2003) temperature and rainfall conditions by McSweeney et al. (2010) indicates that:

- Mean annual temperature has increased by 0.8°C since 1960, an average rate of 0.18°C per decade.
- While there are insufficient daily data available to determine trends in daily temperature extremes for all seasons, there is convincing evidence of significantly increasing trends in the frequency of 'hot'nights[17], which, based on decadal trend, increased by 10.3% between 1960 and 2003.
- Mean annual rainfall over Sierra Leone remains largely variable from year to year, but has decreased since 1960.
- There are generally periods of wetter conditions punctuated by drier periods; the 60s and late 70s were particularly wet, whilst the early 70s and 80s were very dry. Rainfalls in 2005 and 2006 have been very low.
- Significant changes in extremes indices of daily rainfall remain difficult to determine.

[17] 'Hot' day or 'hot' night is defined by the temperature exceeded on 10% of days or nights in current climate of that region and season.

5.1.8 FUTURE CLIMATE SCENARIOS: McSweeney et al. (2010) have also indicated the following projected climate scenarios for Sierra Leone for the 2020s and 2090s, based on different climate change models.

Temperature:

- The mean annual temperature is projected to increase by 1.0 to 2.6°C by the 2060s, and 1.5 to 4.6°C by the 2090s. The range of projections by the 2090s under any one emissions scenario is 1.0 - 2.0°C.
- The projected rate of warming is most rapid in the northern inland regions than the coastal regions.
- All projections indicate substantial increases in the frequency of days and nights that are considered 'hot' in current climate.
  - ✓ Annually, projections indicate that 'hot' days will occur on 26 -63% of days by the 2060s, and 37 -84% of days by the 2090s. Days considered 'hot' by current climate standards for their season may increase most rapidly in July to September (JAS), but the range between model projections is large, occurring on 50 -99% of days of the season by the 2090s.
  - ✓ Nights that are considered 'hot' for the annual climate of 1970 -99 are projected to occur on 41 -79% of nights by the 2060s and 54 -92% of nights by the 2090s. Nights that are considered hot for each season by 1970 -99 standards are projected to increase most rapidly in JAS, occurring on 72 -100% of nights in every season by the 2090s.
  - ✓ Projected increases in hot days and nights are more rapid in the coastal regions than inland.

All projections indicate decreases in the frequency of days and nights that are considered 'cold'[18] in current climate. Cold days and nights occur on less than 2% of days by the 2090s and do not occur at all by the 2090s in any projections under the highest emissions scenario (A2).

Rainfall:

- Significant evidence of overall increases in rainfall in many parts of Sierra Leone, particularly in JAS and October to December (OND). Rainfall in June to

[18]'Cold' days or 'cold' nights are defined as the temperature below which 10% of days or nights are recorded in current climate of that region or season.

September (JJAS) is projected to change by -27 to +29% by the 2090s, and -19 to +33% in OND.

- The proportion of total annual rainfall that falls in heavy events tend towards increases in the ensemble projections, with significant seasonality that varies between tendencies to decrease in January to March (JFM) to increases in JAS and OND.
- 1 - and 5 -day rainfall maxima are projected to increase, particularly in JAS.

Period	Temperature	Rainfall	Extreme Events
Historical (1960 – 2006)	Temperature increased by 0.8°C between 1960 and 2006, an average rate of 0.18°C per decade. Increasing trends in the frequency of 'hot'nights.	Highly variable from year to year, season to season, decade to decade with periods of years alternating with period of dry years. Slight evidence of decrease.	Difficult to determine
2060s	▪ +1.0 - 2.6^{0}C.[19] ▪ 26 – 63% increase in hot days ▪ 41 – 79% increase in hot nights	Wide range of changes with an overall tendency towards increase (June to September)	Heavy events tend towards increases, particularly in July to December. 1- and 5-day rainfall maxima are projected to increase, particularly in JAS
2090s	▪ +1.5 – 4.6^{0}C. ▪ 37 – 84% increase in hot days ▪ 54 – 92% increase in hot nights ▪ 2% decrease in cold nights	▪ -27 - +29% in June to September ▪ -19 - +33% in October to December	Heavy events tend towards further increases, particularly in July to December. 1- and 5-day rainfall maxima are projected to increase, particularly in JAS

5.1.8 TRENDS IN EXTREME WEATHER SCENARIOS

It is reasonable to say that climate change will magnify natural disasters' severity in terms of intensity and frequency in Sierra Leone.

- In general, rainfall heavy events in the months of July to December are projected to increase later in the century and the 1 - and 5 -day rainfall maxima are also projected to increase, particularly at the peak of rainy season in July to September (JAS). This increase, coupled with alternating periods of

[19] Range for different scenarios.

wet and dry years are likely to increase the occurrence of extreme weather events.

- Extreme weather events-induced floods accounted for 90% of people affected by disaster in Sierra Leone. From 1980 to 2010, floods affected 221,204 people and killed 145 people, representing about 11% of people killed by disaster. Vulnerable areas include Western area, Eastern, Southern and Northern regions but the more specifically, the most affected areas during these last years include: Kroo Bay, Susan's Bay, Granville Brook, Lumley area in western Area, Port Loko and Kambia Districts, the Newton catchment area, Pujehun and Bo areas, Kenema and Moyamba Districts, and coastal beaches of the Western Area Peninsular (UNDP, 2012). More recently in August 2017 flooding and mudslide in Freetown killed more than 500 people.
- Loss of life, crops, livestock, damage to infrastructure and settlement areas, disease outbreak are the most common floods consequences in the country.
- Climate variability and climate change-induced extreme weather events will continue to affect the incidence of existing socio-natural hazards in Sierra Leone.

5.2 The Agriculture Sector

5.2.1 Main Characteristics of the Agriculture Sector in Sierra Leone

The Agriculture, Forestry and Food Security sector is the main source of food and essential nutrients and an important livelihood source for many poor people. It plays a crucial role in ensuring food security, poverty reduction and improving the nutrition situation of vulnerable populations. About 70% of the population in Sierra Leone is in rural areas, and engage in small holder agricultural production. About 1% of Sierra Leone's land is under cultivation, and roughly 5% of cropland is irrigated. About 155,000 hectares are believed to be subject to some form of water management, with fewer than 30,000 hectares believed to be irrigated. Irrigable potential, however, is estimated to be more than 800,000 hectares.

Agriculture contributes 40 to 50% of Sierra Leone's GDP, about 10% of exports, and provides employment to approximately two-thirds of the population. The predominant type of farming is the bush fallow system, a labour-intensive method of production that generally limits cultivated holdings to between 0.5 and 2 hectares. Up to 10 different crops are grown in mixed stands in one season; rain fed rice dominates, followed by cassava, sweet potatoes, and legumes. Low yields and productivity are the result of the use of inadequate and rudimentary farm inputs. The land is degraded due to the practice of shifting cultivation, recurrent bushfires, overgrazing, and shortening of fallow periods. In recent years, efforts have been made to introduce mechanised farming practices, through provision of tractors, power tillers and other agricultural tools to farming communities. Over 400 Agricultural Business Centres (ABCs) have been established under the Smallholder Commercialisation Programme and provided with appropriate support to enhance agricultural productivity and promote value addition.

Domestic production of food crops, especially rice, the staple food, has increased in recent years, but the proportion of rice imports as a percentage of total rice consumption remains high. The production of cassava and other food products, including sweet potato, poultry, small ruminants and cattle, also increased. The production of traditional export crops such as cocoa and coffee also increased (by 217% and 60% respectively). Cocoa and coffee exports increased between 2007 and 2011 by 105% and 220% respectively. Despite this growth, agricultural exports remain low and undiversified. Access to market and to credit are severe constraints. The sector strategic objectives and priority activities include (a) to increase the production of staple food crops for food security; (b) to promote and increase value-adding activities for agricultural goods; (c) to increase the production and export of cash-crops; (d) improve access to Finance for Farmers and (e) to strengthen the capacity of the Ministry of Agriculture, Forestry and Food Security (MAFFS).

The just concluded national census in Sierra Leone reported a national population of about 7,092,113 (Population and Housing Census -SSL.2015) and characterized by 1,262,486 households engaged in agriculture representing 89%. Similarly, the Comprehensive Food Security and Vulnerability Analysis (CFSVA 2015-MAFFS/WFP/FAO) reported that 49 % (3,475,135.37) of people in Sierra Leone are food insecure, of which majority are poor smallholder farmers that are living in the rural areas of the country. Despite this high percentage of people involved in agriculture livelihood and coupled with favorable agro-ecological endowment, production and productivity of crops and livestock, production is still below the national requirement. This is as a result of several factors notably land tenure system, small holding subsistence farming system, the use of low yielding and climate resistant varieties and planting materials, awareness of climate change issues and support by government for operationalizing the Food and Nutrition Security Early Warning System with the aim of mitigating hazards and shocks like climate change and crop failure.

Thus Sierra Leone's agriculture is characterized by either large scale plantation production or much smaller scale mixed cropping. The large -scale production

includes export crops such as cocoa, coffee, piassava, and ginger for the export market.
In contrast, the small -scale farming, which accounts for the greater proportion of farm labour, produces a wide range of crops mainly for the domestic market. The crops include yam, potato, banana, plantain, cassava, beans, pumpkin, and a wide range of tropical fruit and vegetables.

Land issues (legal, distribution, tenure, etc)

According to USAID's Sierra Leone Property Rights and Resources Governance Profile, the Ministry of Lands, Country Planning and Environment is responsible for: managing state lands; compulsory acquisition of land; surveying and mapping; planning; development; and establishment and enforcement of building codes.
Land in Sierra Leone is classified as state land, private land, or communal land. In the Western Area, some land is held in private ownership, with freehold rights of exclusivity, use, and transfer. The informal settlements have been constructed on urban and peri-urban land in and around Freetown and are subject to both statutory and customary tenure systems.

Most of the country's land is chieftaincy land that is under customary tenure with chiefs serving as custodians of the land. The land is considered held by ancestors, living community members, and unborn family members; the current generation is responsible for managing and preserving the land in the interests of the ancestors and future generations. Paramount chiefs in Sierra Leone's 149 chiefdoms are considered the traditional custodians of the land in their chiefdoms. The paramount chiefs are assisted by sub-chiefs at the lower administrative levels. In post-war years, the government's efforts to decentralize various functions to local and district council have (to varying degrees) recognized the need to work with the chieftaincy in land matters.

In most of Sierra Leone, land access is controlled by paramount chiefs. These traditional authorities allocate land-use rights to extended families for their further division among family members. In principle, the paramount chiefs hold the land in trust for those extended families or lineages attached to a particular chiefdom. No significant land-related decision is final until the paramount chief approves. Chiefs can grant or obstruct any individual's access to land, especially if they are migrants from outside the chiefdom (known as "strangers") or have abandoned their land. The chief presides over land disputes and determines which claims are valid.

Much of the land has been individualized in the names of lineages, families, and individuals. Most chieftaincy land is held by extended families. Families have rights of access, use, and transfer by lease. In some areas people from outside the chiefdom, including migrants, tenants, ex-combatants, and foreigners (collectively known as “strangers”), make up 20–40% of the chiefdom populations. Landowning families lease land to “strangers” on an annual basis. The “strangers” pay a nominal amount of the crop-yield to the family and are restricted from planting trees and perennial crops as an acknowledgement that they have no long-term interest in the land.

Rights to sell chieftaincy land are generally limited to sales within the family or community and are not recorded; in most regions, customary law prohibits the sale of chieftaincy land to non-family or non-community members. Some chieftaincy land is retained as communal land for community use.

Also according to the National Land Policy 2015 and implementation plan (Ministry of Lands Country Planning and the Environment), Sierra Leone has a dual land tenure system. In the western area the general law-freehold and the leased hold prevailes, while in the provinces we have the legal recognition of the customary (family, indefinite seasonal leasehold with reversionary interest) While the ministry is waiting for the draft policy to go through the legal reforms, there are problems of access/acquisition of land by farmers that is impacting negatively on production and productivity. This is as a result of several factors notably inadequate assess to land by farmers, gender equity and discrimination, tenure insecurity within the dual land tenure, large scale acquisition by land grabbers and lack of integrated national geo-spatial and cadastral information system.

Privately owned land, family ‑owned land (belonging to a descent group that can normally be used by all members), rented land, leasehold, squatted land, caretaking, and rent ‑free also represent the tenurial arrangements in Sierra Leone. Privately owned land and leasehold are the two common options in the western area of the country. The small farming sector has a greater mix of tenurial arrangements. Some small farmers may have a different tenurial arrangement for each piece of land.

5.2.2 Size of Farms

The subsistence farming system in Sierra Leone is characterized by small farm holdings usually between 0.4 to 0.1 hectares on average. This coupled with low levels of production and productivity, smallholder farmers barely produce for consumption. Their level of production to a greater extent is not enough to feed their households throughout the year. size of farms is an important variable as it indicates expansion and development potential of production units. The concept of size as used here is defined on the basis of total land area. The Ministry of Agriculture, Forestry and Food Security defines small farms as those between 0.1 to 5 acres (0.1 to 1.0 Ha) under cultivation of major food crops such as rice , cassava, sweet potato, vegetables and maize. As noted above, land area under cultivation and the number of households engaged in the cultivation of crops vary by crop type. Official national statistics show the distribution of farm sizes by crops (Table 3).

Table 5: Farm Size Distribution and Number of households by crop type

NO	CROPS	AGRICULTURAL HOUSEHOLDS (NO)	AREA/HOUSEHOLDS (Ha)
1	Upland rice	470,807	1.395
2	IVS rice	193,100	0.961
3	Boliland rice	10,175	1.576
4	Riverine	28,190	0.993
5	Mangrove rice	7,164	1.344
6	Cassava	150,383	1.197
7	Sweet Potato	31,568	0.526
8	Groundnut	144,278	0.561
9	Vegetables	41,866	0.287
10	Maize	14,944	0.322

SOURCE: PEMSD 2016 Food Crop Yield Survey

Agricultural Technology

The use of farm equipment, irrigation, and agro -chemicals varies directly with the size of farm. Farms of less than 2.3 hectares (5 acres) access only 8 percent of farm machinery and over 70 percent of the manual equipment whereas, farms of over 227.3 hectares (500 acres) access 62 percent of mechanical energy powered heavy agricultural equipment and 2 percent of manually operated tools.
The small farm sector continues to be labour intensive. Many agricultural projects aimed at small farmers encourage farmers to change their agronomic practices either by changing their crops, intensifying their production, or increasing agro -chemical use. Assessments of sustainability of agricultural technologies are rarely worked out and this sometimes leads to unfavourable repercussions both on the environment and on the quality and quantity of produce.

Forests and Biodiversity Resources
An estimated 39% of Sierra Leone is forested, with most primary forest land located on mountains and hillsides and in isolated reserves. Twenty-two percent of the forests are in 48 forest reserves and conservation areas; 1% is on chiefdom land but managed by the Forest Division; and 23% are within a wetland and marine

ecosystem protected areas (ARD 2010). The 48 forest reserves are under the custody of government occupying approximately 285,000 hectares of total land cover. In addition, there are 300,000 hectares of mangrove forests and 30,000 hectares of constituted community forests. Sierra Leone is part of the Upper Guinea Rainforest, home of a diversity of plants and animals. Tropical rain forests are found in the Eastern Province and Western Area; moist, semi-deciduous forests are found in the central and southern parts of the country. The country also has swamp and mangrove forests and savanna woodlands.

Wood products from the forest have traditionally ranked as an income earner, while fuel wood, bush meat, medicinal plants and other non-timber products have continued to contribute significantly to the welfare of most Sierra Leoneans; charcoal production and trade is also a source of income, especially for rural people. Forests also provide important services such as serving as a carbon sink in climate mitigation; they are a source of water supply and recreational facilities. There is an intricate link between conservation and development; Sierra Leoneans have realized that to sustain the current development strides, there is a need to balance the two competing demands.

In 2003, Sierra Leone developed a national biodiversity strategic action plan which described the status of biodiversity, and action plans for its sustainable management. According to the FAO 2010 Forest Resource Assessment, 38% of Sierra Leone's land area, or over 2.5 million hectares, comprises wooded landscapes. Fifteen protected areas are proposed, eight in the terrestrial ecosystem and seven in the wetlands.

Primary threats to forest resources include the population's dependence on fuelwood for energy, slash-and-burn agricultural practices, urban expansion, industrial and artisanal mining, and illegal logging. These practices place tremendous pressure on forests located inside and outside reserves. Forests can be owned by the state or private parties, or fall within chieftaincy land. Forest land is generally subject to the tenure system governing the land classification, unless the forest has been declared a protected area. The Forestry Act of 1988 empowers the minister to declare any area to be a protected area for the purpose of conservation of soil, water, flora, and fauna. The current extent of state-owned forestland is unknown. The state owns most of the land designated as forest reserves and nationally protected areas, but some percentage of land is also privately held or within chieftaincy land.

The Forestry Division of the Ministry of Agriculture, Forestry and Food Security (MAFFS) is responsible for forest management and biodiversity conservation. The

Forestry and Wildlife division is responsible for natural forest management, management of forest plantations, and management of rangeland and national parks.
The major challenges of forest management include, amongst others (a) poor governance; (b) weak law enforcement (c) lack of coordination among sector ministries and (d) illegal harvesting. To alleviate these challenges identified objectives and strategy for effective forest management include (a) to review and formulate new forestry and wildlife policies; (b) to review and amend the Forestry Act of 1988 and the Wildlife Act of 1972, to accommodate emerging issues such as forest co-management, eco-tourism, biodiversity conservation and climate change; (c) to undertake a national assessment of the forests and woodland resource base; (d) to develop a benefit sharing mechanism that will increase benefits from forest revenue flowing to stakeholders; (e) to promote private sector involvement, including small-holder involvement, in production and value-added activities, including agro-forestry and the long term sustainable utilisation of wood energy resources (f) to mainstream the contribution of forestry and wildlife to sustainable agricultural practices and food security, in cooperation with other agencies; and (g) to mainstream climate change in the forestry and biodiversity policies, strategies, plans and programmes.

5.2.3 Institutional Arrangements for the Management of Agriculture in Sierra Leone

Ministry of Agriculture Structure and Areas of Intervention

The Government of Sierra Leone represented by the Ministry of Agriculture Forestry and Food Security is responsible for the management and development of Sierra Leonean agriculture. It implements these responsibilities through a number of offices, divisions and projects, including:

Forestry Division

Forestry Division with the purpose of sustaining the management and utilization of forest resources and protect the forest environment for biodiversity research, education, extension and conservation.
The specific objectives of the division are to:
1. Develop and maintain recreational sites at suitable locations in the forest reserves to provide forest recreation in the form of camping, hiking and general appreciation for the forest environment.
2. Ensure annual incremental increases in forest cover in the country.

3. Regulate the orderly development of the forest estate.
4. Improve the planning and management of the Forestry Division and other government institutions to manage the project cycle.
5. Strengthen the institutional capabilities in the forest sector, top plan and implement sustainable forest management, and increase awareness of forest throughout the country.

Crops Division

Crop division is charge with the purpose of providing the enabling environment for increased crop productivity, production and profitability through the introduction of improved inputs and practices for the production and processing of crop products.

Livestock Division

Livestock division is responsible for promoting animal health and production to increase the uptake of animal products to enhance nutritional status and incomes of the people.

Agricultural Engineering Division

Agricultural engineering division is responsible for creating the enabling environment for increase food production, processing, supply and profitability through the use of farm machines, processing and storage infrastructure, land and water resources management.

Planning, Evaluation, Monitoring and Statistics Division

Is responsible for agricultural planning, policy analysis, monitoring and evaluation, data generation processing and dissemination

Agricultural Extension Services Division

Is responsible for rehabilitating and Increasing coverage and effectiveness of the agricultural extension delivery services and produce a mass of infrastructure in order to increase the pace of agricultural development, reduce poverty and improve rural welfare.

Agricultural Development Projects

Agricultural Institutions (Sierra Leone Agricultural Research Institute (SARI) and National Protected Area Authority (NPAA))

Farmers' Organizations and Agriculture Private Sector Promotion Organization (NaFFSL. SLeWOFF and SLeCAD)

Office of the Permanent Secretary

This office administers the Ministry and provide support for successful implementation of operations in the Ministry and its institutions.

5.2.4 Arable Land Utilization by Ecology

Despite the relatively large population involvement in agriculture, only 24% (2014) and 30 %(2015) of it arable land is currently being cultivated (PEMSD Annual CROP Production Survey 2014/2015). This is because the target population in farming are resource poor people who are vulnerable to disaster due to both manmade and natural such as flooding, bush fire, drought, pest and disease. Sierra Leone is endowed with two main ecologies that are suitable for both food crops and tree crops. The two main ecologies are upland and lowlands. The lowlands are divided into four ecologies as follows:

1. Inland Valley Swamps (IVS)
2. Riverrine Grasslands
3. Mangrove Swamps
4. Bolis

UPLAND ECOLOGY

The upland ecology is the most dominant food and tree crops growing ecology in Sierra Leone. It is characterised by shifting cultivation farming methods with a high degree of slash and burning of bush. Majority of farmers are engaged in this type of farming which has a negative impact on climate. In addition, production of timber, poles, charcoal, firewood etc for domestic consumption generates a hot national debate on sustainable forest management issues by the forestry division of the ministry of agriculture forestry and food security because of its negative impact on forest loss. Crops grown on these lands depends solely on rainfall and residual moisture throughout the growing season.

LOWLAND ECOLOGY

In Sierra Leone second major ecology is the lowland. The lowland is characterised by low-lying area where water is present continuously throughout the growing season. In some cases water is present in these areas on a permanent basis. The lowlands in the county are comprised of four distinct ecologies as follows: (a) The Inland Valley swamps (a) Mangrove Swamps (c) Riverine Grasslands (d) Boli Lands. The lowlands are most suitable for the cultivation of rice because of high water table in the raining season. In the dry season, vegetables, cassava, okra and groundnuts are cultivated.

Table 5.1: 2014 SIERRA LEONE ARABLE LAND AREA (HA) UTILIZATION BY ECOLOGY BY DISTRICT

No	District	Upland	Boliland	IVS	Riverain Grassland	Mangrove Swamp	Total
1	Bo	115,824	4,688	14,149	2,462	0	**137,12**
2	Bombali	48,762	7,528	18,179	1,343	0	**75,81**
3	Bonthe	62,580	1,582	3,677	5,907	5,171	**78,91**
4	Kailahun	143,926	0	11,593	0	0	**155,51**
5	Kambia	46,709	6,950	19,402	4,471	8,230	**85,76**
6	Kenema	119,122	0	24,745	0	0	**143,86**
7	Koinadugu	31,127	0	29,153	0	0	**60,28**
8	Kono	96,287	0	13,301	0	0	**109,58**
9	Moyamba	76,922	2,250	8,580	1,438	1,895	**91,08**
10	Port Loko	75,563	4,232	21,396	1,688	4,958	**107,83**
11	Pujehun	41.107	1,423	4,689	2,216	1,078	**9,44**
12	Tonkolili	94,298	12543	23,888	1,170	0	**131,89**
13	W/Area	11,675	0	3,005	417	1,788	**16,88**
	National	**922,836**	**41,196**	**195,717**	**21,112**	**23,120**	**1,204,02**

SOURCE: **(PEMSD National Agricultural Sample Survey 2014)**

Table 5.2: 2015 SIERRA LEONE ARABLE LAND AREA (HA) UTILIZATION BY ECOLOGY BY DISTRICT

No	District	Upland	Boliland	IVS	Riverain Grassland	Mangrove Swamp	Total
1	Bo	140,668	5,711	18,976	3,097	0	**168,452**
2	Bombali	60,368	10,547	19,697	1,552	0	**92,164**
3	Bonthe	75,694	2,008	6,519	7,029	6,201	**97,451**
4	Kailahun	161,140	0	15,367	0	0	**176,507**
5	Kambia	55,379	8,181	21,667	5,405	10,016	**100,648**
6	Kenema	137,132	0	26,038	0	0	**163,170**
7	Koinadugu	36,112	0	31,668	0	0	**67,780**
8	Kono	104,521	0	16,215	0	0	**120,736**
9	Moyamba	91,819	4,760	11,352	1,800	2,428	**112,159**
10	Port Loko	107,798	5,140	24,154	2,059	5,579	**144,730**
11	Pujehun	69,164	1,903	6,374	2,844	1,409	**81,694**
12	Tonkolili	119,754	15,158	33,873	1,550	0	**170,337**
13	W/Area	15,612	0	2,609	399	2,255	**20,875**
	National	**1,175,161**	**53,410**	**234,510**	**25,734**	**27,888**	**1,516,703**

SOURCE: **(PEMSD ANNUAL CROP PRODUCTION SURVEY 2015)**

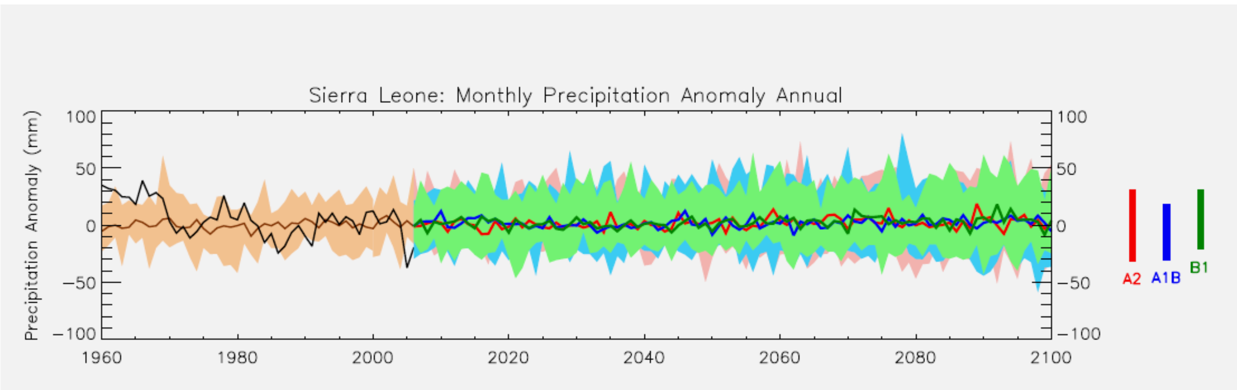
5.2.5 *The Importance of Climate to Agriculture in Sierra Leone*

Rainfall/Precipitation

Projections of mean annual rainfall averaged over the country from different models in the ensemble project show a wide range of changes in precipitation for Sierra Leone, but tend towards overall increases, particularly in JAS and OND. Rainfall in JAS is projected to change by -27 to +29% by the 2090s, and -19 to +33% in OND.

The proportion of total annual rainfall that falls in heavy events is projected to increase. Seasonally, this varies between tendencies to decrease in JFM and to increases in JAS and OND.

1- and 5-day rainfall maxima in projections all tend towards increases, particularly in JAS. The range of changes in projection from the model ensemble covers both increases and decreases in all seasons.



The mean rainfall and temperature in Sierra Leone are presently 1786mm and 28oC respectively (Spence, 2008). The climatic requirements of rainfall and temperature for the main export and domestic crops of Sierra Leone is summarised in Table 4.6. Current climatic conditions are optimum or near -optimum for the production of these crops – both in terms of growing and ripening conditions of the crops, as well as minimization of pests and diseases. It is the climatic variability and extremes experienced in Sierra Leone – in terms of frequent rainstorms and the occurrence of seasonal drought – that present the main climatic challenges to agriculture in Sierra Leone.

Table 5.6: Average Main Climatic Requirements of the Main Export and Domestic Crops of Sierra Leone

Crop	Water requirements (mm/yr)	Temperature (0C)

Rice		
Sugar Cane	1100 to 1500	30 -34o C
Banana		270C optimal
Coconut	1000 to 2250	270C optimal with diurnal variation of 60C to 70C
Citrus	1250 to 1850	28 to 320 C
Cocoa	1250 to 3000	18 -210 C min, 28 -320C max
Pineapple	700 to 1000	23 -240 C optimal
Yam	Approx. 1000	25 -300 C
Cassava	Approx. 1500	25 -290 C

Other factors have an impact on the performance of the agricultural sector such as government policies as well as world market prices for crops, but it is the occurrence of climatic events that demonstrate the vulnerability to current climate of Sierra Leonean agriculture.

The Ebola outbreak of 2013 had by far the greatest economic impact on the agricultural sector. The impacts of the EVD illustrate some of the specific vulnerabilities that crop -types face with respect to the occurrence exigencies and climate variabilities such as thunder storms.

5.2.6 Analysis of Future Climate Risks for Sierra Leonean Agriculture

There are various methods available to assess the impacts of climate, climate change, and climate variability on the agricultural sector. These are summarized in Table 5.7, along with the respective strengths and weaknesses.

Table 5.7: Climate Impact Agricultural Assessment Methods

Type of Model	Key Characteristics
Agro -climatic models and GIS	Based on simple calculations and effective for comparing across regions and crops, but only consider climate
Statistical models	Based on empirical relationships between crop

and yield functions	responses and climate, but do not explain causal mechanisms nor future climate crop relationships
Process -based models	Include climate, soils, and management. Widely used and calibrated and can be used for adaptation assessments. Require significant data input for best results
Economic models	Incorporate land values, commodity prices and economic outcomes, and therefore useful to assess market based and financial adaptation measures – but are complex and require significant data input
Household and village models	Look at current coping strategies under existing conditions, but do not capture future stresses if different from current.

Limited work to date has been undertaken in Sierra Leone on adopting these approaches to investigate the impacts of climate change on key cash and food crops in Sierra Leone. However, this has not progressed to a level that allows quantitative assessments to be carried out with respect to climate change on all food crops yields. Progress has started in the training of staff in the use of modeling approaches to investigate climate and climate change on crop yields.

Given the lack of in -country studies and tools to develop specific risk assessment results for Sierra Leonean crops and livestock, a literature review approach was undertaken to present the findings of studies of key crops and livestock in terms of impact assessment using an analogue approach. This literature review is not intended to be exhaustive, but it is considered that it provides useful results with respect to the likely range of impacts that might be expected for the Sierra Leonean situation, and also illustrates the role of socio -economic factors in the assessment of the overall impacts under future scenarios on crop yields and production. It also provides an indication of the range of modelling approaches that have been adopted by different countries in the preparation of their own V&A studies.

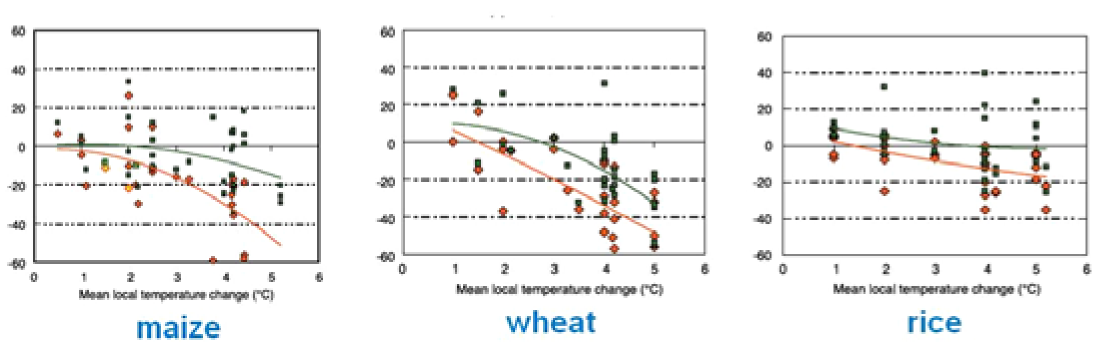
Territories of Agricultural Climate Change in Sierra Leone

TERRITORIES	REGION/AREA	MAJOR CROPS GROWN/LIVESTOCK
Forested Interior Plateau and Mountains	Eastern Region, South East and North East	Rice, Cassava, Cocoa, maize, Groundnut, Coffee, Oil palm, Rubber and Forestry
Coastal Areas	Western Area, Peninsular, South west, Southern Region, North West	Vegetables, Rice, Maize, Groundnut and Fisheries
Savanna Lowlands/Wood Lands, Interior Plateaus,	North East, Parts of Southern Region	Cassava, Rice , Millet, Vegetables, Sorghum and Livestock
Transitional Rain Forest	North East, Southern Region and South East	Rice, Millet, Cassava, Forestry and Livestock

SOURCE: CLIMATE SMART AGRICULTURE IN SIERRA LEONE, MAFFS 2016

IPCC (2007a) includes a chapter discussing the impact of climate change on the food (see Chapter 5:Food, Fibre & Forest Products). Summaries of the results are presented for a range of food crops.
However, it is interesting to note that there are few studies included within the report that focus on food and cash crops that are important to Sierra Leone and other West African countries. For example, Figure 5.5 presented here is extracted from IPCC (2007a) Chapter 5 and presents the results from the pooling of 69 studies looking at the impact of climate on cereal yields (maize, wheat and rice).

Figure 5.5: Percentage cereal yield change with mean local temperature change for maize, wheat, and rice for low latitudes.



(Notes: Studies without adaptation red dots, with adaptation green dots. Polynomial best-fit lines summarise results only and are not for predictive purposes)

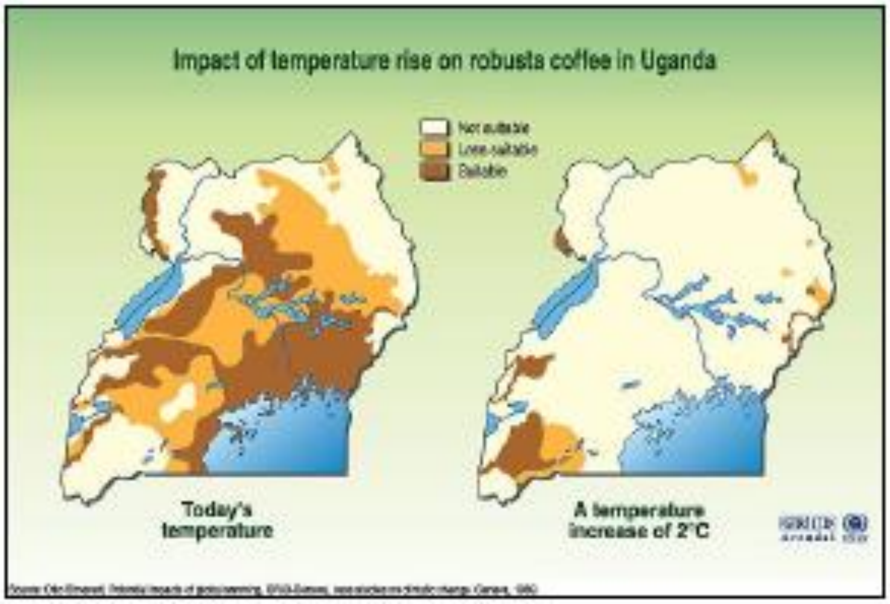
The results provide useful information on the likely range of impacts of climate change on these cereal yields and also the potential impact of adaptation measures to counter potential declines in yield. However, it is clear that Sierra Leone needs to undertake and promote the results from its own studies and assessments to build up a similar database of research to assist with in -country and region -wide V&A studies and resulting policy development.

In the absence of studies specific to Sierra Leone or to West Africa, examples were drawn from the literature on studies relevant to the agricultural sector in Sierra Leone. This includes sugar cane, coffee, yam and livestock, as examples of the range and scope of studies that are required for the country.

Climate modelling projections for 2050 indicate both increased temperatures (approx. +1.30C) and reduced rainfall (approx. -6%). The impacts of this are likely to be increased water/irrigation requirements under higher temperatures and reduced rainfall, and thus increased competition for water resources, as well as the increased incidence of pest and disease outbreaks.

Studies have also been undertaken in Africa using a relatively simple GIS based approach. For example, Figure 5.6 shows the changes in Uganda of the total area suitable for growing Robusta coffee from a temperature increase of 2°C. This analysis indicates that the areas suitable for growing would be significantly reduced. Only higher areas would remain, the rest would become too hot to grow coffee.

Figure 5.6: Impact of Temperature Rise on Robusta Coffee Production Areas in Uganda



In Tanzania the impact of climate change on coffee productivity is estimated to be mixed (United Republic of Tanzania, 2003). Two areas were selected which represent the major producers in the northeastern and southern parts of the country. Using a climate scenario of doubling of carbon dioxide, annual average temperature is estimated to increase between 20°C and 40°C in the two areas (assumed to be by 2100), while annual rainfall is estimated to increase by 37 percent in the north -eastern region but decrease by 10 percent in the southern region.
A temperature increase of 20°C in both areas is within the optimal range for coffee growth, the major determining factor on changes in yield is rainfall. An increase in rainfall implies an increase in the yield.

In the southern areas, the decrease in rainfall is minimal and is estimated to have a minimal impact on yield. Therefore, according to the study, given these estimated changes in temperature and rainfall, yield is estimated to increase by an average of 17 percent in each area. If the annual average temperature increase is closer to 40°C, this would result in the need for irrigation to supplement reduced rainfall. An alternative adaptive approach that is recommended is to develop drought and disease resistant coffee varieties with farmers sensitized to use them if coffee is to remain a major cash crop in these areas. The overall conclusion from the study was that coffee is likely to be grown successfully where rainfall is estimated to increase i.e., in the northern, north -eastern and south -eastern parts of Tanzania.

Yam and Cassava: The study that investigated sugar cane in Fiji also looked at the potential impacts of climate change on yam and cassava productivity on the island of Viti Levu using the PLANTGRO model in PACCLIM. Six climate change scenarios were considered, comparing yields under current climate with those estimated for 2050. This was based on occurrences of El Nino and La Nina for both current and future climate and the impact such occurrences have on crop yield. In the case of yam, the study estimated changes in yield of between -15.4 percent and +0.8 percent by 2050, while for cassava, the range was from -11.0 percent to +4.3 percent by 2050.

Livestock Production:

Climate change impacts on animal husbandry in Africa were investigated by the Centre for Environmental Economics and Policy in Africa (CEEPA, 2006b) using the same economic approach described earlier by Deressa, Hassan & Poonyth (2005). In this study, net revenue from raising animals on small and large farms across Africa was regressed on climate, soils, and other control variables to test the climate sensitivity of livestock in Africa. The study was based on a survey of over 9,000 farmers across 11 countries. From this dataset, 5,400 farms were found to rely on livestock. The farms were split into two groups: small farms that tended to be more labour intensive, relying on native stocks and with few animals; and large farms that tended to be more commercial operations, with much larger stocks and more modern approaches to production.

The analysis showed that livestock net revenues of large farms in Africa fell as temperatures rose but that small farms were not temperature sensitive. In addition, it was found that higher temperatures reduced both the size of the stock and the net revenue per value of stock for large farms. However, for small farms, higher temperatures did not affect the size of the stock and the net revenues per value of stock increased. This indicates that large farms in Africa are vulnerable to global warming but small farms are not. It is likely that large farms are vulnerable because they rely on species such as beef cattle that are not well suited to high temperatures. Small farms are not vulnerable because they can substitute species such as goats that can tolerate high temperatures.

The analysis also indicated that increased precipitation reduces livestock net revenue per farm for both small and large farms. The elasticity of net revenue per farm is particularly large for small farms. Further analysis indicated that increased precipitation reduces both the size of the stock and the net revenue per animal owned. Although higher precipitation generally increases the productivity of grasslands, it also leads to the conversion of grasslands into forest. Further, animal diseases are likely to increase with warm wet conditions. Finally, as precipitation increases, many farmers find it advantageous to shift from livestock to crops. The positive side of these precipitation findings is that if precipitation declines, livestock net revenues will increase, especially for small farmers. The study concluded that livestock provides an important agricultural adaptation against reductions in precipitation should they occur.

3.2.7 Proposed Elements of an Agriculture Adaptation Strategy for Sierra Leone

As demonstrated by this brief literature review, there are already a substantial number of V&A studies under climate change and climate variability that have been carried out in various countries looking at crops that are important to Sierra Leone's agriculture. It is therefore important that the Sierra Leonean agricultural sector develops the technical and managerial capacity, as well as funding, to support similar climate impact agricultural assessments to first understand how vulnerability is likely to vary under future climate change and climate variability, and then to take these studies forward to investigate possible adaptation strategies as part of a wider adaptation programme for the agricultural sector.

Recommendations for the Agriculture Sector

A number of key recommendations on the way forward to address issues of climate vulnerability and the development of adaptation projects, programmes and policy were developed as part of the V&A analysis. These recommendations were presented at a stakeholder workshop on the 5th of December 2017 in the southern city of Bo review, comments, and ranking. The ranking was based on a simplified multi -criteria analysis approach that included considerations of relative cost of recommendations, effectiveness of proposed solutions, technical / skills availability for implementing the recommendations, technology, and number of beneficiaries, political and social acceptability, environmental impact, and consistency with objectives of the National Development Plan. The scores provided by three breakout groups were averaged.

The climate change adaptation recommendations for the agriculture sector are presented in the table below including the workshop rankings. A ranking of 1 gives the most preferred option.

Reccomendation	Justification	Responsibility	Workshop ranking
Leverage and co -ordinate international funding to maximize benefits within the Agricultural sector	Significant investment is required in a number of areas within the sector. If multi -lateral grant -aid & bi -lateral soft loans are to be used to support this work, then the benefits accrued must be maximized, both in outputs and capacity building	Ministries of Agriculture and Land and International Trade, Finance and Planning,	High
Improve access to loan / grant funding to domestic crop producers	Historically this sub -sector has not received the same magnitude of financial support as has the export subsector, yet it is important for food security and rural incomes, and to provide funds to allow these producers to adapt to climate change This will lead to the empowerment of domestic producers.	Ministry of Agriculture & Lands .	High
Raise awareness of the potential impacts of climate change on the agricultural sector , food security and cultural practices	Climate change is not mentioned in the Agricultural Development Strategy 2005 -2008 documentation. This suggests that the potential impacts of climate change on the agricultural sector have not yet informed agricultural policy & practice	Ministry of Agriculture, Forestry & Food Security, with support from Met. Service and others s well as Tertiary Institutions and Farming Organizations	High
Review approaches to integrated cropping and management systems	Existing pest management strategies may require modification under climate change. Care must be taken that any changes to these strategies do not	Ministry of Agriculture, Forestry & Food Security, Research Institutes, Industry, International and	High

under climate change	have negative impacts on the environment e.g. increased pesticide use.	regional organizations	
Capacitating SLARI to collect relevant agricultural climate related data together with Njala University and the Meteorological Agency for modeling		Ministry of Agriculture, Forestry & Food Security, Research Institutes, Industry, International and regional organizations	High

Additional comments and feedback were received from the working groups as follows:

- The "Agenda for Prosperity" presented by the President of Sierra Leone in 2012 to 2017 provides a framework for the sustainable development of agriculture throughout the country and has identified the need to adapt to the potential impacts of climate change, as well as stabilizing national food security;
- The use of economic instruments to assist with adaptation and changing practices and behavior was raised, particularly focused on domestic crop and livestock producers;
- Wastewater reuse for the agricultural sector was raised as a possible underused water resource, including flushing effluent from fish farming onto nearby lands;
- The need for strengthening the Climate Change Secretariat of EPA-SL and the newly created Meteorological Agency's agro climatological section was emphasized.

The highest placed recommendation proposed developing mechanisms to maximize benefits to the agricultural sector from international funding. This was followed by the recommendation to improve access to loans and grants for domestic crop producers. There are two recommendations ranked equal third: one to raise awareness of the potential impacts of climate change on the agriculture sector and one to review approaches to integrated cropping and management systems under climate change.

The recommendations receiving the lowest scores were the setting up of a climate change working group for agriculture (although one group placed this second), and the proposed development of modeling approaches and impact assessment tools (which the preparation of the this report has been shown to be a significant gap in the knowledge base to aid decision making). Capacitating Sierra Leone Agricultural Research Institute (SLARI) to collect relevant agricultural climate related data together with Njala University and the Meteorological Agency for modeling purposes was ranked third by one group. The proposed review of the role of financial instruments to provide insurance protection, was not given the ranking expected. It was noticed that some rankings were subjective based of the composition of the consultative group.

5.2.8 Agriculture Vulnerability and Adaptation Assessment Constraints

Much of the assessment for the agriculture sector was qualitative in nature. Necessary technical training and capacity building within the agricultural sector on approaches to impact assessment and adaptation development began with the attendance of Sierra Leonean hired task force members for the development of the V&A component of the FNC in the Gambia in 2003. Such activities should be encouraged, supported and expanded since they will inform policy development and decision making with respect to understanding existing and future vulnerabilities of Sierra Leone's agriculture and how best to counter these vulnerabilities while at the same time ensuring increased food security.

5.3 The Water Resources Sector

5.3.1 Background

Water Resources Sector

Sierra Leone has nine major river systems. The Rokel/Seli, Pampana/Jong, Sewa and Waanje systems originate from within the country, as do the numerous coastal streams and creeks; the Great and Little Scarcies and Moa Rivers originate from the Fouta Jallon Plateau in the Republic of Guinea, and the Mano River originates from the Republic of Liberia. These rivers range in length from 160 km for the Great Scarcies to 430 km for the Sewa River; their catchment areas range from 2,530 km^2 for the coastal streams and creeks, to 14,140 km^2 for the Sewa River. The total mean annual runoff from the river basins is of the order of 160 km3, with monthly runoff following rainfall variability.

Internally, renewable water resources are over 29,000 km^3 per capita, which is six times the average for Africa. Water as a natural resource in Sierra Leone is estimated to be in the region of 160 Km^3 of total mean annual runoff from the nine river basins. Rain water also accounts for a significant proportion of water resources, and is often available in the rainy season between late May and late October, with peak periods from June to August. Annual rainfall range in Sierra Leone is from 5000mm to 1800mm. In the West African region, Sierra Leone ranks second after Liberia in volume of actual renewable water availability.

About 80% of the rural population obtains its water from surface sources, including many streams and ponds. Groundwater is used for a limited number of rural wells and recent installations for large cities. A number of provincial towns enjoy pipe-borne treated water. Water from hydro-electric power generation, a “non-consumptive” water use, is the principle source of electricity provision and holds further development potential. Water for energy, an urgent development need for Sierra Leonean citizens, thus plays a key role in water resource management and as a mitigation measure for GHG reduction. Water consumption for industry and mining is increasing; much of this too is “non-consumptive” but affects water quality. Finally water is used for irrigation (currently the largest “consumptive use”) and there is potential for substantial further irrigation development.

The Water and Sanitation policy is aimed at (a) effective and sustainable development and management of water resources; (b) development of water supply and sanitation services and improving the provision of safe water supplies and sanitation facilities in urban and rural areas; and (c) promoting and scaling up the Community Led Total Sanitation and Open Defecation-Free Communities concepts (Ousman Barrie, 2012).

According to the National Water and Sanitation Policy (NWSP), policy formulation, coordination and regulation in water and sanitation are the central government’s role. The Ministry of Water Resources is the policy, regulatory and oversight entity with respect to water resources. The Ministry of Health and Sanitation is responsible for policy oversight, coordination and regulation in respect of sanitation and hygiene, including solid and liquid waste management.

At the service delivery level, local councils have responsibility for rural water supply and solid waste management in urban areas. Rural sanitation is assumed to be a household matter. In terms of urban water supply, the Guma Valley Water Company (GVWC) is responsible for Freetown, while the Sierra Leone Water Company (SALWACO) is responsible for other urban and peri-urban areas and for rural water supply, including the provision of technical support to local councils. International organisations, including UNICEF and WHO, also intervene either directly or through

NGOs in the service delivery process. There is currently not much public organisation and civil society action around governance, and service delivery in the water and sanitation sector is weak. Sector working groups are only at the conceptual stage.

These demographic pressures make it difficult for planning and infrastructure to keep pace. Hardly any significant water and sanitation infrastructure has really been developed in the country after the first two post-independence decades. The Guma Dam, constructed immediately after post-independence and still the sole public water infrastructure to Greater Freetown, is designed to supply a population of 300,000 people, but over 1.5 million people live there today. The Water Point Mapping in 2012 reported that 18% of existing water points across the country was broken, while another 14% are partly damaged and currently dysfunctional.

Many communities in Sierra Leone, especially the rural poor, depend on streams and swamps, which dry up during severe droughts. Floods overwhelm existing systems, contaminating drinking water and creating sewerage overflows. The likelihood and intensity of extreme weather events will increase with the smallest change in temperatures.

In nominal terms, total disbursements to the water and sanitation sector in Sierra Leone have increased year on year since 2009. Disbursements in 2011 were up by 119% from 2009. In real terms, expenditures declined in the last year by 11% from 2010 figures. Despite an increase in 2010 disbursements compared to the previous year, 2011 disbursements still only represent a 17% increase from 2008 levels. Viewed as a % of GDP, disbursements present a picture of stagnation with the exception of a considerable dip in 2009. Having said this, current levels, at 1.4% or 1.5% of GDP, are high relative to many other sub-Saharan African countries.

A significant proportion of the above increases in funding have been focused on rural and peri-urban water and sanitation. Just over eight-tenths of expenditure currently being disbursed is targeted at rural areas, following a steady increase in rural expenditure since 2008. The rate of growth in rural expenditure is currently leading to growing discrepancies in per capita funding. Urban per capita expenditure was just over a third of rural per capita expenditure. The expenditures have been mostly capital outlays focused on rehabilitation of water works and the development of new facilities, including gravity water supply systems around the country.

While significant attention was paid to surface water in the second national communication, this assessment emphasizes the prominence that groundwater now assumes in the development of water resources for drinking and other domestic and commercial use. This is due mainly to the uncertainties that characterize the management of surface water resources as we witness changes in the rainfall pattern.

Groundwater is becoming an increasingly important resource not only in rural areas but also in urban settings, including the capital, Freetown where borehole drilling has intensified in recent years. Groundwater sources are being harnessed to augment the ailing surface water system characterized by a dilapidated distribution network exacerbated by an unprecedented increase in consumer population. Even as new groundwater sources are being investigated and developed concerns are being expressed about the quality of shallow sources which are believed to have been compromised by the presence of faecal coliform bacteria symptomatic of unsound sanitation practices.

The National Adaptation Programme of Action (NAPA) for Sierra Leone identifies Water resources as a priority, with urgent and immediate adaptation needs including the institutional strengthening of the water sector; rehabilitation & reconstruction of meteorological monitoring stations in the country; and development of appropriate water and sanitation program activities in urban areas of the western area of Sierra Leone. The criteria for prioritization of adaptation interventions in the NAPA are based on the potential adverse impacts on water availability, quality and accessibility, with secondary benefits for health.

Improving water research, monitoring & management is identified as the topmost priority for the water sector, with improvement of the efficiency of existing water supply systems in both urban rural areas. Promoting rain water harvesting and developing an integrated management system for fresh water bodies are identified as the second and third priorities respectively. It is gratifying to note that the project profiles developed in the NAPA are currently being implemented by the Sierra Leone Water Company, within the framework of the Rural Water Supply and Sanitation Project (RWSSP), with funds from the African Development Bank (AfDB), the British Government's Department for International Development (DfID), and the Global Environment Facility (GEF).

The GEF-LDCF project "Building Resilience to Climate Change through the Water and Sanitation Sector" has been established to ensure that interventions of the baseline RWSSP are climate-resilient (African Development Bank, 2016). The components of the GEF-LDCF resilience project include:

- Ensuring access to climate-resilient water supply and sanitation;
- Building the institutional framework required for the climate-resilient management of the water and sanitation sector;
- Building improved awareness of climate-resilient WASH practices;
- Establishing collaborative research and monitoring to enable efficient, climate-resilient water management; and

- Monitoring and evaluation and knowledge management.

Components of the RWSSP include:

- Installation of rainwater harvesting systems which is one of the project profiles developed in the NAPA;
- Construction of boreholes, hand dug wells, spring boxes, gravity fed system, and rehabilitation of water points, aimed at increasing access to improved sources of drinking water;
- Installation of rain gauges and hydrological monitoring stations meant to provide early warning signals of impending disasters such as drought and flooding (Table1).

These are measures put together to adapt to the impacts of climate change on the water resources sector, which is becoming increasingly vulnerable.

5.3.2 Overview

There is a plethora of anecdotes and published materials on the vulnerability of the water resources sector to climate change. On the same token there is a dearth of plausible measures to mitigate the impacts of climatic variability and change on both the quantity and quality of freshwater resources. In the Second National Communications GCMs were used to predict runoff of a major river with and without climate change using the Water Balance (Watbal) Model. All except one of the models predict an increase in runoff occasioned by an increase in temperature of about 2 degrees Celsius by 2021.

Table1. Proposed climate-resilient water and sanitation infrastructure for the RWSSP (Source: African Development Bank, 2013)

	North	East	South	Total
	Kambia & Koinadugu	**Kono**	**Bonthe & Pujehun**	
Water points proposed for rehabilitation				
Hand Dug Well/Borehole/Spring box	655	528	240	**1423**
Gravity flow scheme Rehabilitation	0	2	0	**2**
Water points proposed –New Construction				
Dug well	186	130	150	**466**
Boreholes with hand pumps	38	30	16	**84**
Spring box	28	52	30	**110**
Gravity flow scheme (GFS)	4	12	2	**18**
Boreholes with solar-powered pump system	7	7	7	**21**

For schools and public places				
Rainwater harvesting	7	8	10	**25**
Public sanitation facilities (Toilets (EcoSan and VIP) 6 stance	104	146	139	**389**

The current study looks specifically at groundwater resources which is becoming increasingly important in our development, not least because of the growing scarcity of surface sources as the hydrological cycle becomes engineered, occasioned by deforestation and exacerbated by urbanization. Groundwater development has intensified in the country as more knowledge is acquired of its resilience to climate change. However, shallow groundwater sources may not be as resilient as short-term changes in the weather pattern could have devastating effects on its availability and quality.

According to the Joint Monitoring Programme (JMP) access to improved water supply in Sierra Leone reached 57 percent in 2011 up from 49 percent in 2008. Disaggregated, 87 percent of the urban population was estimated to have access compared to only 40 percent in rural areas. Although there was a much more significant rise (9 percent) in rural access compared to the rise of 1 percent in urban access, there still exists a huge divide and inequity between urban and rural areas. Sierra Leone missed the opportunity of achieving the water and sanitation MDG, but it is among the eight sub-Saharan African countries which performed above the regional average of 26% in terms of the population that gained access to safe water during the period.

5.3.3.1 Geology and Hydrogeology of Sierra Leone

Most of the country is underlain by Precambrian crystalline rock formations distributed mainly in the south eastern and central parts of the country, which have no primary porosity. The Basement rocks consist principally of granitoids and gneisses, with isolated belts of greenstone lithology and structure occurring in the northern and eastern regions. Younger (sedimentary) rocks of Infra-Cambrian and Tertiary to Quaternary ages are found in the central parts and the coastal zone, respectively. The fractured rocks of the crystalline basement together with the overlying weathered mantle (regolith) form the Crystalline Basement Aquifer.

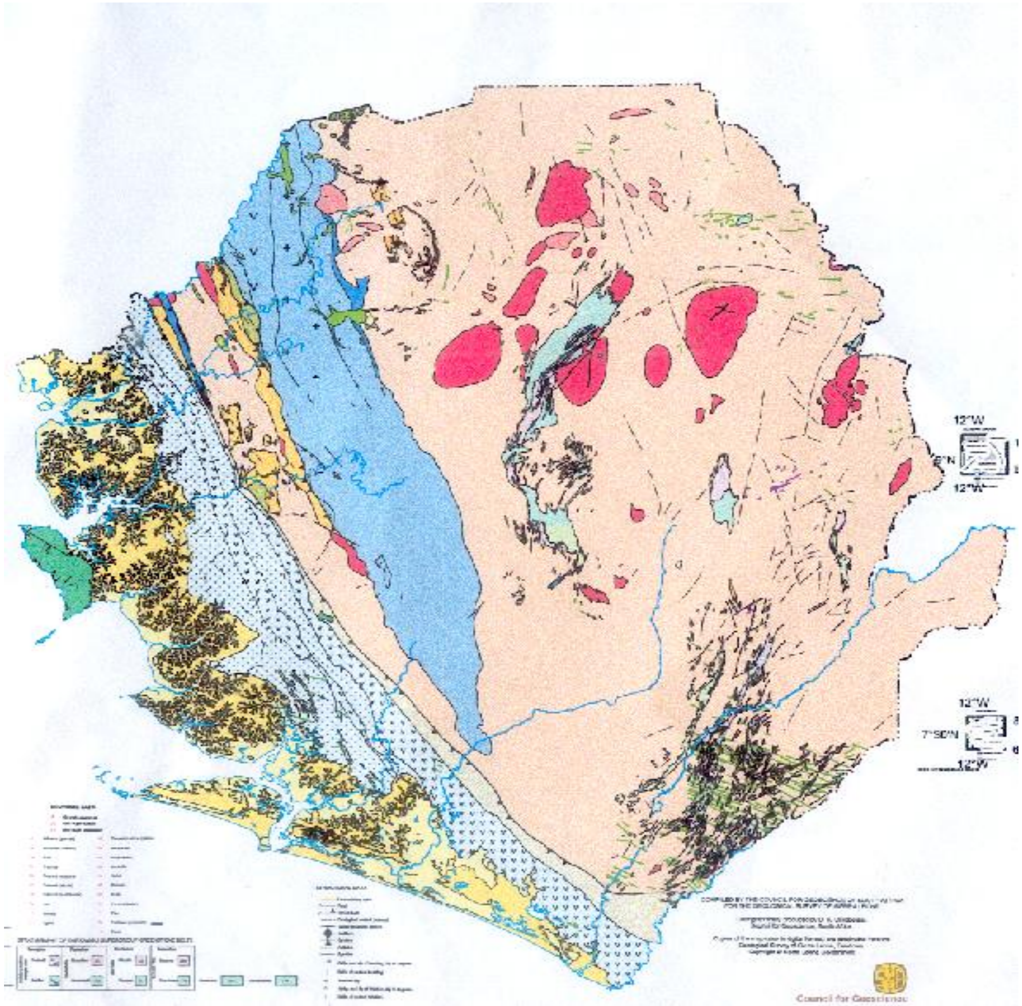


Figure5.8 Geological Map of Sierra Leone showing main aquifer types

MAIN AQUIFER TYPES

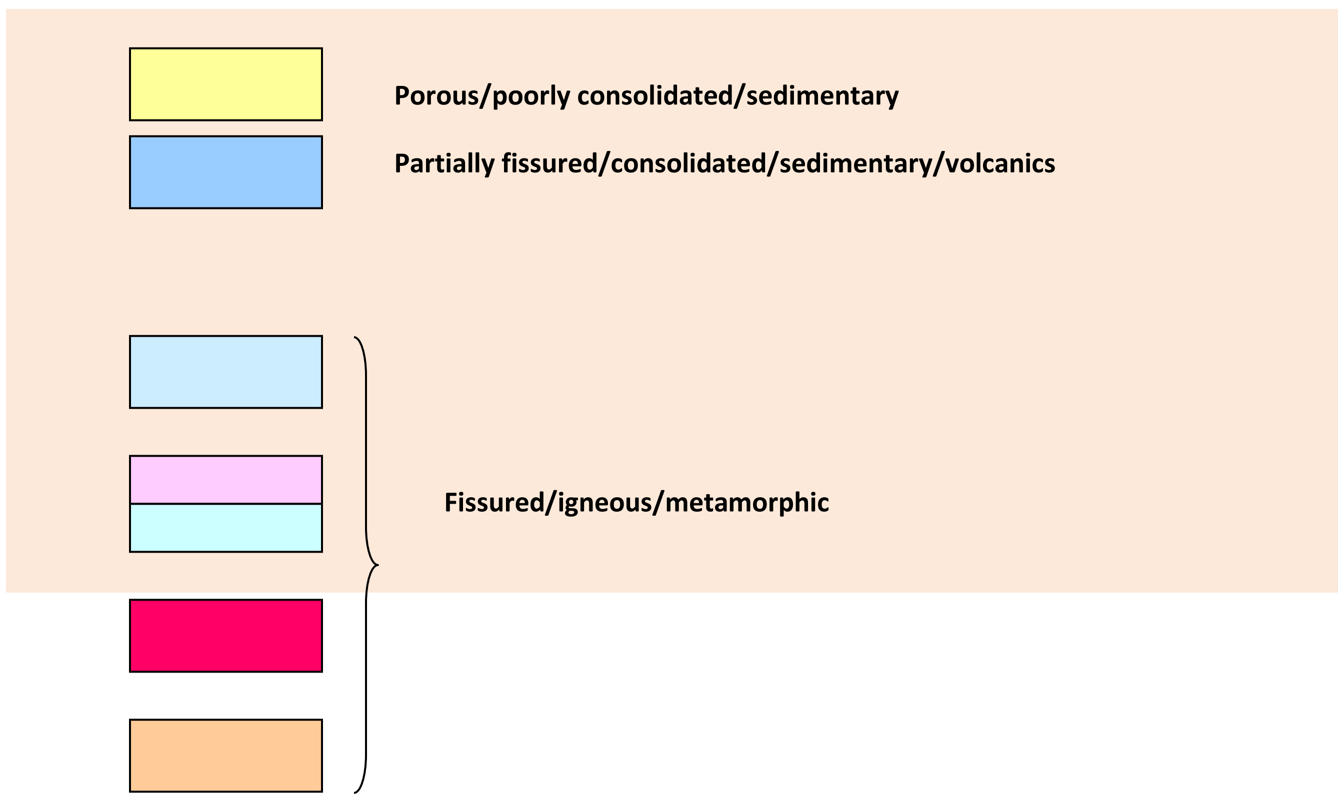


Table2. Hydraulic characteristics of the various rock units

Annotation	Lithology	Permeability	Flow Type	Natural Water Quality
	Granites, migmatitic gneisses	Fracture-controlled	Fissure flow	Excellent- low solute content
	Granite	Fracture-controlled	Fissure flow	Excellent- low solute content
	Schists, amphibolite, quartzite, BIFs	Fracture-controlled	Fissure flow	Good-low solute content
	Gneisses, amphibolite	Fracture-controlled	Fissure flow	Excellent- low solute content
	Sandstone, shale, mudstone, volcanic	Interstitial, fracture	Interstitial/Fissure flow	Good
	Poorly consolidated sand, silt, clay, intraformational laterite	Interstitial	Interstitial	Good to poor (saline conditions near the coast)

This aquifer occupies about 60% of the country and provides potable water for mainly rural communities. Groundwater accumulation therefore occurs in fractures, joints, and fissures. The aquifers are consequently not continuous. Internally produced ground water is estimated at 50km3 annually and much of this (80%) overlaps between surface and ground water. The lower unit comprising fractured bedrock is the target for boreholes while regolith provides shallow groundwater which could be harnessed by digging large diameter wells. The natural quality of groundwater in the Crystalline Basement Aquifer is excellent, although this may be compromised by high levels of faecal coliform bacteria present in regolith.

Borehole yields can vary according to the number and aperture sizes of fractures present in the bedrock aquifer as well as the amount of recharge it receives from surface sources. Depth to water varies from less than 3m in valleys to greater than 20m in interfluves. The water table experiences large seasonal fluctuations and this could have serious consequences for water supply in a dry year or period of low rainfall.

5.3.2 Groundwater

5.3.2.1 Overview

Groundwater is a critical resource in many parts of the world, yet there have been very few direct studies of the effects of global warming on groundwater recharge (IPCC, 1996). The trend seems to be changing as new methodologies are developed to assess the overall impacts of climate change on both the quantity and quality of subsurface water.

Sierra Leone has a rich supply of freshwater resources yet the quantity available for drinking and other domestic and commercial use is grossly inadequate for its rapidly growing population. In 2016, ten years after a water crisis, occasioned by late rains, the country witnessed the drying up of scores of what were regarded as permanent streams on the Freetown Peninsula. This was attributed to an unprecedented drop in base flow symptomatic of low infiltration, exacerbated by widespread deforestation within catchment areas.

Groundwater sources are being impacted by man's direct action and as climatic variability and change intensify we are likely to witness more water crises. Groundwater has a greater resilience to climate change than surface water. Consequently, the impacts would take a longer time for it to be felt. However, if deforestation within the catchments continues unhindered the impact on groundwater resources would be long term and devastating.

5.3.2.2 Major groundwater reservoirs (aquifers)

5.3.2.2.1 Overview

The high cost of harnessing surface water has necessitated a dramatic shift towards groundwater development which uses low-cost technology, in addition to being less sensitive to climatic variability and change. The aquifer systems in Sierra Leone are few in number and may be classified as follows:

5.3.2.2.2 The Crystalline Basement Aquifer

This is the major aquifer system in the country and comprises the Crystalline Basement and the overlying weathered mantle or Regolith. Groundwater is harnessed by drilling boreholes into fractured bedrock or by constructing shallow dug wells within regolith. The Aquifer (groundwater reservoir) is invariably unconfined and receives its recharge by normal infiltration of precipitation and less frequently from nearby surface sources. Yields measured from this aquifer are relatively low due to the presence of clay formed by weathering of feldspars. However, boreholes equipped with solar-powered pumps drilled in the crystalline basement provide potable drinking water for rural and peri-urban communities. The quality of groundwater in the shallow aquifer may be compromised by high levels of faecal coliform associated with poor sanitation practices, especially in rural areas.

5.3.2.3 The Consolidated Sedimentary Aquifer

Not much is known about this aquifer system attributable to the paucity of data on the rock formation, exacerbated by lack of interest by geologists, symptomatic of its poor mineralization potential. However, by its very nature, the Aquifer, which comprises sandstone, greywacke, and arkosic beds has huge potential of becoming an important source of water for both domestic and industrial use. At the moment boreholes drilled into this aquifer are providing sustainable water for communities in the northern and central parts of the country. Borehole logs obtained from drilling reveal both unconfined and confined aquifers, with the latter having good potential of providing sustainable groundwater for drinking and other domestic use.

5.3.2.4 The Sand and Gravel Aquifer

The coastal plain of sierra Leone is covered by poorly consolidated Tertiary and Quaternary sediments comprising quartz sands and gravel with intervening clay layers and occasional lateritised sands. The aquifer has been the source of drinking water for hundreds of thousands of people living along the coast stretching from Kambia District in the north to Pujehun District in the south. However, its exploitation is limited by saline conditions experienced in areas adjacent to the sea. Such areas are usually avoided by groundwater development agencies.

5.4 Institutional Arrangements for the Management of Water Resources in Sierra Leone

5.4.1 Ministry of Water Resources

Formerly Ministry of Energy and Water Resources, the latter's overarching responsibility is formulating and implementing policies relating to urban and rural water supply through its Water Directorate (formerly the Water Supply Division), planning and coordination through the Sector Policy Coordination Committee. The Ministry also exercises supervisory control over the Sierra Leone Water Company (SALWACO). With the formulation of the new Water Policy and implementation of the subsequent organisational reforms, the responsibility of the Water Directorate is now limited to strategic oversight through policy development, planning and coordination, monitoring and evaluation and quality assurance.

5.4.2 Guma Valley Water Company (GVWC)

The Guma Valley Water Company was established by an act of parliament to provide treated water and sewerage services to the Freetown Municipality and the Western Urban Area. It is the largest provider of potable water and responsible for the small sewer network around the Central Business District (CBD).

5.4.3 Sierra Leone Water Company (SALWACO)

SALWACO was established in 2001 also by an act of parliament as a parastatal entity fully owned by the Government of Sierra Leone (GoSL) and under the supervision of the Ministry of Water Resources. It enjoys sufficient autonomy to operate outside the government's control, although, in reality, SALWACO is still heavily dependent on subventions from the Government. The new Water Policy (2010) extended SALWACO's mandate to that of providing water supply and related sanitation services to all urban centres outside the jurisdiction of Guma Valley Water Company, in addition to technical oversight and support to the district councils. A new law has been enacted that extends SALWACO's mandate to include all rural areas of the country.

5.4.4 District Councils

There are 14 district councils responsible for delivering water and sanitation services in the rural areas under the strategic oversight of the MWR-WD with technical oversight being provided by SALWACO. Due to the general deterioration of water and sanitation infrastructure and the poor service delivery, most districts are without qualified water personnel. Much of the water supply and sanitation services related work is carried out by the staff of the Ministry of Health and Sanitation which has a greater footprint at district level through its District Health Management Teams.

5.4.5 Ministry of Agriculture and Food Security

The Ministry through its Land and Water Department is a key stakeholder and periodically undertakes studies on both surface water and groundwater sources, which culminate in the construction of small-scale irrigation schemes.

5.4.6 Ministry of Mines and Mineral Resources

The Ministry is responsible for ensuring that mining activities are environmentally friendly. The Ministry also undertakes geological mapping and exploration activities that have direct impact on water resources. Also, huge amounts of raw water are used in mining operations either for mineral processing or for dust suppression.

5.4.7 Ministry of Lands, Country Planning and the Environment (MLCPE).

Key responsibilities of the MLCPE include mapping of catchment areas, watersheds, rivers, and lakes. The need to protect our catchments is even greater now that evidence has beginning to emerge about declining water levels in rivers and lakes.

5.4.8 Ministry of Health and Sanitation

This all important ministry is responsible for public health and sanitation in the country. Among its numerous responsibilities it conducts health studies and report incidences of water borne communicable diseases. It also does water quality testing, and investigates sources of water pollution.

4.4.9 Ministry of Finance and Economic Development

This ministry is responsible for the coordination of national development policies. It is also responsible for mobilization both internal and external sources of funds for development and co-ordinates all external aid. Its Local Government Finance Department (LGFD) is responsible for fiscal oversight of the Local Councils. It administers the sector conditional grant allocations to the Local Councils.

5.4.10 Ministry of Transport and Aviation

Through its Meteorological Department this ministry is responsible for the climatological aspects of water resources and as such undertakes all meteorological activities. It also oversees control of all inland waterways, issuance of 'navigation licensees and safety of 'nautical navigation.

5.4.11National Meteorological Service

The Weather Branch of the National Meteorological Agency (NMA) is concerned with the observation and forecasting of weather conditions over and around Sierra Leone. It also maintains a continuous weather watch during the rainy season and is responsible for the issuance of severe weather warnings. Data for forecasts are obtained locally from observation points at the surface, as well as from the radar station, and internationally through telecommunication links with regional and international centres and via stationary and polar orbiting satellites.

The Climate Branch is responsible for maintaining a current database of the climate of Sierra Leone and for using this data in informing productive sectors of the country. A Data Acquisition Section maintains a country wide network of rainfall and climatological stations; a Data Processing Section gathers, archives and analyses the climatological data with a view to monitoring and assessing the climate of the country; and an Applied Meteorology Section processes the needs of clients, which include crop water requirements, design criteria for hydrologists and engineers, and climatological information for resolving weather related legal and insurance issues.

5.4.11 Ministry of Marine Resources

Has exclusive mandate for management and control over fisheries and other aquatic resources within the territorial waters of Sierra Leone. It is responsible for planning, developing, managing and conserving all living and in collaboration with other MDAs non-living aquatic resources of the country.

5.4.12 Environment Protection Agency

Established within the Office of the President, this agency coordinates all environmental activities in the country and acts as a link between key institutions of the Government involved in the environment sector, including, but not limited to, the Ministry of Agriculture and Food Security, Ministry of Lands and Country Planning, Ministry of Mineral Resources, Ministry of Water Resources and Ministry of Marine Resources. It issues environmental permits for all development projects following a due process of Environmental, Health and Social Impact Assessment (EHSIA) preparation and disclosure.

5.4.13 Office of National Security

The Disaster Management Department in the Office of National Security is responsible for the coordination of all disaster management activities, including water related disasters such as flooding.

5.5 Local government

Under the Local Government Act 2004, responsibility for providing water supply to urban centers and rural communities has been devolved to local councils. The local councils are therefore in the process of taking over the responsibilities of rural, small towns water supplies – currently engaged in rehabilitation of some small town water supplies and delivering rural water services using the district conditional grant allocations. There will be need for harmonisation of the functions of the Local Government and SALWACO due to the overlapping responsibilities. At the moment, SALWACO is in charge of all three provincial capitals (Bo, Kenema and Makeni) and directly undertaking rehabilitation of some of the water supply facilities for some small towns.

5.6 Decentralization

Decentralization was reintroduced in Sierra Leone in the immediate post-war years after three decades of suspension. The devolution of water supply services started taking place only during the second phase (post-2008) and is only now being devolved to the councils, and is still currently largely limited to rural water supply.

Delays in devolution, experienced in the past years, have largely been due to weak local level capacities especially in the district councils against associated financial and other risks. The decentralization policy requires that the central government transfer both funds and personnel for devolved functions. However, the payroll and personnel management aspect of devolved functions continue to be centralized in Freetown. Therefore councils generally manage with the staff either recruited by them or assigned from the central government to carry on core support administrative and management functions rather than actual technical service delivery functions.

5.7 Other relevant partners

Donor agencies, including bilateral partners, INGOs and NNGOs also play an active role in the provision of potable water to remote parts of the country using low cost technologies. However, INGO and NNGO activities in the water sector have not been well coordinated by the relevant line Ministry.

5.8 NATIONAL WATER AND SANITATION POLICY

Sierra Leone is currently undertaking water sector policy and regulatory reforms. The National Water and Sanitation Policy came into effect in 2010 and the Water Resources Management Act was passed into law in May, 2017. Embedded in the National Water and Sanitation Policy are five specific objectives:

- To extend WASH coverage in urban, peri-urban, and rural areas;
- To operationalise water resources management (WRM) at local, district, national and transboundary levels, thereby reducing degradation of land and water resources;
- To establish sector learning and research and development (R&D) as part of the GoSL's larger strategy of becoming a science and technology based nation;
- To devolve responsibilities for WASH service delivery to local councils in accordance with the Local Government Regulations 2004;
- To contribute to Sierra Leone's Poverty Reduction Strategy Plan (PRSP), Agenda for Change and achievement of the water supply, sanitation and hygiene targets set out in the Millennium Development Goals (MDGs).

The Policy contains ambitious targets of extending water supply and sanitation services to the entire population by 2025. In the short term, the policy commits Sierra Leone to achieving its 2015 MDG targets of 74 percent and 66 percent for improved water supply and sanitation coverage, respectively. To achieve these targets, the extension of water and sanitation coverage ought to have been accelerated substantially, while at the same time ensure that the issue of sustaining services is addressed so that the population that is currently served does not slip into the un-served category.

5. WATER RESOURCES AND THE ECONOMY

Groundwater is the world's largest accessible store of freshwater. It is the primary source of drinking water for half of the world's population and supplies over one-third of the water used to irrigate land globally. As such, groundwater is critical not only to global freshwater security but also to global food security.

At the local level water is seen as a critical resource in ensuring food security. The Small-holder Commercialization Programme currently being implemented by government identifies small-scale irrigation development as crucial in ensuring sustainable agricultural production, thereby contributing to food security. The Programme aims at developing appropriate small scale irrigation infrastructure in order to boost rice production, a major staple in the country. Results expected from small scale irrigation development would substantially contribute to increased food security, the generation of marketable surplus for lowland smallholders and their insertion in national agricultural trade, as well as creation of wealth and employment for youth.

5.5 VULNERABILITY ASSESSMENT

5.5.1 Overview

Assessments of the vulnerability of groundwater resources to climate change are still challenging, attributable to a dearth of time series data which underpins any meaningful approach to determining how water levels in aquifers will respond to long term changes in the hydrological cycle. However, some success has been achieved in identifying potential impacts of both climatic variability and change on groundwater quantity and quality. It should be borne in mind that most of the assessments are qualitative and vary according to climatic regime and other related factors.

A clear distinction has to be made between impacts associated with man's direct action and that due to climatic variability and change. The hydrological cycle is being engineered by the accelerated development of urban areas occasioned by massive deforestation and construction of pavement structures in the form of roads and parking lots, with both activities limiting infiltration of available precipitation. When the hydrological cycle is engineered in this way surface runoff becomes more pronounced culminating in incidences of flash and drainage floods. Also, aquifer recharge may be impeded and this has direct impact on groundwater storage.

5.2 Impacts on groundwater availability

A decrease in the amount and intensity of rainfall would cause a decrease in the amount of recharge to aquifers which could have serious implications for groundwater storage. In Sierra Leone, the shallow aquifers are characterized by low storage capacity and recharge follows the annual seasonal rainfall cycle. This recharge water as it were, is used up relatively quickly for drinking and other domestic use where it is discharged into pumping wells and springs. Also, it is discharged naturally as base flow to rivers and lakes during periods of low or no rainfall. The ubiquitous drying up of streams experienced in 2016 on the Freetown Peninsula as explained earlier was as a result of a reduction in base flow attributable to low infiltration, exacerbated by widespread deforestation.

5.3 Impacts on groundwater quality

The impacts of climate change on the quality of groundwater in Sierra Leonean aquifers have not yet been documented. However, studies have shown (Thomas, 2010; Thomas and Momoh, 2017) that the quality of groundwater in the shallow aquifer may be compromised by high levels of faecal coliform bacteria acquired through surface runoff in rural areas where open defecation remains a common practice. This has been associated with cholera outbreaks which seem to follow closely the seasonal rainfall pattern. An increase in the amount and intensity of rainfall would result in massive runoff with the likelihood of contaminating the shallow aquifer through excreta-laden flood waters. Increasing climate-change-induced storm surges will also lead to flooding in coastal areas, threatening the quality of groundwater supplies and compromising their usability.

ADAPTATION

Control of deforestation

Some progress has been made in the control of deforestation especially in major catchments and sub-catchments. The National Protected Area Authority was established by an act of parliament to protect the country's forests and wetlands. The law gives the authority powers to arrest poachers of wild life and encroachers of forested land and wetlands with a view to controlling deforestation and conserving water. Forests are known to hold significant amounts of water which is released slowly to streams as base flow during dry periods or low rainfall.

5.3.1 Installation of early warning systems

Rain gauging stations

Weather stations were vandalized during the civil conflict and this has created huge gaps in the precipitation record. The UNDP project that guarantees support to the Ministry of Water Resources will see the installation of rain gauges in many parts of the country. The Sierra Leone Water Company as part of its Rural Water Supply and Sanitation Project will install 25 rain gauges in five districts in the country

(Table3). The rain gauges will measure and record daily precipitation and this information will be fed into a system that provides early warning of extreme events like drought and flooding.

Table3. Proposed rain gauging stations

Station No	Station Name	Latitude	Longitude
866	Bonthe	07 32	12 30
896	Bunumbu	08 10	10 52
	Falaba	09 52	11 20
886	Kabala	09 35	11 34
871	Kamakwe	09 30	12 14
858	Kambia	09 08	12 55
850	Kent	08 11	13 08
	Koribondo	07 44	11 41
862	Kukuna	09 52	12 39
894	Kurubonla	09 32	10 57
873	Makeni	08 53	12 03
	Mambolo	08 25	13 02
895	Mongo Bendugu	09 32	10 57
864	Moyamba	08 10	12 25
	Pepel	08 35	13 04
859	Port Loko	08 46	12 47
	Potoru	07 32	11 28
880	Pujehun	07 23	11 41
855	Rokupr	09 01	12 57
892	Sefadu	08 40	10 59
857	Shenge	08 57	12 56
883	Sulima	06 59	11 33
	Sumbuya	07 39	11 58
874	Torma Bum	07 25	12 00
854	Waterloo	08 21	13 04
877	Yele	08 25	11 49
891	Yengema	08 37	11 03
888	Zimmi	09 17	11 6

5.3.2 Hydrological Monitoring Stations

With the support of UNDP and with financing from the Global Environment Facility (GEF) as part of a project on climate information and early warning, the Ministry of

Water Resources is implementing a programme aimed at rebuilding and strengthening the National Hydrological System. Already a needs assessment has been conducted for hydrological monitoring to support warnings of flash floods, develop a plan and a national framework for integrating hydrological monitoring into watershed management and develop a program of support in operational watershed monitoring and hydrological modeling for Hydromet officers. The assessment focused on the following:

a) An assessment of existing hydrological equipment;
b) Identification of gaps in operational hydrology;
c) Identification of additional stations at strategic locations (Table 4; Figure2)
d) Assessment of the need for hydrological monitoring in terms of equipment for data collection, processing, analysis and storage;
e) Inclusion of equipment for data processing and storage;
f) Community Sensitization;
g) Development of a plan and a framework for hydrological monitoring and management;
h) Development of capacity-building programme for Hydromet Officers in operational hydrological monitoring and watershed modeling; and
i) Training of Ministry of Water Resources Staff on data collection, processing and analysis which would enable them to respond to end users demand for pertinent hydrological information on water resources.

The expected outcomes include:

1. A network of national hydrological observing systems that can provide reliable and homogenous information, transmitted in appropriate channel(s);
2. A network that promotes and facilitates the dissemination and use of derivative information and products adapted to water resources management, to environmental protection and to the protection of life and property against water-related risks (floods and droughts) by using the most suitable means of dissemination, and in particular the possibilities offered by the new communication technologies.

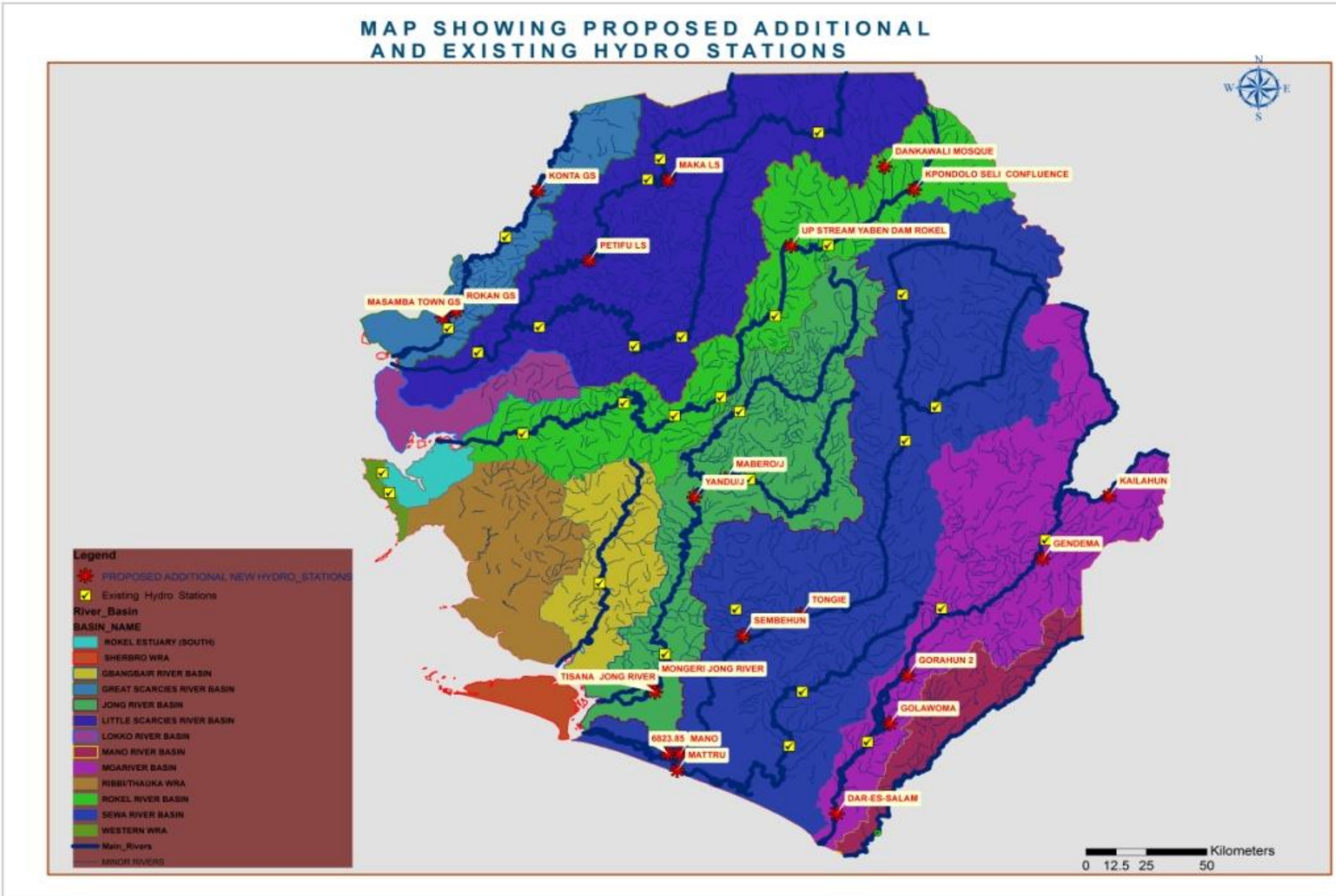


Figure5.9 Proposed hydrological monitoring stations

Table4. Details of hydrometric stations

N°	River Basin	River/tributary	Station Name	District	Coordinates		Hydromet Station Assessment	Recommended Equipment	Datum	Brief Description of site
					Latitude	Longitude				
1	**Rokel**	Rokel	Bumbuna Bridge	Tonkolili	N 9.05228	W 11.75294	Existing staff gauge from 2-3 m, 4-6 m, missing one 0-2 m and 3-4 m installed by Onchoserchosis projet	Staff gauges	No Datum	Downstream Bumbuna hydro power dam Staff gauge to be rehabilitated
2		Rokel	Magburuka	Tonkolili	N 8.72789	W 11.94947	There is existing staff gauge 6-9 m installed by Onchoserchosis projet	Proposed site for DCP	No Datum	Site within SALWACO water Intake
3		Rokel	Alfanya (Badala)	Koinadugu	N 9.32378	W 11.54061	There is existing staff gauge 1-3 m and 3-5 m installed by Onchoserchosis projet	Proposed site for DCP	Datum	Presence of plantation within the site
4		Rokel	Upstream ADDAX	Bambali	N 8.75250	W 12.30978	New site	Proposed site for DCP	No Datum	River use to supply water for ADDAX Sugar cane Bio Energy
5		Rokel Seli River Basin	ADDAX Downstream	Bombali	816509.84	958354.5682	New site			
6		Rokel	Rogbere Junction	Port Loko	N 8.59289	W 12.68733	No staff gauge, new propose	Proposed site for DCP	No Datum	Proposed intake to supply Freetown

N°	River Basin	River/tributary	Station Name	District	Coordinates		Hydromet Station Assessment	Recommended Equipment	Datum	Brief Description of site
							site			
7		Tonkolili	Tonkolili	Tonkolili	N 8.98689	W 11.79342	Trace of old staff gauge on the bridge	Staff gages	No Datum	A tributary of river Rokel.It joint it downstream Bumbuna
8		ROKEL RIVER	UP STREAM YABEN DAM ROKEL		864665.15	1032310.632	New site	STAFF GUAGE + DCP		
9		KPONDOLO RIVER	KPONDOLO SELI CONFLUENCE		915634.61	1056811.985	New site	STAFF GAUGE		
10		MELI RIVER	DANKAWALI MOSQUE		903374.34	1066792.052	New site	STAFF GAUGE		
11	**MANO**	MANO	JENDAMA	PUJEHUN	237379	775934	NO G/STATION	Proposed site for DCP	NO DATUM	INTERNATIONAL RIVER
12	**Great Scarcies**	Great Scarcies (Tasse)	Tatmalaya	Kambia	N 9.36592	W 12.75283	Staff Gauge to be installed	STAFF GAUGE	No Datum	Site accessible
13		Great Scarcies	Rokon		722973.49	996443.3996		STAFF GAUGE		
14		MASAMBA CREEK	MASAMBA TOWN GS		720574.25	1001182.339	New site	STAFF GAUGE		
15		TONKO RIVER	ROKAN GS		726073.43	1003907.541	New site	STAFF GAUGE		
16		GREAT SCARCIES	KONTA GS		760072.62	1056148.096	New site	STAFF GAUGE + LIMNIGRAPH		
17	**JONG**	JONG	MOKEPE	MOYAMBA	812577	854708	STAFF GAUGE	STAFF GAUGE		SOURCE OF DRINKING WATER
18		Taia	Yele	Tonkolili	N 8.40800	W 11. 84439	Existing old staff gauge (5-6 m, 6-7 m)	STAFF GAUGE	Existing datum (value to be checked)	Existing intake for water supply to,Yele town and a mini hydro power station
19		TAIA	TAIAMA	BO	8.232E+11		STAFF GAUGE	STAFF GAUGE		AGRIC/WATER SUPPLY

N°	River Basin	River/tributary	Station Name	District	Coordinates		Hydromet Station Assessment	Recommended Equipment	Datum	Brief Description of site
20		Pumpana	Pumpana bridge at Matotoka	Tonkolili	N 8.67000	W 11. 88503	No staff gauge	Proposed site for DCP	No Datum	Within the premise of MASENCH mining Company, Maning activities carry out along the river
21		Pumpana	Ropity	Tonkolili	N 8.73011	W 11.68483	No staff gauge, new propose site	Proposed site for DCP	No Datum	Proposed site for a big hydro dam project, the site is not accessible except by foot and 15 km away in the forest from the Ropity village
22		JONG RIVER	YANDU/J		824734.6	922897.6785	New site	STAFF GAUGE		
23		TEYE RIVER	MABERO/J		837496.24	930668.6124	New site	STAFF GAUGE		
24		MONGERI CREEK	TISANA JONG RIVER		808476.34	838117.8403	New site	STAFF GAUGE		
25		JONG RIVER	MONGERI JONG RIVER		806685.47	841587.3604	New site	STAFF GAUGE		
26	**SEWA**	WANJE	PUJEHUN	PUJEHUN	201103	819949	NO G/STATION	STAFF GAUGE	NO DATUM	
27		WANJE BANDAJUMA	BANDAJUMA TOWN	PUJEHUN	201106	81938	NO G/STATION	STAFF GAUGE	NO DATUM	
28		LEMBAYMA	LEMBAYMA VILLAGE	BO	207546	837894	STAFF GAUGE	STAFF GAUGE	NO DATUM	
29		BUNDOYE	GOMA	KENEMA	252405	900008	STAFF GAUGE	STAFF GAUGE	NO DATUM	
30		KENEMA	KENEMA	KENEMA	257881	871120	GW	STAFF GAUGE		WR DIRECTORATE
31		RIVER TABE	BUMPE	BO	180295	873412	STAFF GAUGE	STAFF GAUGE	NO DATUM	
32		SEWA	GONDAMA VILAGE	BO	201124	870987	NO G/STATION	Proposed site for DCP	NO DATUM	Within Salwaco Project

N°	River Basin	River/tributary	Station Name	District	Coordinates		Hydromet Station Assessment	Recommended Equipment	Datum	Brief Description of site
33		BABEYE	TONGIE		868800.51	871607.3094	New site	STAFF GAUGE		
34		BEBEYE	TONGI		876823.85	868069.232	New site	STAFF GAUGE		
35		SEWA RIVER BASI	SEMBEHUN		844868.25	862596.4921	New site	STAFF GAUGE		
36		WANNJE RIVER	MATTRU		817669.47	804045.7838	New site	STAFF GAUGE		
37		SEWA RIVER	MANO		818616.91	811135.9262	New site	STAFF GAUGE		
38		SEWA RIVER	6823.85		813664.45	811288.0838	New site	STAFF GAUGE	NO DATUM	SALWACO INTAKE
39	**MOA**	MOA	NJAYEWURO	PUJEHUN	233053	814303	NO G/STATION	Proposed site for DCP	NO DATUM	
40		BATIWA	MANOWA	KAILAHUN	308695	902205		STAFF GAUGE		
41		GOFOR	GOFOR KOMELA VILLAGE	KENEMA	259993	863844	STAFF GAUGE		ND	SALWACO INTAKE
42		UUK MOA RIVER	KAILAHUN		996118.18	923369.8406		STAFF GAUGE		
43		RIVER MAUWA	GENDEMA		968702.69	896087.2981	New site	STAFF GAUGE		
44		MABIYE	GORAHUN 2		913001.27	845333.1394	New site	STAFF GAUGE		
45		MASE RIVER	GOLAWOMA		905599.69	824381.3309	New site	STAFF GAUGE		
46		MOA RIVER	DAR-ES-SALAM		883608.91	785197.7944	New site	STAFF GAUGE		
47	**Little Scarcies**	Mabole	Manegrie	Bambali	N 8.96192	W 12.08611	There is existing staff gauge 4-6 m installed by Onchoserchosis projet	Proposed site for DCP	No Datum	Site within SALWACO water Intake to Makeni
48		Mongo	Musaia	Koinadugu	N 9.75853	W 11.57783	New site	Proposed site for DCP	No Datum	Site within the CHICO compound (SALWACO intake)

N°	River Basin	River/tributary	Station Name	District	Coordinates		Hydromet Station Assessment	Recommended Equipment	Datum	Brief Description of site
49		Mabole	Robat	Kambia	N 8.93094	W 12.83989	Gauge to be rehabilitated	STAFF GAUGE	No Datum	Site accessible
50		MONGO RIVER	MAKA LS		813933.36	1060863.736	New site	STAFF GAUGE		
51		KABA RIVER/LITTLE SCARCIES	PETIFU LS		781264.16	1025866.651	New site	STAFF GAUGE		
52	GBANGBAIA	GBANGBAIA	MOKASI	MOYAMBA	785558	885585	STAFF GAUGE	STAFF GAUGE	ND	PROPOSED SITE FOR HYDROPOWER
53	WRA	WRA	FREETOWN	CAPITAL	697608	930898	SG	STAFF GAUGE		NO SG
54		WRA	FREETOWN	CAPITAL	0		DCP	STAFF GAUGE		

Preconceived stations New stations **DCPs**

5.3.3 Artificial recharge of major aquifers

It is becoming increasingly likely that artificial recharge will be considered in any strategic planning aimed at thwarting the effects of low aquifer recharge occasioned by climatic variability and change. However, there are problems associated with the injection of excess surface water into an aquifer. Artificial recharge is usually associated with water quality issues. Until the effects of introducing water of questionable quality into an aquifer are fully understood opinions will remain divided on the suitability of this adaptation strategy.

5.3.4 Innovative designs of sanitation facilities

Sanitation facilities are highly sensitive to storm surge, sea level rise, and flooding. Wastewater collection and treatment facilities are often situated at the lowest point possible as their operation often depends on gravity flow, hence they can easily be inundated by water level rise. When storm water and sewer collection systems are combined, higher intensity storms can overwhelm treatment facilities leading to a failure of treatment. Hence, climate-sensitive innovative designs of sanitation infrastructure are critical in adapting to climate change.

The Vulnerability of Sierra Leone's water sector

By far the highest vulnerability is the current infrastructure, which still is lacking or very poor and is only now being rehabilitated and has been impacted as a result of the war. Most communities rely on surface water, which has implications in terms of water-borne diseases.

Already, a large percentage of the population has no access to clean water. This will be further exacerbated by climate change.

Major water uses include domestic (drinking, cooking, hygiene), agriculture (irrigation), industrial (beer, spirits, soft drink, cooling and waste disposal), and energy production (hydro electrical power production). Migration of the rural population to the capital, Freetown, during the civil conflict has put considerable pressure on the water demand.

Shifting rainfall has created water supply problems resulting in the decrease to consumers, reduced stream flow of rivers and streams and also health related problems associated with the outbreak of water borne disease.

For example, following the drop in rainfall since 1970s, the flows of major rivers has fallen significantly. The stream flow to the Mano River fell by 30% between 1971 and 1989.

On the other hand intense rainfall and increased flooding could cause serious problems, such as pollution of ground water and destruction of current water-related infrastructure. Long dry spells in north and western areas of the country have already disrupted water supply resulting in negative health impacts. As water resources become scarce and competition for water increases, polluted water may be used for drinking and bathing, and this spreads infectious diseases such as typhoid, cholera and gastroenteritis. These diseases particularly affect the urban poor. Moreover, decreased availability of water for irrigation food production heightens the risk of poor nutrition and increased susceptibility to disease.

The water sector is also already limited in terms of capacity and investment opportunity (especially in the forms of tariffs). The institutional and individual capacity for climate change adaptation is extremely low, leaving this sector particularly vulnerable.

Because virtually all other sectors depend on an effective supply of water, the high vulnerability of the water sector has a “domino” effect on the increasing vulnerability of other sectors, e.g. agriculture, mining, health. It also has major implications on other important aspects, like food security. As a whole it can seriously undermine the Suatainable Development Goals, the improvement of livelihoods.

The fact that 90% of Freetown’s population depends on one water source, the Guma Valley reservoir, puts immense pressure on the source. The Guma Valley Water Company, the company responsible for water provision, has a severely weak monitoring system in place. In 2006, the water level fell way below the intake level causing a major water shortage in the city. On the other hand, during intense rainy seasons, the reservoir is at full capacity – leaving it highly vulnerable to overflow. Either one of these situations causes immense vulnerability to the city’s inhabitants, and with no Early Warning System, or effective monitoring in place, elevates the vulnerability even more so.

5.3.5 Long-term solutions and barriers

The ultimate long-term solution would be to have an enhanced capacity of decision-makers in the public and private sector involved in water provision to plan for and respond effectively to climate change risks on water resources to ensure that water sector investments made are climate resilient, with mainstreamed adaptation in water development frameworks at country level and targeted vulnerable areas, and adaptive mechanisms in place in target pilot sites for up-scaling.

5.3.6 Stakeholder and baseline analysis

International Agencies and donor community in Sierra Leone

United Nations agencies and multilateral donors including the World Bank, EC, USAID, DFID and others maintain an active presence in Sierra Leone and play influential roles in determining national priorities and mechanisms for their implementation in Sierra Leone’s post war reconstruction. The issue of climate change is now high on the international agenda. There is intense pressure on western governments to tackle climate change, largely within the conditions set by peripheral bodies, especially those with funding that needs to be channelled into these activities. But weak institutional capacity faced by Sierra Leone is making funding for the implementation of the NAPA difficult. In addition, programs funded by the World Bank, EC, USAID, DFID and United Nations agencies have emphasized environmental impact assessments, but many are not holding their implementing agencies accountable for integrating climate change adaptation into the design and implementation of these programs.

AfDB Project: Building resilience to climate change in the water and sanitation sector

The AfDB are currently developing a project on water and sanitation sector climate resilience which will focus on water supply and sanitation infrastructure, rural water supply and sanitation programme development, and capacity building – and will include water monitoring and research and adaptation mechanisms at rural level building on this project's activities. The design of the AfDB project will be coordinated with this project, incorporating the good practices and expanding the geographical range by implementing five additional districts not covered by this project.

Non-Government Organizations

Several international NGOs, who formed part of the WASH consortium, will form a strong part of the stakeholder process, especially with regards the work done on community water harvesting conducted in and around Freetown, these include Action Aid Sierra Leone, Action Contre la Faim (ACF), Concern International, GOAL Ireland, Oxfam GB, and Save the Children UK. A breakdown of various NGO activities is given below.

Private Sector

The private sector has already been involved in the project development phase, and will play a large role towards the project's success. This, in terms of water infrastructure investment, but also in terms of improving water society capacity as a result of the implementation of various capacity building initiatives of the project. The Guma Valley Water Company (GVWC), responsible for Freetown's water supply, will directly benefit from the monitoring system to be improved and put in place through the project.

In addition to the recommendations presented at the workshop, one workshop breakout group also included the following additional options for their own consideration:

- Develop and implement a public education plan on Water Resource and Climate Change;
- Put legislative framework in place to support individual storage (cistern) systems for property developments;
- The use of economic instruments (e.g., water tariffs) to modify behaviour and encourage water conservation;

Other interesting topics related to natural dam producing processes in rivers and their possible use as storage for local water supply were also raised, with the need to monitor the water quality of any stored waters and designing appropriate water treatment plants to ensure that a wholesome supply is provided. Noting that the construction of hydros is being up scaled, the development of flood risk mapping was also proposed together with investment in hydrological monitoring.

KEY BARRIERS

Difficulty to react to uncertainty of climate risk

Climate change is a hard issue to address and manage: (1) effects may take a long time to be felt (2) it is still not clear what they will be, and (3) therefore the best way to manage them cannot be predicted with any precision. Above all there is a complex interrelationship with the impacts of environmental destruction because of human action that leaves many societies vulnerable to the slightest change in weather regimes that are so important for their access to clean and safe water.

The increase in variability and unpredictability of global climate will have impacts across the world. In West Africa, rainfall patterns will be disrupted and temperatures will increase, but the detail of these effects cannot be accurately predicted and the effects of climate change at country level are similarly poorly understood. Sierra Leone needs to formulate and start to implement responses to the likely future global changes in climate.

Current policies, strategies and regulatory mechanism have limited or no consideration of climate change issues

Key institutions such as the Water policy Planning and Coordination Unit (WPPCU) and the Environmental Protection Agency of Sierra Leone (EPA-SL), as well as the Meteorological Agency are severely constrained by human resources with the appropriate scientific and technical capacities necessary to internalize climate change issues into policies, strategies and regulatory mechanisms. Without dynamic and sustainable systems, including local competencies to generate and use relevant information on climate change risks (and associated economic impacts), integrated climate resilient policy formulation is severely constrained, if at all possible.

Absence of reliable/up to date information on climate impacts on key sectors

Inadequate staff and poor facilities for weather forecasting and related activities have undermined the ability of the Meteorological Agency to provide adequate support information to other sectors of the economy so that they can better adapt to the impacts of climate change. Gaps in technical skills for generation information on climate change (for example: downscaled or long-term forecasts are non-existent and/or not utilized); there is limited dissemination of available forecasts, and forecasts are not packaged in a format that is accessible to end-users such as district planners or policy makers.

Currently there is no access to reliable information for effective climate risk management. The lack of a climate information communication system enhances the country's vulnerability. Without appropriate information and climate risk management tools, policies will lack the right navigation to govern climate risks in all sectors.

Weak national and local knowledge base on climate impacts, risks and opportunities

As a result of the war, desegregation of communities due to migration has severely weakened the local knowledge-base with limited transfer of indigenous skills between and within communities. The use of available global and other external knowledge bases is also limited for a number of reasons that span from awareness that various tools exist and are available to knowing what to do with the information once it is secured. Consequently, it is not surprising that there is limited public awareness of (a) climate change impacts, (b) adaptation measures, and (c) how human interaction can either diminish (through adaptation and preparedness) or exacerbate climate change impacts.

Public financing shortfalls lead to insufficient coverage of climate resilient water supply

Since 2008, local councils have been required to manage all urban water supply activities (except Freetown) and peri-urban water supply schemes. Unfortunately, these decentralized public bodies are frequently not prepared for the task, lacking finances, capacity and institutional authority to respond effectively to the demands of the population, specifically on climate resilient water supply systems. Scarce public finance needs to be used to catalyse and leverage additional resources for the necessary investments for the operation, maintenance, and management of vulnerable infrastructure.

Insufficient sharing and learning mechanisms on climate change

Climate risk information, adaptation options and knowledge are not shared and disseminated as widely as needed to enable communities to cope with the adverse climate impacts. There is no learning system in place to capture, codify and inform scaling up methods. In addition, there is no regular flow of information and dialogue on climate change between parliamentarians, local council members, traditional authorities, NGOs/CBOs, and the private sector.

Overall poor water and other infrastructure

Since the war only just some basic water infrastructure has been rehabilitated or newly established. Investments into the development of new or old water infrastructure are being made by several donors both for urban water supply in Freetown and in the various districts. This specific project is designed to assist some such donor supported investments in building climate resilience in their project work. But it is recognized that the overall infrastructure challenges are still a major concern and barrier to achieving the overall solution.

Limited technical capacities

Similarly, it is recognized that in Sierra Leone the technical capacities are very limited, mostly as an entire generation of (young) professionals is missing due to the war. One key barrier is the lack of technocrats and practitioners in the water sector including water engineers and others, another is that those professionals who are employed often lack the opportunity for professional updating on emerging issues such as climate risks and adaptation options and solutions in the water sector.

5.3.7. Solution:

Difficulty to react to uncertainty of climate risk
Putting in place a sustainable climate risk information and communication system to facilitate access to data will go a long way in improving the uncertainties, and towards planning for climate risks and projections.

Enhanced capacity and understanding of climate risk management in the technical staff pool as well as within the decision-makers base will improve planning for resilience and climate risk management.

Putting in place climate smart infrastructure which is resilient as a pro-active approach will enhance overall access to water within a climate insecure future.

Effective monitoring systems, especially for the Gum Reservoir, which provides water for 90% of Freetown, will secure pre-planning for water access and also help towards building an Early Warning System.

Current policies, strategies and regulatory mechanisms have limited or no consideration of climate change issues
Capacity building initiatives of both technical staff and decision-makers will enhance understanding of climate resilience and risk management for effective integration of climate risk into planning and policy development.

The envisaged bottom-up approach in which dialogues are formed between all decision-makers will also create a platform in which planning can be conducted based on vulnerabilities within the water sector to climate change.

Effective monitoring, as well as a central climate communication and information system, will also aid planning and policy development in an integrated and climate smart manner.

Absence of reliable/up to date information on climate impacts on key sectors
Enhanced capacity of key staff, coupled with an integrated and sustainable climate information and communication system will greatly enhance the information necessary for planning, including information necessary for climate smart investments and development.

Weak national and local knowledge base on climate impacts, risks and opportunities
With capacity building programmes at institutional and local level, a sample of working force will have a much better understanding of the risks and impacts of climate change, as well as the potential of coping mechanisms and resilience.

A sharing of information on existing coping mechanisms, what works, and what doesn't will help shape up country knowledge, at community level, the opportunities that exist within the adaptation arena to create and maintain resilient water supply infrastructure.

Public financing shortfalls lead to insufficient coverage of climate resilient water supply

Private Public Partnership building will support cooperative responsibilities in climate smart water supply infrastructure investments, create a platform for innovative entrepreneurships for effective water supply and harvesting mechanisms.

Overall poor water and other infrastructure

With support to various existing developments for climate smart infrastructure, specific to site, such as earth dams in more arid zones, rainwater harvesting mechanisms for humid areas, could greatly enhance the water infrastructure in Sierra Leone.

Limited technical capacities

Targeted capacity building approaches through both components of this project will focus on climate risk analysis and management, especially within the pool of engineers, community water supply practitioners, government officials, and the like.

Despite the vital contributions of groundwater to human welfare and ecosystems, our understanding of the sustainability of current and projected groundwater demand, its impact on the earth system, and the impact of climate change on groundwater is limited. The International Association of Hydro geologists' Commission on Groundwater and Climate Change (IAH-CGCC) and UNESCO-IHP GRAPHIC Programme are working together to improve our limited understanding of the relationships among groundwater, human development, and climate change. To achieve this goal, we have the following key objectives:

- To promote international and inter-disciplinary research among hydrogeologists, climate scientists as well as physical, social, and health scientists regarding the relationship between groundwater and climate change;
- To facilitate the dissemination of knowledge and exchanges of experiences related to groundwater and climate change through the organisation of conferences, lectures and meetings as well as the preparation of books, journal articles and popular articles; and
- To coordinate research activities and knowledge dissemination pertaining to groundwater and climate change with allied global initiatives.

5.3.8 Constraints to the Water Resources Assessment

Much of the assessment for the water sector was qualitative in nature, although some quantitative analysis was presented.

CONCLUSIONS AND RECOMMENDATIONS

REFERENCES

5.4 Human Health

5.4.1 Main Characteristics of the Human Health Sector of Sierra Leone

Health Sector

According to Statistics Sierra Leone (2004), the average population density is about 75 inhabitants per square kilometre. Life expectancy at birth is 41.1 years and the fertility rate (i.e. births per woman) is 6.5. The infant mortality rate is 165.4 out of 1,000 live births. Whilst according to the latest WHO data published in 2015 life expectancy in Sierra Leone is: Male 45.8, female 46.2 and total life expectancy is 46.0 which give Sierra Leone a World Life Expectancy ranking of 178. Malnutrition and low birth weight are among the top 20 causes of death in Sierra Leone.

Significant scale-up in investment in health care was achieved under Sierra Leone's Second Generation Poverty Reduction Strategy – Agenda for Change. There was a major roll-out of free health care services for pregnant women, lactating mothers, and children under five nationwide; health infrastructure and health management systems received higher investment and improvement. Maternal and child mortality rates have dropped significantly, and the incidence of HIV/AIDS has remained low and under control. Access to water supply has increased; improved drinking water now reaches well over half of the population, and access to adequate sanitation has grown substantially.

Prosperity for Sierra Leoneans will be measured by the levels of access to reasonable health care; high quality education; and equal opportunities for all, regardless of age, gender, religion and tribe, and with special attention to the needs of the disabled and vulnerable. Thus, improvements in the quality of life for ordinary citizens will be reflected in incremental changes in the UNDP Human Development Index (HDI). Sierra Leone's HDI was 0.33 in 2010 (below the average for Low HDI countries, at 0.45). The target is to improve these figures radically over the medium term, by aiming for Sierra Leone to achieve the average Medium HDI level (0.625) in 25 years' time. This would take the HDI to a level higher than the current rates of many countries (GOSL, 2012).

Gains in the human development index will involve improvements in health and education indicators. Health targets include increasing life expectancy by 10 years (from 47 to 57 years) over the next 25 years. They will involve providing access to a modern hospital for every mother; building on the Free Health Care and Scaled-Up Nutrition Initiatives, and improving the number of doctors, nurses, and other essential medical personnel; increased coverage for child immunization, as well as increased percentage of the population with access to clean water and sanitation facilities. Education is one of the most transformative factors among the social services to be delivered. The march to prosperity will require that the country improves basic, secondary, technical and tertiary education systems, with wide access across the population and especially for girls, to better meet the needs of society, and of growing investment opportunities.

Sierra Leone is facing serious challenges in delivering health care services. The country has a poor health status mainly due to a high disease burden caused by environment related communicable diseases and aggravated by poor nutrition. Malaria (38%), acute respiratory infection (16.9%) and watery & bloody diarrhea (9.7%) are the top most causes of outpatient attendance, together accounting for about 65%. Although stunting prevalence in under-fives has decreased from 40% in 2005 to 36.4% in 2008, poor nutritional status is still a public health problem in the country. Public Health services are delivered through a network of health facilities in the country. This network consist of 1,040 Peripheral health facilities which are composed of Community Health Centres (CHCs), Community Health Posts (CHPs), Maternal and Child Health Posts (MCHPs) and 40 hospitals (23 government owned and the rest owned by private, non-governmental and faith based organizations). These health facilities, which are inadequately equipped and under-staffed, provide only limited services to the population.

Table 5.4 shows the leading causes of hospitalization and death in Sierra Leone in 2005.

Hospitalisation	Deaths
Obstetrics	Cerebrovascular diseases
Accidents and Injuries	Neoplasms
Diseases of the respiratory system	Diabetes
Diseases of the circulatory system	Diseases of the respiratory system
Diseases of the digestive system	Ischemic heart disease
Nutrition and endocrine conditions	Trauma, homicides, injuries
Diseases of the genitor-urinary system	HIV/AIDS
Watery and bloody diarrhea	Malaria

Sierra Leone's health care delivery is organized in a three tier system. The first tier includes the Peripheral Health Units (PHU); the second, District Hospitals; and the third, the Referral Hospitals. The PHUs are the first line health services, and are further sub-classified into three levels. a) The maternal and child health posts (MCHPs) are situated at village level for populations of less than 5000. They are staffed by MCH Aides who are trained to provide numerous services, namely: antenatal care, supervised deliveries, postnatal care, family planning, growth monitoring and promotion for under-five children, immunization, health education, management of minor ailments, and referral of cases to the next level. The MCH Aides are supported by community health workers (TBAs, Community volunteers, etc). b) Community Health Posts (CHPs) are at small town level with population between 5,000 and 10,000 and are staffed by State Enrolled Community Health Nurses (SECHNs) and MCH Aides. They provide the same types of services that are provided at the MCHPs but they also include prevention and control of communicable diseases and rehabilitation. They refer more complicated cases to the Community Health Centres. C) the Community Health Centres (CHCs), which are located at Chiefdom level, usually covering a population ranging from 10,000 to 20,000 and staffed with a community health officer (CHO), SECHN, MCH Aides, an epidemiological disease control assistant and an environmental health assistant. They provide all the services provided at the CHP level in addition to environmental sanitation and supervise the CHPs and MCHPs within the Chiefdom. The district hospital is a secondary level facility providing back-stopping for the PHUs. It provides the following services: outpatient services for referred cases from PHUs and the population living within its immediate environs, inpatient and diagnostic services, management of accidents and emergencies, and technical support to PHUs. when compared to the health facilities and the population they serve, a clear picture is drawn showing that HCFs are not evenly distributed among the population, thereby increasing the struggle to get appropriate health care services in the country.

Table 5.4.1 Type of health facilities and number beds

Type of Facilities	Number of facilities	Mini Bed	Max Bed	Serve a population
Government Hospitals	23	45	More than 100	5000000
CHC	178	6	12	10-30000 (5-10miles radius
Private Hospital	48			
NGO	17			
CHP	176	bed only used for observation		5000- 10000 (5 miles radius)
MCHP	520	Bed only used for observation		500- 5000 (3 Miles radius)

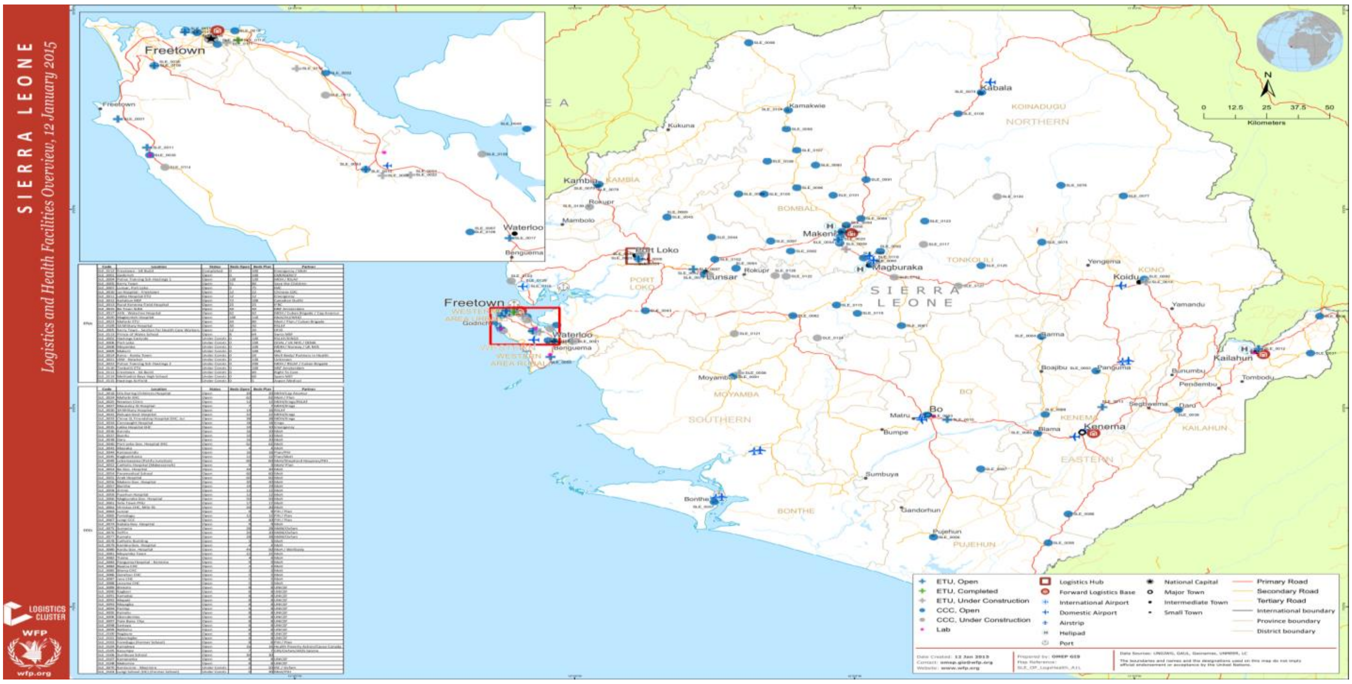
The limitations in the numbers and distribution of government health facilities make it difficult for the Ministry of Health and Sanitation to provide services across the Sierra Leonean population by itself. For this reason, the Government is giving considerable attention to work out ways whereby the private, not-for-profit and for-profit sectors can become responsible partners in health care implementation.

Table 5.4.2 Distribution of health facilities in Sierra Leone

	Government					Mission		private		NGO	
District	**CHC**	**CHP**	**MCHP**	**Clinic**	**Hospital**	**Clinic**	**Hospital**	**Hospital**	**Clinic**	**Clinic**	**Total**
Bo	**23**	**12**	**50**	**1**	**1**	**6**	**1**	**0**	**11**	**3**	**108**
Bombali	**16**	**20**	**49**	**0**	**2**	**3**	**2**	**1**	**3**	**0**	**96**
Bonthe	**9**	**9**	**20**	**0**	**2**	**2**	**1**	**0**	**0**	**2**	**45**

Kailahun	**9**	**34**	**12**	**0**	**2**	**1**	**1**	**0**	**0**	**0**	**59**
Kambia	**11**	**8**	**31**	**0**	**1**	**2**	**0**	**0**	**0**	**1**	**54**
Kenema	**21**	**17**	**63**	**1**	**2**	**2**	**1**	**0**	**3**	**1**	**111**
Koinadugu	**12**	**6**	**33**	**1**	**1**	**0**	**0**	**0**	**0**	**1**	**54**
Kono	**11**	**15**	**46**	**0**	**1**	**1**	**0**	**0**	**4**	**4**	**82**
Moyamba	**12**	**6**	**56**	**1**	**2**	**5**	**0**	**0**	**0**	**1**	**83**
PortLoko	**11**	**21**	**55**	**0**	**2**	**4**	**1**	**0**	**1**	**0**	**95**
Pujehun	**14**	**10**	**25**	**0**	**1**	**0**	**0**	**0**	**0**	**0**	**50**
Tonkolili	**9**	**8**	**65**	**0**	**1**	**1**	**2**	**0**	**0**	**1**	**87**
Western Area	**20**	**10**	**15**	**7**	**12**	**11**	**2**	**2**	**23**	**3**	**105**
Total	**178**	**176**	**520**	**11**	**30**	**38**	**11**	**3**	**45**	**17**	**1029**

Figure 5.9 Map showing the distribution of hospital in Sierra Leone



5.4.1.2 Primary Health Care in Sierra Leone

The main providers of health care in Sierra Leone are traditional medical services, allopathic private medical services, government medical services in rural health centers, public health programs in rural areas, and hospitals in urban areas.

Government is struggling against enormous hurdles to improve health care situation in Sierra Leone and is committed in meeting the Abuja target of 15% of the national budget (Abuja Declaration of ECOWAS Heads of State, Abuja Nigeria)to be allocated to the health sector. This is in itself will be grossly insufficient to finance the effective in delivery health care service in the country. The state of impoverishment of the population precludes the recovery of any reasonable degree of health sector costs from the consumers. Job opportunities have been and continue to be scarce, and the pursuit of sustainable livelihoods is elusive. Sierra Leone will certainly be dependent on large amounts of foreign assistance for many years to come. The government human resources for health are grossly inadequate both in quantity and quality. Factors responsible for these include among others, low motivation, low salaries, inadequate staff quarters, slow career progression and a high attrition rate. The reluctance of key personnel, especially clinical, to live and work in the rural areas where their services are most needed, continues to pose problems of adequately staffing health facilities. As is usually the case, the health sector in post-conflict Sierra Leone is fragmented by vertical programs and global initiatives. Furthermore, the MoHS recognizes that it will not have the ability to deliver services to the entire population alone and therefore allows private organizations to be responsible for service delivery. Therefore, its attempts to implement local priority programs such as climate change programs would require proper coordination of the activities of all partners and other relative sectors. The capacity of the public sector has been strengthened by the setting up of various structures to coordinate and monitor the many players charged with service delivery by the national Health Policy and Strategic Plan 2010-2015.

An increase in the population under the age of 15, together with decreasing life expectancy, war and disease outbreaks, has resulted in a rapid demographic transition. At the other end of the spectrum, the population aged less than five years forms about 20 percent of the population.

5.4.1.3 Cause of Death in infant and under five

According to the Sierra Leone Demographic Health survey 2008, infant mortality rate 89 per 1,000 live births, under-five mortality rate 140 per 1,000 live births and a maternal mortality ratio of 857 per 100,000 births. A Majority of the causes of illness and death in Sierra Leone are preventable, with most deaths attributable to nutritional deficiencies, pneumonia, diarrhea diseases, anemia, malaria, tuberculosis and HIV/AIDS. Malaria and watery & bloody diarrhea. Malnutrition in under-five children is high with a prevalence of underweight, stunting and wasting (2 SD ≤ / 3 SD ≤) of 21.1 / 3.5%, 36.4 / 20.6% and 10.2 / 4.2%, respectively. Malnutrition is the underlying cause of morbidity and mortality in under five children, with pneumonia, diarrhoea, malaria, neonatal problems, and HIV/AIDS being the major direct causes. Malaria is the leading cause, accounting for about 41% of all hospital deaths among under-fives. Acute respiratory Infection (ARI), anaemia and diarrhoea accounted for 17%, 12% and 5%, respectively, of the deaths among children under-fives at hospital. (HMIS Data 2010). In addition, two out of every five child deaths are due to malaria. The survey also reported that over 24% of children younger than five years had malaria in the two weeks preceding the survey; 26% of under-fives and 27% of pregnant women slept under ITNs; only 15% of children with fever received anti-malarial medicines within 24 hours of onset of symptoms, and less than 2% of under-fives received the drug within 24 hours (SLDHS, 2008).

Table 5.4.4 shows the causes of death in the under -five age group in Sierra Leone from 2008 and underscores the importance of diarrhea diseases. Infant mortality rate 89 per 1,000 live births, under-five mortality rate 140 per 1,000 live births.

Table 5.4.4 Causes of death in the under five age group in Sierra Leone (2008)

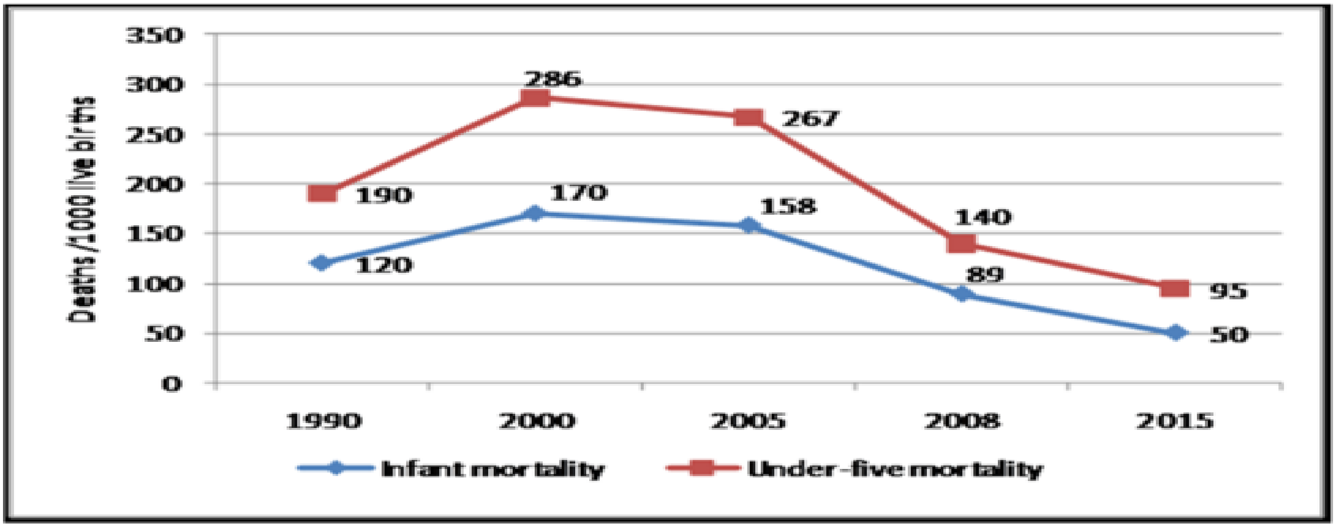
Diseases	Percentage
Malnutrition	46%
diarrhoea,	5%
malaria,	24%
neonatal problems	17%
Acute respiratory Infection	20%
anaemia	12%

(Child Health Policy 2007)

Table 14.23 Rate of death in the under five age group in Sierra Leone (2005 and 2008)

	2000(MICS2)	2005 (MICS3)	SLDHS 2008
Infant mortality rate (per 1000)	170	170	89
Under five mortality rate (per 1000)	286	286	140
Maternal Mortality Ratio (per 100,000)	1800	1300	857
Underweight prevalence (2 SD ≤ / 3 SD ≤)		31 / 9	21.1 / 3.5%
Stunting prevalence	34/16	40/20	36.4/20.6%

Sources : MiCS 2000, MICS 2005 and Sierra Leone Demographic Health Survey (DHS) of 2008



- Figure 5.10 Sierra Leone:Analytical summary - Health Status and Trends

The graph above shows that infant and under five mortality rate increase in 2000 and 2005, where as in 2008 the date rate stated decreasing until 2015 reflecting the measure government put in place to address the high infant and under five mortality rate in the country (free health care for under five and pregnant woman)

Recent Developments

The government of Sierra Leone has made substantial investments in health, with the help of it partners. Health services provided by the government include health education and promotion, maternal and child health care, immunization, prevention and control of locally endemic diseases (provision of bed net for Malaria), prevention, control, and management of common diseases and injuries. Over the past years, the country has improved its health indicators especially in maternal and infant mortality and life expectancy. Due to increased life expectancy and changing disease patterns, Sierra Leone now faces a major challenge to provide health services for non-communicable diseases, such as diabetes, cancer, heart diseases, mental health disorders, and injuries. Apart from these issues are the increasing trends in new epidemics - namely the vector, rodent, water and food borne diseases - which may be further exacerbated due to climate change and require increasing attention in this context.

In Sierra Leone the incidence of vector borne diseases such as Malaria continue to rise whilst others are curtailed. Lassa is another major health issue that needs to be actively addressed. Morbidity due to diarrhoeal/water-borne diseases also remains high to date. Irrespective of the impact of climate change on the incidence of these diseases, there are well defined primary, secondary and tertiary preventive measures aimed at minimizing the disease burden, deaths and disabilities. These measures are worth considering as currently existing measures, which can be stepped up in Sierra Leone effort to adapt to climate change.

The overall strategy of assessment of the burden of priority diseases in the country by the health sector reviews the situation of these diseases. Information with regard to public health issues are already available over a long period of time and they provide the baseline for comparative purposes for vector borne, rodent borne, diarrheal and respiratory tract diseases which are the main diseases currently linked to climate change in Sierra Leone. Policies and plans aimed at reducing public health issues Policies, the incidence and impacts of these diseases should be initiated and implemented by the development of strategies and action plans. Such plans include:

- Malaria Control action plan (ongoing)
- District Diarrhoeal Disease control plan
- Lassa control plan
- Response system plans

5.4.2 The Institutional Arrangements for the Management of the Health Sector in Sierra Leone (Adaptive Capacity)

The adaptive capacity of a country to respond to climate change related health impacts depends to a large measure on the efficiency of the health system. Until 2001, health care in Sierra Leone was organized, delivered, and coordinated centrally by the Ministry of Health in Freetown.

Under the National Health Services Act, the functions of the Ministry were decentralized. Delivery was assigned to four provinces, while policy, planning and purchasing functions were retained by the Head Office. The objective of the exercise was, in part, to make the system more sensitive and responsive to local needs.

The South Eastern Region embraces Bo, Moyamba, Kenema and Kailahun. The North, comprising Koinadugu, Bombali and Tonkolili. The Western Region comprises Freetown.

Decentralization of services were supposed to confer several benefits to the populations served –greater sensitivity to local preferences, reduction in inequalities, cost containment in view of sharper targeting, greater capacity to involve local community. An evaluation of the impact of decentralization in Sierra Leone concluded that the actual benefits were less than expected and there were minimal improvement in service delivery or in the health of the population of the districts (MOHS, 2007).

A major problem appears to be under -financing. The activities in country are financed by external donors and grants from the government Despite increases in the grant, there is are source gap.
This has affected the ability of the country to attract trained technical personnel. The Ministry of Health has encountered problems in the diagnosis and treatment of hemorrhagic fever both in the health centres and among private physicians. The problem should be addressed through staff training through the Medical and Dental Association of Sierra Leone as well as direct contact with private physicians (Huntley, 2008).

Institutional and Policy Framework

The main institutions and agencies that have an impact on management of the health sector in the country are given in Table

Ministries	Key Directorate	Other Units
Ministry of Health and Sanitation	• Directorate of Environmental Health Services -Epidemiology Unit -Environmental and Occupational Health -Medical Research Institute -Anti-Malaria Campaign -Anti-Filaria Campaign -National Dengue Control Unit - Integrated waste management -ESICOME -Housing and vector unit • directorate of Diseases prevention and control • Family Health • Health Education	• State Pharmaceutical Corporation • State Pharmaceutical Manufacturing Corporation • All National, Teaching and Specified Government Hospitals • Private Hospital Regulatory Body • Association of Private Hospitals

• Ministry of Education City Council	Medical faculties of the Universities Environmental and Social unit	Municipal Solid Waste Management MASSADA Waste Management Company Klin Salone Waste Management Company
Office of the President • Ministry of Child Development & Women's Affairs	Environmental Protection Agency National Child Protection Authority	
Ministry of Agriculture	Directorate of forestry	•
Ministry of Water Resources	Water Resources Board National Water Supply and Drainage Board (NWS&DB)	• Irrigation Department
Ministry of Media • Ministry of Provincial Councils and Local Authorities	• Local Authorities	Justice system and legal authorities including police
Ministry of works and Infrastructure	Sierra Leone Road Authority	Other construction companies

The free healthcare system provided by the government aims to ensure easy access to quality and modern healthcare services for all with emphasis on the needs of the poorer and most vulnerable population segments Children and pregnant woman). The Ministry of Health has a strong ground level health services network to support public health requirements through the free services provided by Public Health Inspectors, and the Medical Officers of Health/Divisional Health Officers. Networks such as the Maternal and Child Health (MCH) programme coordinated by the Ministry further strengthen the available services especially for women and children. Traditional medicine as well as private sector health developments are encouraged and promoted in complimenting the free national healthcare system.

Apart from the ministries several UN Agencies, International NGOs, local NGOs, and bilateral and multilateral agencies are also involved in the health sector actively.

National Health Policy (2006 - 15) & Strategic Plan (2006 - 10)

In the National Health Policy (2006 - 15) and Strategic Plan (2006 - 10), the Ministry of Health outlined the policy context in which priorities for health were developed (MOH, 2005). The Sustainable Development Goals were taken into account, with plans to target the health of mothers and their children, infectious diseases especially HIV/AIDS and malaria, water and sanitation, as well as access to essential drugs.

The national context was also taken into consideration, i.e., the physiographic, demographic, economic, and social realities of the country. However, despite accidents and injuries being the leading causes of morbidity and mortality, and diabetes and hypertension increasing causes of concern, the outcome indicators of the plans are heavily weighted in favour of risk/lifestyle behaviours – drug use, sexual practices, road safety, and obesity.

Key policies and legislations that govern the health sector are shown below.

Main legislations governing the Health sector	Other legislations having impact on the Health sector	Key policies/plans/strategies governing the Health sector
○ **public health Ordinance** **Environmental Health and Sanitation policy and strategy** **Environment Social Management Framework**		• Health Master Plan 2006 • National Malaria Action Plan 2004

The possible impact of climate change on health is not specifically mentioned. However, surveillance of internationally notifiable nationally monitored newly emerging and re -emerging diseases are mentioned as goals. Emerging and re -emerging diseases are considered a consequence of the ecological changes associated with climate change and the unsustainable use of resources. So there is some recognition in the Plan, though not explicit, of the likely effects of climate change.

Moreover, in response to the threat of emerging and re -emerging diseases as well as the anticipated changes in vector borne diseases, the Ministry of Health prepared a national vector control plan with the goal of re establishing a Vector Control Unit in the Ministry (Huntley, 2008). The plan makes proposals for financing in the areas of staffing, procurement of supplies, adaptation of new technologies and strategies for vector control, the strengthening of surveillance systems, and the improvement of inter -sectoral, inter -agency capacities and research. Staff shortages are affecting the vector control programme since councils are not adequately staffed to conduct surveillance at the levels required and with the projected increase in abundance. There is some surveillance of high risk communities and at ports of entry, however significant percentage of the surveillance equipment was non -functional. The virology laboratory is under -equipped. The Ministry of Health has also identified a need for operational research into the best method of control for vectors.

Other relevant organizations

Prevention, preparedness and enhanced response to the health threats posed by climate change require inter agency and intersectoral cooperation. Already,

some key agencies in Sierra Leone are working together on health issues, although more focused on disaster related health concerns.
These include but not limited to:

The Disaster Management Department (DMD) under the Office of National Security has a mandate to develop and administer disaster preparedness policies and to manage all aspects of disaster mitigation. It does so by working in partnership with other ministries, agencies and departments, an approach which allows it to influence national risk reduction (Heslop -Thomas *et a*l, 2008). In so far as climate change is concerned, sea level rise and the inundation of coastal areas, with resulting population displacement, are the DMD's areas of greatest concern. Health is not seen as a part of their basic mandate, per se.

The Meteorological Service provides warnings and advice on extreme and hazardous weather phenomena. The officials there saw their role as far as climate change was concerned in terms of weather observation for those sectors that may be affected by the phenomenon, and communicating the information both to the stakeholders and the public (Johnson*et al*, 2008). There was full appreciation of the health implications of climate change – those related to heat stress, respiratory diseases as well as the role of higher temperatures in the transmission of vector borne diseases.

The Water Resources Authority is responsible for the regulation, conservation and management of the water resources ,and provides technical advice to the government and its agencies. The Water Resources Development Master Plan, should be develod to provide a complete inventory of the water resources, including the level of availability and demand.

The Forestry Department conserves and protects the country's forests, manages forested watersheds, protected lands and forested lands and gives advice to private land owners on the management of private forests. They also develop programmes for soil conservation. Their mandate covers a resource that is vital to the development of sustainable water supplies.

There are also international organizations involved in emergency preparedness and response. UNICEF, for example, in response to its mandate to protect disadvantaged children supports the activities of DMD in the wake of disasters, supplying food, shelter and emergency kits. As a result, there is a relatively high level of preparedness for disasters. However there are several areas where improvements are necessary – community preparedness, increase in emergency stocks, emergency water supplies, and improvement in community shelters. But as important as these initiatives may be, they cover just one aspect of the preparedness and they are not sufficiently focused on people and the health impacts of the hazard. A similar structure but one that is more inclusive, that is capable of providing a response to the broader health implications of climate change is necessary.

4.4.3 Vulnerability of the Health Sector in Sierra Leone to Climate Change

Sierra Leone is vulnerable to climate change factors such as extreme conditions of temperature and rainfall that is currently presenting itself. These conditions will influence the prevailing ecosystem equilibrium with changes in hydrology and agriculture, which will influence microbial contamination pathways. Transmission dynamics of vectors which are common in the country are vulnerable to change depending on environmental factors such as temperature, rainfall regimes, sanitation, etc. The broad categories of health outcomes which are anticipated to increase are morbidity and mortality through air pollution, water and food borne diseases, vector and rodent borne diseases and effects of food and water shortages. The performance of the health sector is heavily dependent on the performance of other sectors including water, agriculture, fisheries and livestock, urban infrastructure and human settlements. These sectors are addressed in separate Sector Vulnerability Profiles . In dealing with public health issues, the necessity to work in close collaboration with the other sectors is critical in addressing climate change.

General overview of the impacts of climate change on health

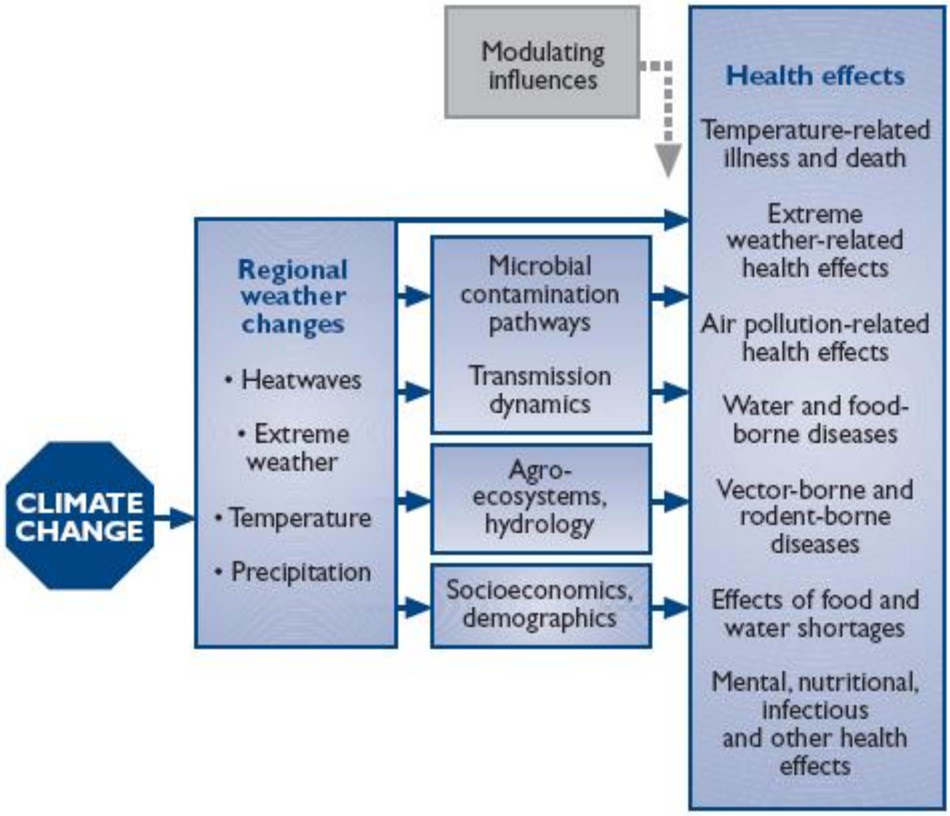
The Health Sector is vulnerable to climate change. Higher temperatures in the tropics and subtropics tend to increase disease out breaks and to encourage vector proliferation. Greater variations in precipitation patterns increase the likelihood of communicable and water-borne diseases. The overall impacts of climate change on health are expected to be negative, threatening national development goals. The impacts are:

- Direct, on health and health related activities domestically;
- Indirect, on availability/prices of food domestically and in international markets ;
- Indirect, on incomes at the country levels;

While the general consequences of climate change are becoming increasingly well known, great uncertainty remains about how climate change effects will play out in specific locations.

A comprehensive review of the issues related to climate change impacts on health has been produced in a book called *Climate Change and Health: Risks and Response* by Mc Michael et al. (2003). The various pathways by which climate change can impact on human health are complex, as shown in the Figure below.

Figure 5.11 Pathways by which climate change can impact on human health



Exposure to Weather Extremes

Indeed, Sierra Leone is experiencing climatic hazards such as seasonal drought, strong winds, thunderstorms, landslides, heat waves, floods and changed rainfall patterns. As reported in the Sierra Leone's National Adaptation Programmme of Action (NAPA), poor communities have suffered the most from climate change impacts, as floods and increased droughts caused water shortages in some areas of the country. As an example of predicted climate change impact on health, for temperature above 25° C malaria infection is expected to rise. Other diseases such as cholera, diarrhea etc. are projected to be positevely affected by climate change. The rainfall in the country is increasingly becoming sporadic and in the last two years more rain has fallen in March which is the driest month of the year than the last three decades. Furthermore, the country is now experiencing prolong period of dry days even in the months of July/august and September which are supposed to receive the highest precipitation. The heavy rains now falling in March have increase the likelihood of the outbreak of communicable diseases.

Economic consideration

Pathways of exposure of human health to climate variability are twofold. Direct exposure occurs through events such as frequent extreme weather conditions while indirect bearings are exerted through changes in quantity of air, ecosystems, agriculture and livelihood infrastructure, etc.

The direct impacts on health are mainly those due to changes **in exposure** to weather extremes. These include extremes in temperature (heat during the dry season and cool during the rainy season in tropical regions), extremes in precipitation (floods and droughts), and extremes in wind (tornadoes and storm surges). Increased production of certain air pollutants and aeroallergens (spores and moulds) may also be directly linked to the weather. The impacts of climate change will depend on the extent of change in the frequency, intensity and location of extreme weather events due to climate change, which remains uncertain.

Climate change, acting via less direct mechanisms, could also affect the transmission of many infectious diseases (especially water, food, vector -borne, and rodent -borne diseases) and regional food productivity (especially cereal grains). In the longer term, these indirect impacts are likely to have greater magnitude than the more direct (McMichael et al., 2001, and Epstein, 1999).

Other illnesses, such as mental stress, could also be indirectly be impacted by climate change.

Climate change is only one of several important factors influencing the incidence of infectious diseases.
Other important considerations include human migration and transportation; drug resistance and nutrition; environmental influences such as deforestation; agricultural development; water projects; and urbanization. In this era of global development and land -use change, it is highly unlikely that climatic changes exert an isolated effect on disease. Rather, the effect is likely dependent on the extent to which humans cope with or counter the trends of other disease modifying influences. While recognizing the important independent role of these non -climatic factors, the focus of this section is to examine the extent to which they may compound the effects of climatic conditions on disease outcomes.

When ecosystem equilibrium is compromised, social and economic factors such as increasing population densities, can aggravate the negative health outcomes that could emanate from climate change. Sierra Leone depends on its minerals and agriculture for food security and has still not reached its optimal potential in terms of providing enough food of the population. Climate change is envisaged to have severe impacts in terms of growth and development of children and productivity of older age groups and future generations. The socio economic status of the country is bound to be affected if the main determinants to health, which are affected by climate change, are not addressed

Sensitivity

Diseases prevalence in the country is very sensitive to climate and climate variation. Health is one of the largest socio economic sector in Sierra Leone, employing over 55% of the labor force. The fluctuation in yearly diseases trend is mostly due to weather effects and climate variability. The impact of climate change is already tangible in the country.

Sierra Leone is at the point in the epidemiological transition in which, while non -communicable diseases are the leading causes of death, the health system must still cope with infectious and parasitic diseases as well as rising levels of HIV/AIDS and intentional and unintentional injuries.
Table 5.22 shows the varying sensitivity to climate changes to the communicable diseases that can affect the Sierra Leonean population.

Table 5.22: Sensitivity of Communicable Diseases to Climate Change in Sierra Leone

Very weak	Some sensitivity	moderate	strong	Very strong
Intestinal nematodes	Influenza Diarrhoeal diseases	Meningococcal meningitis	Dengue	Malaria

Source: World Health Organization (2000a)

With respect to the leading causes of death in Sierra Leone(Table 4.20), heat stress increases susceptible to a high incidence of cerebrovascular diseases, but this is considered to be of greater importance in cold than in hot countries. This problem, however, could be exacerbated by the construction material used and the design of housing. Buildings need to be designed to reduce heat stress and vector -borne diseases. Of the respiratory conditions prevalent in Sierra Leone, asthma is a cause for concern with respect to climate change. Rising carbon dioxide levels could increase allergenic plant pollens. Increasing quantities of dust clouds containing minute particles and microbes are blown into West Africa from the Sahel region of Africa. The African atmospheric system is a long standing phenomenon. However, human activity in the expanding desert region of Africa has intensified the problem and dust concentrations in West Africa can be correlated with rainfall deficits in the Sahel. Climate change and increasing drought could therefore have a significant effect on the concentration of dust.

Vulnerability

The country has a poor health status mainly due to a high disease burden caused by environment related communicable diseases and aggravated by poor nutrition. Malaria (38%), acute respiratory infection (16.9%) and watery & bloody diarrhoea (9.7%) are the top most causes of outpatient attendance, together accounting for about 65%. Although stunting prevalence in under-fives has decreased from 40% in 2005 to 36.4% in 2008, poor nutritional status is still a public health problem. The above-mentioned three diseases together with malnutrition account for about 70% of under– five consultations. Although the under–fives constitute about 17% of the population, they make up 49% of consultations at PHUs. Malaria is hyper – endemic/holo-endemic in the country

and affects the whole population, but children under five years and pregnant women are most vulnerable with high morbidity and mortality rates. The country also, from time to time, experiences outbreaks of the following epidemic prone diseases: Cholera, Yellow fever, Shigellosis, Lassa fever, Measles and Meningitis.
Various aspects of public health are also vulnerable to climate change impacts, including sanitation, water supplies, and disaster responses.

Public health concerns influenced by climate change

Climate change may contribute to social disruption, economic decline and displacement of populations and overall decline in human health in certain regions due to effects on agricultural production, water scarcity, extreme weather event, etc. It is therefore essential to have a better understanding of the relationships between climate change and human health along with cross sectoral linkages

Climate change impacts are significant for the following areas:

• Vector borne diseases–essentially mosquito borne diseases

• Rodent borne diseases

• Food and water borne diseases

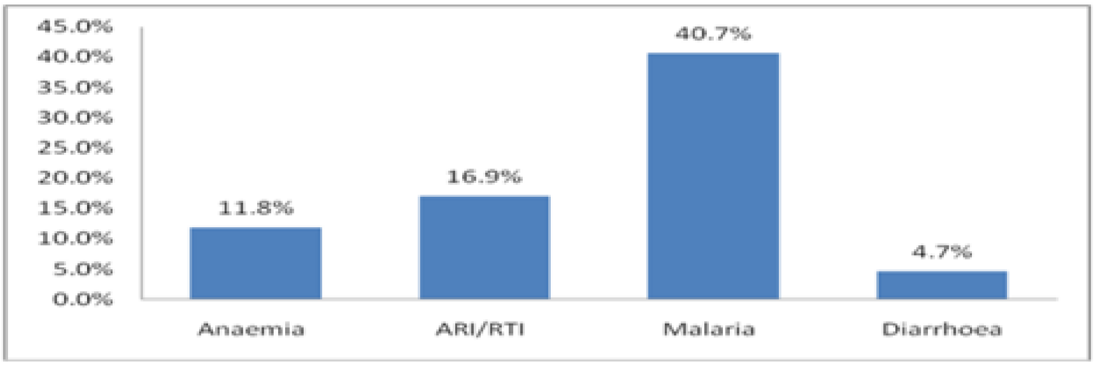
• Nutritional status

• Other environment related disorders

Mosquito vector borne diseases

The main mosquito vector borne diseases in Sierra Leone are typhoid fever, malaria , filariasis (endemic in the Western coastal belt with signs of spreading into the interior). Mosquito vector borne diseases have emerged as a serious public health problem , particularly Malaria. Though other vector borne diseases are still prevalent, they are on the decline through successful public health programmes. Malaria is one of the most serious public health problems in Sierra Leone. It is the most common cause of illness and death in the country, accounting for about 50% of outpatient visits and 38% of admissions. Malaria-related illnesses contribute to 38% and 25% of child and all-ages mortality rates, respectively. The most vulnerable groups include children aged under 5 years and pregnant women.
The 2011 Sierra Leone service availability and readiness assessment reported that over 24% of children aged under 5 years had malaria in the 2 weeks preceding the survey and that 26% of children aged under 5 years and 27% of pregnant women slept under insecticide-treated nets. The survey also reported that only 15% of children with fever received antimalarial medicines within 24 hours of onset of symptoms and less than 2% of children under 5 years received

drugs within 24 hours. The prevailing climatic conditions, environmental pollution, rapid urbanization, overcrowding of cities and bad practices are proving conducive for the rapid breeding of the mosquito vector and the spread of this infection. Malaria transmission simulations have shown high sensitivity to relative humidity and temperature.



ARI, acute respiratory infection; RTI, respiratory tract infection.

- [Sierra Leone:Analytical summary - Health Status and Trends]

Rodent borne diseases

Rodent borne diseases are those that are carried by rodents such as rats, mice and bats and even cattle. These diseases can be transmitted to humans through animal bites, contact with animal waste, eating food or drinking water contaminated by rodent waste, or through parasites that use rodents and humans as hosts (e.g. fleas and ticks). The main rodent borne disease in Sierra Leone is Lassa Fever, Lassa fever is an acute, sometimes severe haemorrhagic infection caused by the Lassa virus and transmitted by the multimammate rat, Mastomys natalensis. It is endemic in parts of West Africa, including eastern Sierra Leone.

The disease dynamics of Lassa fever interact with a range of local social and ecosystem service processes – these local system contexts and interactions in turn being shaped by wider drivers of change. For some of these there is an evidence base for the Drivers of Disease study to build upon. These include: Climate For example, it is known that M. natalensis is a prolific breeder and population explosions can occur when environmental conditions are favourable (i.e. there is increased rainfall). Biodiversity for example, it is known that Lassa virus spillovers do occur in other rodent species. (Though unknown whether these species play a role as bridge vectors or amplifying hosts, or whether interspecies rodent aggression or resource competition is significant in regulating M. natalensis.) Land Use Disease emergence with all the haemorrhagic fevers identified in the past 60 years has been associated with human impact on the landscape (anthropogenic change). Other drivers of disease remain largely uncharted territory. The effects of spatial and seasonal variations in rodent habitat and Lassa fever transmission in the shifting farm-fallow-upland-swamp sites of village landscapes remain unknown. Gender, age and social relations have important impacts on livelihood opportunities and poverty in rural areas and on the ways people move throughout the landscape in accessing resources and ecosystem services. This raises important questions surrounding different social and demographic groups' exposure to the Lassa virus. There are also questions to be asked in respect of different people's understandings and behaviours in relation to the disease. Further complexity is added as Sierra Leone's environment undergoes larger-scale changes, shaped by factors such as climate change, rapid urbanisation and major transformations of land use associated with recent large-scale commercial land deals to grow crops for export and biofuels.

Other environment related disorders

Other than the above mentioned diseases there are a range of other environment related disorders including non communicable diseases. An increase in temperature can potentially exacerbate incidence of heat rashes, heat syncope, heat cramps, heat exhaustion and heat stroke. Respiratory diseases such as asthma and allergies are also expected to increase with increasing temperature by speeding up chemical reactions and consequently worsening pollution from ozone. Heat may also spur pollen production in some plants which could in turn worsen asthma and allergies in some people. Other public health issues such increase in respiratory tract illnesses and cardiovascular illnesses have also been identified to potentially linked to climate change induced changes in atmospheric conditions. Other non-communicable diseases that need to be studied in relation to the impacts of climate change in Sierra Leone include heart disease which is also driven by environmental factors/conditions and the likes of chronic kidney disease and cancer (Ministry of Health, pers. com., 2010). Acute or chronic events such as natural disasters, traumatic events or crowding or isolation cause stressful conditions as well as a major disruption in an individual's day-to-day life and affects their well-being. As such psycho-social stress is another important aspect that needs to be addressed especially with the anticipated increase in disaster events associated with climate change.

Food and water-borne illnesses

Food and water-borne illnesses may be caused by micro-organisms created by growing bacteria or contamination of food and/or water with certain bacteria, viruses or parasites. The main illnesses in this category are typhoid (also known as enteric fever), dysentery, cholera, diarrhoea, hepatitis B, and polio. Of all the food and water borne diseases currently occurring in the country, dysentery and cholera is the most prevalent during the rains. Typhoid incidence has been increasing over the years. Extreme conditions resulting from climate change induced impacts (floods, land-slides and droughts) are expected to cause more water and food borne diseases. The incidence of dysentery has been declining since 2000. Incidence ranged from 14.2 to 59.8 cases per 100,000 population with the case fatality rate being less than 1%, except in 2005 when it was 1.6%. Some changes may be attributed to demographic changes and not climate change. The most vulnerable population segments to dysentery are children below 15 years, and affects both male and female populations equally. Vulnerability to the disease is significantly lower in those over 50 years.

Nutritional status

The nutritional status is a driving factor in human health and is governed by food availability and access to it. Climate change will affect food production, especially cereal crops due to changes in temperature, rainfall patterns, soil moisture and fertility. Situations of food insecurity as a result of climate change would lead to widespread malnutrition and hunger affecting mainly children and pregnant mothers. The main nutritional problems among children under five are under-nutrition and micronutrient deficiencies. Under-nutrition can manifest as wasting which is a reflection of acute malnutrition, stunting (are reflections of chronic malnutrition) and underweight which is a combined measure of stunting and wasting . Two of the main micronutrient deficiencies among children are iron deficiency (leading to anaemia) and vitamin A deficiency. In pregnant mothers, the main nutritional problems are underweight and anaemia.

Vulnerability is also affected by surveillance programs and efforts at vector control. Disease surveillance in Sierra Leone has active and passive forms. Under the passive system, reports are received from a number of public and private primary care facilities as well as hospitals, laboratories and selected hotels. This provides critical information necessary for the monitoring of community health but there are obvious draw backs to this type of dependence.

Epidemiological surveillance including entomological surveillance and the monitoring of the types of behaviors that promote the proliferation of larval habitats are considered priorities by the WHO. For example, in Sierra Leone, the major breeding ground for mosquitoes has been found to be receptacles for stagnant pools of water. The promotion of behavioral change through the development of guidelines for sustainable prevention and control of vectors are also WHO priorities (Heslop -Thomas, *et al.*, 2008).

Some of the geographic factors affecting vulnerability have been referred to – the country's location and susceptibility to high rainfall events These events have underscored the vulnerability of those living in environmentally sensitive areas as they cause death and the dislocation of people and economic activity. Coastal communities are not the only areas that are susceptible to these events. A combination of high precipitation, a small catchment, geology, and human influence combine to make many slopes in the east of Freetown unstable, creating landslide conditions. Coastal areas, unstable slopes, river courses, especially those supporting poor communities, have been shown to be extremely vulnerable to landslides and the ravages of flood waters.

Cross sectoral linkages

In order to address the issues of climate change, addressing cross sectoral issues are critical as the agriculture and fisheries sector along with the water sector have a pivotal role too. For example, decreasing river flows, rising salinity of estuaries, loss of fish and aquatic plant species and reduction in coastal sediments are likely to damage the fishing industry which is a primary source of protein for coastal and riverside populations. The existing issues related to vector, rodent and food and water borne diseases often arise due to conditions of water logging caused by floods, water scarcity due to droughts, and over-exploitation of available resources (such as water). Sanitation and overall environmental cleanliness are also important factors in the proliferation of these diseases, through the creation of environments that are conducive to their breeding patterns.

The topic of whether to scale-up traditional rice varieties known to be of higher nutritional value and to have characteristics beneficial to health issues versus the high yielding hybrid varieties is rather controversial at the moment. Since food security is very high on the agenda, high yielding hybrid varieties are being promoted currently, though small scale farming of the traditional varieties are taking place and they are available in the market at higher prices. In promoting the nutritional value of the staple diet, tubers also should be encouraged in addition to traditional rice varieties (Nutrition Department, pers. comm. during preparation of this report, 2010). Health, Water and food borne diseases are directly linked to the performance of the drinking water sector, and the effectiveness of water resource management and distribution. Such diseases are also directly linked with the country ability to anticipate and effectively respond to disaster events. Similarly, the planning and management of urban settlements, drainage, solid waste, etc. have direct impacts on the spread of food and water borne diseases as well as vector borne diseases. Rodent borne diseases can be clearly linked to the agriculture sector as well as to urban planning, solid waste and drainage sectors. Repeated occurrences of diseases such as dysentery can impact the nutritional status of communities.

Broader nutrition requirements are directly linked to the agriculture sector. Erratic yields due to climate change affecting farming communities and changes in quantity, quality and pricing of food available can lead to high levels of malnourishment. It will aggravate the acute and chronic under nutrition among children and mothers - especially micro-nutrient deficiencies. Efforts to manage key vector, rodent, food and water borne diseases, and malnourishment, therefore, must involve extensive cross-sectoral collaboration. Often, major public health problems result due to issues not addressed in other sectors, and are not necessarily reflective of the performance of the health sector by itself. The need for close collaboration across such a wide range of sectors to achieve results, of course, adds to the complexity of the pressures affecting the health sector. Climate change, in turn, affects the performance of all these other related sectors, compounding the impacts they have on human health. New settlements and demographic movement should also be managed and guided carefully in minimizing health implications.

Other Climate Change   Health Related Issues and Vulnerability

Vulnerability to natural hazards Possible impacts of sea level rise and coastal flooding: † Increase in salinity of surface and ground water in coastal areas will affect freshwater availability for communities with regard to domestic use. This will result in reduced sanitary facilities in the area, further exacerbating the current morbidity due to common water and food borne diseases.

Possible impacts of a rise in temperature:

Extreme effects of temperature anomalies may misbalance the thermo-regulation processes of the body and increase morbidity and mortality depending on the severity of the heat and the vulnerability of the exposed population. Increased temperatures may increase air pollutants which can result in increased incidence of respiratory disorders and cardio-vascular diseases. This would have significant implications as Sierra Leone is experiencing epidemiological and demographic transitions showing increasing trends in the number of non-communicable diseases including cardio-vascular and respiratory system illnesses.

5.4.4 Future Climate Risks For Human Health in Sierra Leone

4.4.5 Proposed Elements of an Health Adaptation Strategy for Sierra Leone

A Strengths, Weaknesses, Opportunities and Threats (SWOT) analysis (see Table below) was undertaken based upon the threats to human health posed by scenarios of future climate change and the state of readiness of response agents such as the Ministry of Health, Ministry of Agriculture, Disaster Management Department , Environmental Protection Agency, National Water Commission, Forestry Department and the Meteorological Department.

Strengths	Weaknesses	Opportunities	Threats
Efficient health service by world standards.	The health system is under resourced.	Take advantage of PRSPs development plan to mainstream climate change into all sectors and policies	Threat from droughts and higher temperatures, leading to food shortage, hunger and malnutrition.
Fairly good physical access to primary health care facilities.	Inadequate fit between health services provision and needs of elderly	Increase efforts to reduce poverty.	Effect of water shortage, poor sanitation and the spread of diseases.
Interest in research -based evidence within	Inadequate provision for children in shelters.	Implement early warning systems for dengue	Threats from increased rainfall intensity leading to

the Ministry of Health.		and other vector borne diseases.	flooding,loss of habitat, increased risk of water -borne and rodentborne diseases, such as typhoid and leptospirosis.
Adaptation strategies have been proposed	Climate change not mainstreamed in health policy.		Increased incidence of diseases in shelters following disaster
High level of willingness displayed by communities to work alongside the Government in eliminating mosquito breeding habitats.	Link between climate change, agriculture and health not sufficiently appreciated.	Include climate change issues in the mandate of response agencies.	Threat of temperature increases leading to increased rates of transmission of dengue and dengue hemorrhagic fever
Good working relationship among organizations involved in disaster preparedness	Link between extremes in weather, disaster preparedness and health not sufficiently appreciated.	Stimulate inter agency and intersectoral collaboration Improve disease surveillance	Threat of air pollution, including ozone increases, and forest fires, leading to respiratory diseases

In Table 5.26, a matrix of possible adaptation options is described for coping with an increased threat of dengue fever. The methods listed include those options practiced elsewhere in the world or on a very limited scale within the region, and options that present themselves as future (though not too distant) possibility as a result of ongoing research in the region.

Table 5.26: Adaptation Options for Coping with Increased Threat of Disease outbreak in Sierra Leone

Recommendation	Justification	Responsibility	Workshop Ranking
Leverage and co -ordinate international funding to maximize benefits within the Health Sector	Significant investment is required in a number of areas within the sector. If multi -lateral grant -aid & bi -lateral soft loans are to be used to support this work, then the benefits accrued must be maximized, both in	Ministries of Health and sanitation and World Health Organisation, Ministry of Finance and Economic Development.	**High**

	outputs and capacity building.		
Raise awareness of the potential impacts of climate change on the Health sector	Climate change is not mentioned in the Health Sector Development documentation. This suggests that the potential impacts of climate change on the sector have not yet informed Health policy & practice.	Ministries of Health and sanitation and others as well as Tertiary Institutions and Farming Organizations.	**High**

Other necessary actions identified at the stakeholder workshops are:

• Identification of the most vulnerable population groups to be impacted by climate change
• Monitor the food price effect with the climate change closely – surveillance system
• Targeting the existing supplementary feeding programmes
• Set up emergency feeding programmes for needy population with the climate change.

Support from projects and institutional programmes

- Establishment of the health sector disaster preparedness and response system.
- Establishment of district and national disaster management units to smoothened the operation of the district health sector as epidemics of diseases are categorized under disasters.
- Under the same concept, the health sector disaster preparedness and response system should be harmonized with the DMD of the office of National Security to mitigate the health implications of natural and man-made disasters.

The options are assessed on six characteristics which are rated high, medium and low. For example, cost is a serious adaptive constraint and so each proposed adaptation option is rated on the likely cost of implementation within the context of the country.

The assessments are based on expert opinion and are guided by the responses on questionnaires administered to the attendees of the end -of project workshops. They therefore reflect the considered views and knowledge of the country's environmental health officers. The assessment characteristics were:

- Cost of implementation;
- Effectiveness (as measured by its long -term ability to reduce risk or address vulnerability);
- Social acceptability;
- Environmental friendliness;

- Promotion of neighborliness; and
- Technical and/or socioeconomic challenges to implementation.

A simple qualitative score is offered in the final column for comparison purposes.

Best Practice Recommendations for Addressing Malaria

No single "best" adaptation option exists to counteract the threat of increasing malaria within Sierra Leone. The variety of strategies has their relative merits and demerits. In light of that, three adaptation options are offered as possible ways of approaching the problem. The options give primacy to the need to address the issues of vulnerability, namely the lack of capacity and knowledge about malaria, the lack of community structure to facilitate collective action, and the issues of water storage. The options require an increase in human and economic investment and assume that the currently practiced strategies outlined are at least maintained.

Option 1 *– Refocusing Current Strategies*: Option 1 advocate that currently employed strategies are maintained at least at their present level of activity and funding, but that approaches to them be refocused, and relatively minor modifications be made.

Education is emphasized as the lynchpin of this option with, however, a slant towards the personal and community good that would derive from the environmental sanitation and vector control strategies proposed in the campaign. This is as opposed to merely providing information about the disease and the steps to be taken to reduce mosquito abundance. A proposed modification would also be to engage communities prior to the rainy season through organized activities in nearby churches, schools, youth and service clubs and utilizing competitions to test knowledge and community cleanliness. Involvement prior to malaria onset would promote long -term behavioral change (not just a malaria season problem) and community responsibility. Vector surveillance in its current form would provide support for the educational activities, particularly approaching the malaria season.

Option 1 would call for the least additional investment, though an upgrading of the capacity of the education and promotion units of the health ministry to initiate and sustain activities outside the malaria season would be required. The possibility of cost sharing with the engaged community groups should also be explored.

Option 2 – Adding Proper Water Storage: Option 1 does not address the vulnerability issues surrounding proper water storage. The proposed adaptation strategies (design of drums and covers and security) often are costly, however, and consequently requires greater investment by the Ministry of Health.

For Option 2, the refocusing actions of Option 1 are still undertaken as they address education deficiencies and community involvement and responsibility. In addition, however, the design of a suitable low -cost water storage drum or

drum cover would be actively pursued. Currently, water is stored in discarded 'oil' drums which are left open to catch water running from rooftops when it rains.
The open nature allows for the breeding of the vector. A unit which allows water in, with a cover is easily removable but secure, or from which water can be easily removed otherwise is the ideal. The option to design a drum cover that meets the latter characteristics also exists as the storage drums commonly utilized are fairly standard in size. Such units/covers do not exist currently and might be costly to design and manufacture with little guarantee of their eventual use by the community. To ensure the latter, incentives would have to be offered, e.g., subsidies and an intensive public education emphasizing the value of the drums/drum covers. Incentives may also have to be given to cover the drums, despite the presence of the drum covers, while efforts would also have to be made to ensure that other habitats are made vector -free.

Option 3 – Adding an Early Warning System: Like Option 1, an early warning system has the advantage of anticipatory action. However, whereas Option 1 promotes education simply based on the knowledge that there is a malaria season, an early warning system attempts to gauge the severity of any possible outbreak. Consequently, enhanced or diminished responses can be made on the basis of the anticipated level of threat. Option 3 therefore proposes the actions of Option 1, but coupled with an early warning system.
On this basis, the frequency of surveillance would be altered and the education campaign tailored to meet the level of perceived threat. If surveillance data confirm the presence of the pathogen or an increase in its abundance, subsequent warnings could be issued as needed. A benefit of this multi -staged early warning approach is that response plans can be gradually ramped up (e.g., the inclusion of other strategies such as chemical or biological control) as forecast certainty increases. This would give public health officials several opportunities to weigh the costs of response actions against the risk posed to the public.
The implementation of Option 3, however, requires a memorandum of understanding between the cooperating institutions, a definition of roles, a focal point, some investment in research, and the possibility of staging of a pilot project.

Additional Recommendations for the Ministry of Health

- The public should be educated about ways of handling heat stresses;
- Taxes on electric fans should be eliminated to encourage persons less well off to purchase them, although this would not be the direct responsibility of the Ministry;
- Public education in the area of sanitation and food poisoning need to be increased and steps taken to be prepared for increases incidents of food poisoning;
- Public health inspection for mosquitoes should increase, even at higher elevations;
- Pest and rodent eradication should be improved.
- A Nutrition and Food Security Assessment in Sierra Leone needs to be carried out by MOHS in collaboration with UNICEF, WHO and WFP to provide details on malnutrition across various segments of the population.

Additional Recommendations for Ministry with Responsibility for Housing

- House designs are strongly influenced by styles that are more appropriate for temperate living.
- Sustainable design standard are needed for housing in areas subjected not only to year -round high temperatures that are projected to increase, but also to high rainfall and strong winds.
- Roofing material used in Sierra Leone can increase heat absorption and retention and increase thermal stress. Modern designs are replacing the louvered windows that increase ventilation.
- The elevation of houses would also increase ventilation and reduce the risk of flood damage in low lying areas. These changes would help address impacts of heat stress and effects of disasters on human health.
- More attention should be paid to the design of settlements to reduce those aspects that would result in the amplification of vector borne diseases and floods.

Priorities

It is recognized that the recommendations stated above are for an ideal situation, but funding may not be available for all needed actions. Priority should be given to:

- Options for adapting to increased incidence of malaria and rodet related diseases, particularly the design of suitable drums for water storage and for an early warning system;
- Better water monitoring and management through improvements in the National Water Commission and the Water Resources Authority to reduce risks of water -borne diseases;
- Improving the capabilities of the Office of Disaster Management Department to warn of, and react to, disasters;
- Improving the data gathering ability and technical and support staff of the Meteorological Department since parameters such a temperature, air quality and flooding are related to human health;
- More collaboration between research institutions and national agencies involved in dealing with health and climate change issues.

Even if the dangerous climate change scenarios do not materialize, these measures would be in the best interest of the nation, i.e., they would be 'no -regrets' adaptation options.

5.4.6 Constraints of the Health Sector V&A Assessment

Constraints	*Proposed Solution*
Uncertainties related to health and climate change studies could be reduced with improved data andmodelling.	All available climate data from national sources, such as private weather stations, national weather stations, public works agencies, etc., should be collected and subject to quality control so it can be used to validate regional models and

	calibrate statistical models. Support should also be given to research institutions to run as many regional and statistical downscaling models as possible for calibration and inter -comparison purposes in order to reduce uncertainty.
The true cost of the impact of climate change on the Sierra Leone with respect to the health sector is unknown.	A cost benefit analysis should be conducted to determine these costs.
A design for a safe storage drum which will store potable water free of mosquitoes is not available.	Incentives should be provided to encourage the design of such a drum.
An early warning system for malaria/ dengue fever is not available.	The mechanisms for the operation of an early warning system for malaria/dengue fever should be put in place.

2008 Demographic and Health Survey Key Findings

References

http://www.measuredhs.com/pubs/pdf/sr171/sr171.pdf

5.5.1 Main Characteristics of the Coastal Zones Sector in Sierra Leone

The coastal zone of Sierra Leone covers 155 square kilometres from Kiragba in the north, to Mano in the south. The coastline measures 560 kilometres much of which is sheltered. The sheltered coast is dominated by extensive mangrove systems and mudflats.
The coastal zone is one of the most densely areas of the country and is vulnerable to a number of natural and man-made hazards including, inundation from major rivers, flash floods during the rainy season and saline intrusions due to decreased low water flows in the dry season. About 150 kilometres of the coastline is developed including Freetown. A large percentage of the population is concentrated in the coastal zone, that is, about 55 per cent which make substantial use of the coastal resources. The population along the coastline is unevenly distributed with the highest around the Freetown peninsula of about 1,250,000 and between 8,000-9,000 in Shenge and Bonthe Shebro area in the south. The total population in the coastal are is about 1,347,000 with an annual growth rate of 2.5 per cent. The coastline is dotted with over 70 hotels and tourist resorts. This high population density is putting pressure on the coastal resources.

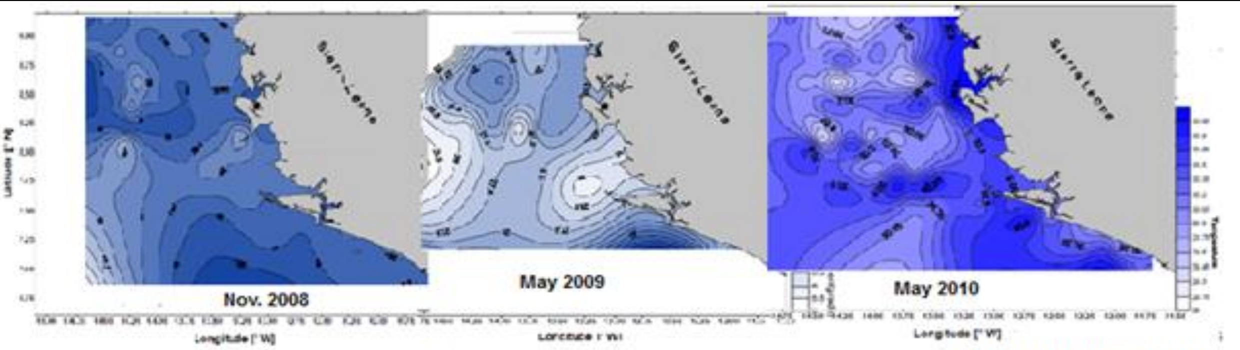
The coastline of Sierra Leone can be divided into two sections. The section to the north of Bonthe is characterized by a series of indentations representing estuaries, bays and creeks and the section south of Bonthe Island has about

200 kilometers of nearly unbroken steep sandy coast, and beach ridge backed with coastal swamps.
The beaches are either rocky or sandy and serve as a natural barrier or protection for the shoreline from coastal erosion and flooding from the Eastern Atlantic Ocean. Sandy beaches form gradual transition zones which dissipate wave energy of the ocean and serve as a source of sand for movement by long shore currents.

Oceanography

Sea Temperature

The average temperature of the sea surface waters off the Sierra Leonean coast is generally greater than 26°C (Fig. 5). Mean annual cycle of sea surface temperature off Sierra Leone (7°N to 9°N and 11°W to 14°W), derived from COADS 195° to 1990 show that between February and May, sea surface temperatures range from 27°C and 28.5°C between May and August temperatures drop from 28.5°C to around 26.8°C and between August and November the temperatures again rose from 26.8°C to 27.0°C and the average water temperature in December is around 28.5°C and around 27.8°C in January. The peaks in May and December are associated with seasonal cycles and closely related to the solar heights.



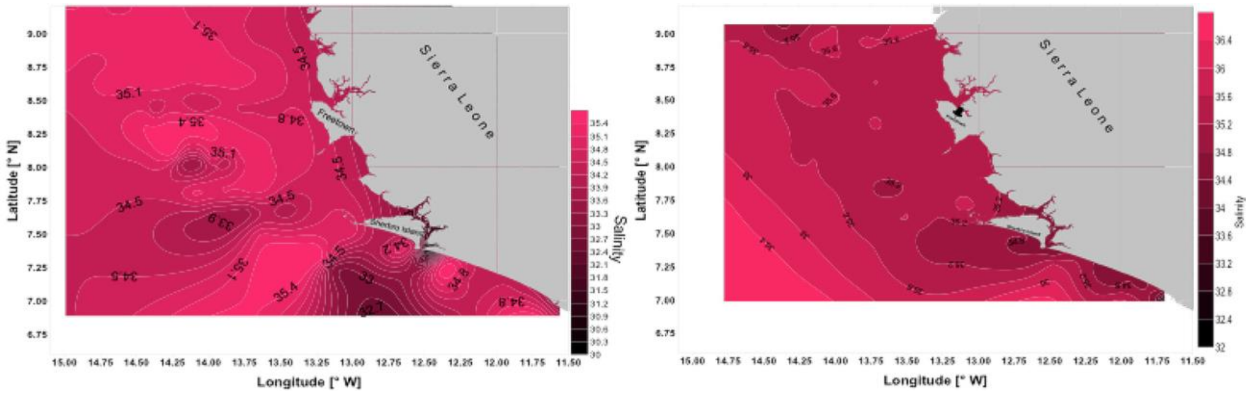
Surface salinity temperatures (Source: Lamin, 2011)

Mean temperature profiles up to 500m depth in the area of the continental shelf show the development of a sharp thermocline below the warm surface waters. The gradient of temperature here sometimes exceeds 3°C/10m. Below the thermocline temperatures continue to fall gradually with depth.

Sea Salinity

The average salinity of the sea surface waters off the Sierra Leonean coast is generally less than 35.5. The salinity is influenced by fresh water run-off from land and rainfall especially during the rainy season

Mean salinity profiles in the shallow areas close to the coast are characterised by low salinities at the surface, which result from the inflow of fresh water. The limits of the salinity homogeneous layer correspond to the upper limits of the thermocline showing that the salinity and thermal structures are similar in the surface layer. Below the surface a sub-surface salinity maximum (S=35.7°) exists between 60 – 70m depth. Below the maximum, salinity gradually decreases to a minimum around 500m depth.

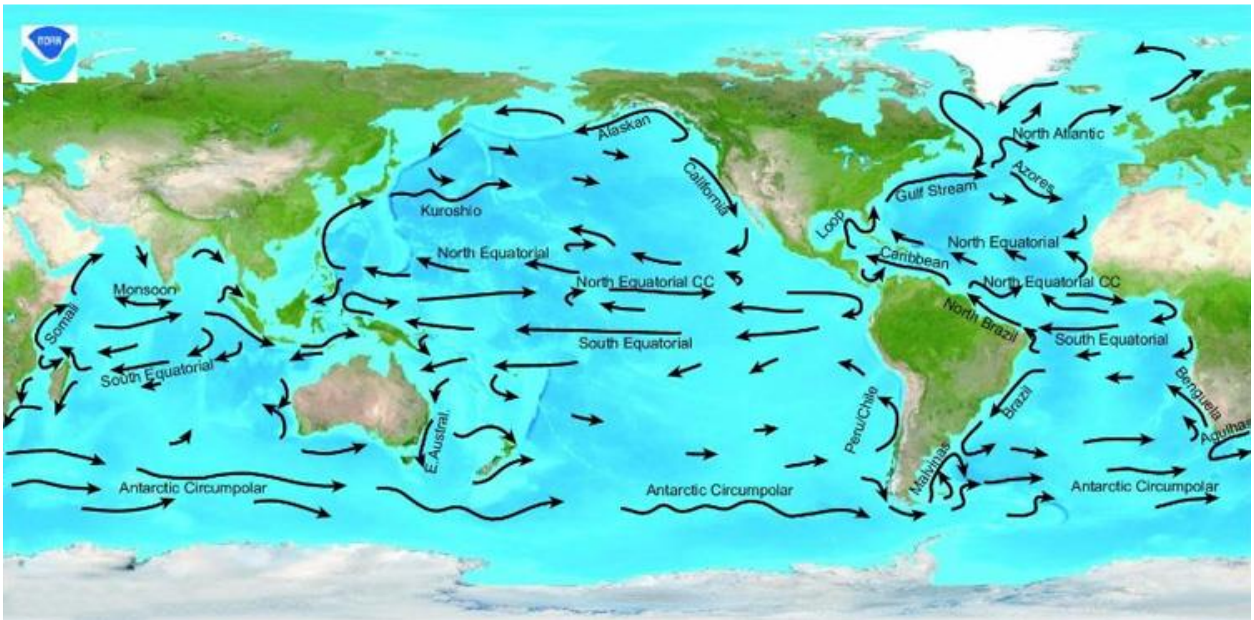


Ocean Currents

Currents are dynamic features of coastal waters of Sierra Leone and affect the coastal zone in a number of ways. It consists of Ocean currents, Long shore currents, Tidal currents and Rip currents.

General Circulation

The general water circulation along the Atlantic coast of Sierra Leone is shown in figure below.



The surface currents are significantly influenced by the Southeast and Northeast trade winds. During the spring in the Northern Hemisphere when the Southeast Trades noticeably weakens, the Northeast trades are full developed. During this period the Canary currents intensifies bringing cool water to the coast of Sierra Leone. This current generally flows in a south-easterly direction at the surface in the near-shelf regions. The canary current is mainly southward from August to April. When this current approaches the equator, it turns westward as the North equatorial current. The monsoon period generally lasts from July to August; during the Northern Hemisphere summer. During this period, the equatorial counter current is strongly developed and is the source of much water joining the Guinea current. In the winter months (December to February) however, the equatorial counter current ceases to be of importance and the canary current is the main source of water joining the Guinea current. In the autumn the southeast trades strengthens reaching maximum strength in August. During the May – July period, the Canary current lows temporarily northward carrying low salinity Liberian surface waters to the north as far as Senegal (Berrit, 1969).

Waves and Swells

A micro -tidal regime exists along most of the Sierra Leone coastline, The tidal range is between 1.8 to 2.6m. The direction of travel and the height of incoming waves are primarily governed by the Trade Winds, so that most wave trains arrive from the northeast, east and southeast. These are refracted around the various headlands, so that along the north coast wave sets arrive dominantly from east to northeast, whereas on the south coast the waves come from the southeast. The rainy season weather systems are generated by high pressure build -ups over the North Atlantic. As a result, dry season wave trains may arrive at the north coast from a north to north -easterly direction. At this time, conditions along the south coast tend to be relatively calm.

Table 4.29: Data (mean values) from NOAA Buoy 41018 (August 1994 to January 1996)

Wind speed (m/s)	**7.79**
Wind direction (deg.)	90.93
Significant wave height (m)	1.63
Wave period (s)	5.19

Source: Adapted from Calverly et al., 2001

Almost a perennial swell of moderate height, coming in from the Atlantic disturb ships at their moorings within the estuary. This phenomenon is particularly evident during the wet season when both frequency and amplitude are greatest. The maximum amplitude is in the region of 1.0 metre. Winds waves, usually not higher than 1.0 metre, only occur for brief spells usually just before the change of seasons about May and October.

Sediment Transport Processes

Longshore drift current is the main mechanism by which sediments are transported along the Sierra Leone coast. The sediment transport takes place mainly within the 1-10m water depth. Three main longshore drift current directions can be recognized along the Sierra Leone coastline. These currents flow in a northeastern direction causing erosion of the northern coastline around Yelliboya Island and Konakridee. Similar south easterly flowing currents in the south carry sediments from the Freetown Peninsular beaches and along the entire southern coastline of Sierra Leone.

Tidal currents also influence the sediment transport dynamics particularly those of very fine sand and mud mainly at the entrances of bays and estuaries.

Longshore Currents

Along the Sierra Leone coast, longshore currents accompany large swell waves breaking obliquely to the coastline. These currents flow in a northeast direction along the northern shores causing a fairly serious erosion of the northern parts of the coastline around Yelibuya Island and Konakridee.

In the south, similar south-easterly flowing currents carry sediments from the coastal beaches of the Freetown Peninsular and all along the southern part of the Sierra Leone coastline to the Liberian border enhancing beach erosion.

The waves, which generate these currents, are themselves generated by wind force of 3-4 beau fort, which are strongest during the harmattan (Northeast trades) months of December and February and August to October during the monsoon winds from mainly the Southwest. Longshore current velocities along the Freetown Peninsular can range from 0.20m/sec to 1.5m/sec.

Tides and Tidal Currents

The astronomical tide manifest itself as a periodical rising and falling of the sea level which results from the attracting forces of the celestial bodies, mainly those exercised by the sun and moon on the adjacent water masses.

Off the Sierra Leone coast, the tide is mainly semi-diurnal, with two daily maximums and minimums, the mean height of the tide or mean tidal range is between 18m to 2.6m. The tidal currents are generally of moderate velocities of between 0.1mls to 0.2mls.

Rip Currents

These are localised out flowing currents through occasional depressions or 'lows' in offshore bars resulting from the outflow of water that would otherwise accumulate inside the zone of breakers after wave breaking.

Rip currents may sometimes appear as long lanes of foamy or turbid water stretching out to sea. They weaken and gradually die out further out to sea. These currents have not been reported along the coast of Sierra Leone.

Defining the Coastal Zone of Sierra Leone

Defining the coastal zone is a complex exercise, presenting many challenges. It may be simply defined as that transitional area between the land and sea, but the nature, size and shape of its boundaries depend on several criteria that relate to the resources within the zone and the geographical factors of importance for each segment of the coast. Natural factors might include the extent of typical coastal vegetation, physical features such as beaches and wetlands, the presence of or absence of coral reefs, width of the continental shelf. Human factors include coastal -dependent industries, settlement patterns, aesthetic and recreational features, and management and administrative factors.

4.5.2 General Impacts of Climate Change on the Coastal Zone Sector

Sea -level Change

The effects of changes in sea -level on any particular coastline depend on the geological and geomorphological characteristics of that coastline, including sediment supplies, and the extent to which coastal features have been modified by human activities.

It is generally accepted that sea level is rising, and that this rise will continue into the foreseeable future.

The most recent internationally researched publication (IPCC, 2007) suggested, conservatively, that the rise between the present (1980 -99) and the end of this century (2090 -99) would be about 0.35m (0.21 -0.48m) for the A1B scenario and 0.26 -0.59m for the A1F1 scenario (IPCC, 2007, see Section 10.6).

Table 4.30 (simplified from IPCC, 2007) lists projected rises for a number of scenarios by the year 2100).

Scenario		Temperature Change (degrees C)			Sea-level Rise (m)
		Best Estimate		Likely range	Model-based range

B1		1.8				
A1T		2.4				
B2		2.4				
A1		2.8				
B 2		8.1				
A2		3.4				
A1F1		4.0				

Source: Adapted from IPCC 2007, Table TS.6

Table 4.30: Projected Global Average Surface Warming and Sea -Level Rise by 2100

Although the rate of sea -level rise varies between different ocean basins, historically, the rate of sea level rise in the North eastern atlantic has been close to the global average rate and is expected to continue close to the global rate (IPCC, 2007, chapter 11 p. 915 and figure 10.32). Therefore projected global average rates are used in this report.

Since the IPCC published these findings, several peer -reviewed publications suggest that sea -level rise by the year 2100 could be more than twice the amount projected by the IPCC, perhaps as much as 1.6m (Rahmstorf, 2007; Rignot et al., 2008; Rohling et al., 2008). Further evidence for possible sea -level rise up to three times that projected by the IPCC was presented by Svetlana Jevrejeva and others to the European Geosciences Union conference in April 2008 (Reuter's news report, April 15, 2008; review by Ananthaswamy, 2009).

Research on the future dimensions of rising sea level (IPCC, 2001, 2007) suggests that the current rise will continue at least until there is partial or complete melting of the world's smaller ice caps and the Greenland ice cap. Together with thermal expansion of sea water, this will eventually produce a sea level rise of up to 6 metres, that is, within the 7.6 m (25 ft) contour.

Changes in Acidity (pH)

The current rate of acidification of the oceans is unprecedented. Reductions of average global surface ocean pH of between 0.14 and 0.35 units are projected over the 21st century, adding to the present decrease of 0.1 units since pre -industrial times (the range is very roughly 8.13 decreased to 8.09 over 1985 -05, or 0.04 units over the past 20 years (IPCC, 2007, Chapter 5, p. 404)). If this projected reduction is realized, ocean acidity will reach a level probably not seen for the past 20 million years (Feely et al. 2004; Guinotte & Fabry, 2008).The main effect of increased acidity will be to reduce calcification rates of many organisms that generate biogenic calcium carbonate skeletons. No measurements of ocean pH values are known to have been made around Sierra Leone (pers. comm., Marcia Creary).

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Severe Weather Events

Since 2005, heavy rainfall causing increasing of rivers water volume and overflowing have increased considerably, along with increases in sea surface temperatures. Controversy continues over whether or not the projected increases in sea surface temperatures will lead to a continued increase in storm frequency (IPCC, 2007). There is more general agreement that there may be an increase in the frequency of severe rainstorms.

Flooding

Flooding in the coastal zone can arise from severe weather events, such as thunderstorms, that result in storm surges and flooding from the sea, as well as intense rainfall that may result in riverine floods, debris floods, or flows along coastal gullies. In the worst case scenario, flooding from the sea surge and run -up from a severe hurricane, added to a high spring tide, coincides with extreme rainfall resulting in riverine and gully flooding. The surge and tide causes backup of the riverine flood. Over the long term, sea -level rise will lead to gradual inundation of very low -lying areas, either from the sea or from the accompanying rise in the groundwater table, but such effects will tend to be masked by the consequences of flooding from severe weather impacts. **Floods affected the most important number of people in the last 30 years, representing 90% of people affected by disaster in Sierra Leone**. From 2008 to 2011, floods affected 221,204 people and killed 145 people (11% of people killed by disaster)[20]. Floods are of regular, annual occurrence between May and October but may occur any time during rainy season. Urban and rural seasonal flooding, recurrent flash flooding, and coastal flooding are the most common observed, leading to seasonal flooding of agricultural fields and low lying areas, flooding along the coast areas and flood waters overflowing into roads and into residents' homes. Vulnerable areas include Western area, Eastern, Southern and Northern regions but the more specifically, the most affected areas during these last years include: Kroo Bay, Susan's Bay, Granville Brook, Lumley area in western Area, Port Loko and Kambia Districts, the Newton catchment area, Pujehun and Bo areas, Kenema and Moyamba Districts, and coastal beaches of the Western Area Peninsular.

Rare events such as seismic sea waves (tsunami) will also inundate the coastline to varying extents, depending on the energy level of the event. While tsunamis

[20] *"EM-DAT: The OFDA/CRED International Disaster Database- www.em-dat.net - UniversitéCatholique de Louvain - Brussels - Belgium" – Nov 2011*

are not directly related to climate change, the flooding effects will become more severe as sea -level rises. Tsunami events are uncommon in the West African Region.

4.5.3 Responses of the Coastal Zone

Coastal Erosion/Recession
Beaches
Shoreline retreat along sandy beaches is caused by various physical shoreline processes. Because of the complexity of the variables there is considerable controversy over the kinds of changes that will take place as sea -level rises (Gutierrez et al., 2007). Over short time -scales, storms are probably the dominant factor (Zhang et al., 2002). Over longer time -scales, variation in sand supply, the geological setting and sea -level rise become important (Zhang et al., 2002; Pilkey & Cooper, 2004). Where there is an adequate supply of sediment, a beach will change its position in space as sea level rises, migrating upwards and inland. Vertical incision occurs (i.e., sea -level continues to rise but no shoreline retreat takes place) when the beach is constrained, either by rocky outcrops or by sea -walls and other anthropogenic structures, and an equilibrium profile can no longer be maintained further inland. If there is no development, the natural progression of sea level rise would result in the beach system incrementally transgressing over the sub -aerial part of the coastal zone. However, the presence of sea -walls, highways and other coastal structures will prevent this, and lead to increased vertical incision as hardened structures proliferate.
The natural erosion of the beach region ceases, causing sand starvation to the beach profile. This will increase in severity unless fresh supplies of sand are available from near -shore or riverine sources. Even if appreciable long -shore drift takes place to supply new beach materials, the reduction in the availability of erodible shoreline deposits will likely still lead to progressive loss of beaches.

Sediment supply is different for the two main kinds of sand beaches in Sierra Leone:

- For **siliciclastic (dark sand) beaches** such as those along the mouths of the Scarcies, Rokel/Sierra Leone rivers and entrances to bays of the Freetown Peninsula, sediment is supplied via transport through river systems, usually during flood events, from the island's interior. Supplies necessary for the natural maintenance of such beaches depend on regular supplies from the hinterland. These can be reduced during periods of drought or by excessive removal of sand from the river bed by sand mining. This may be counterbalanced by increased supplies over time if deforestation leads to accelerated soil erosion in the interior.

- For **carbonate (white sand) beaches** such as those along the Atlantic shores of Sierra Leone, Lumley, Lakka, No. 2 river, Kent etc. and the Turner's Peninsula, sand supplies are sourced from the near continental shelf.

The maintenance of a healthy nearshore marine environment is essential for supplies to continue, as carbonate sand grains have a much shorter life span than the siliclastic grains of dark sand beaches, and degrade to mud from abrasion and chemical solution.

Predicting Beach Changes.

Two methods are in widespread use in attempting to predict the rate at which a shoreline will retreat in the future, whether due to sea -level rise or to other shoreline processes. The first uses the evidence of past shoreline positions and sea -levels to estimate the possible locations of future shorelines (Crowell et al, 1999; Fletcher et al., 2003; Figure 4.27). The second uses the so -called "Bruun Rule" to calculate the positions of future shorelines, based on the concept that each particular beach strives to maintain the shape of its equilibrium profile as sea level rises (Masselink & Hughes, 2003). Both methods have their critics as well as their supporters (Dubois, 1975; Pilkey & Cooper, 2004).

Sand loss to the system.

In Sierra Leone, the monsoon period which is associated with squally weather and frequent storms over a shelf dominated by white sand, may generate wave heights of up to 1.5 -2.5m and can cause flushing of sand from shelf edge areas into deep water.
Many times the amount of sediment as is usually moved in fair weather can be transported. The volume of sediment removed from these beaches can be approximately equivalent to the amount of sediment that would have built up during periods of fair weather. The storm surge can be about1.0 -1.5 m because of the narrow shelf in the south of the country. Similar losses, especially of the increasingly hard to replace carbonate sand, are likely to occur along the coasts lined with carbonate beach sand.
Geological evidence, in the form of debris fans at the foot of the continental shelf, in water too deep for natural recovery to take place, indicates that this is happening on a continued basis.

Cliffs and Rocky Coasts

The coastal environment also consists of low cliffs (5-20 kilometers) of poorly consolidated clay, sand, silt and gravel of Eocene to upper Pleistocene age, some of which have been subjected to intense erosion e.g. at Konakridi, Tisana, Shenge and Sulima point.
In some areas along the Sierra Leonean coast, rocky shores are a prominent feature. There may be not more than a few kilometers of rocky shorelines (<10km) but the most impressive is the Cape Sierra, Juba-Hamilton complex (Adam, 1987). Rocky shores along the Sierra Leonean coast are of two types; those composed of granitic rocks and those of lateritic rocks. Granitic rocky shores are associated with Cape Sierra, Goderich, York, Kent and Hamilton along the shores of the Freetown Peninsula as well as Banana Island. Lateritic rocky shores are found along the southeastern shores around the Kagboro creek at Shenge. The biodiversity of the rocky shores include molluscs, barnacles, oysters, mussels, periwinkles, limpets, gastropods, algae and coralline sponges.

Recession rates along cliffed coasts are usually much less than along beaches, but recession may occur suddenly as a collapse, so that care needs to be taken in building along such coasts. In addition, hurricanes can deposit large quantities of rock debris over the cliff tops along such coasts.
The effect of sea -level rise on cliff lines may result in deepening of the water at the cliff base, allowing higher energy waves to attack the cliff, possibly resulting in increased rates of recession. Whether or not this occurs depends on the availability of marine sediments to act as a buffer to wave attack.

Wetlands

Coastal wetlands are recognized as unique and vulnerable, but valuable habitats. By their very nature, they lie close to sea -level and exhibit a range of temperature and salinity variation, from salinities approaching that of the open ocean to freshwater, due to the varying influences of tides and drainage from the interior. They are widely recognized to be one of the most productive ecosystems, as well as buffering the effects of inundation from ocean surges due to hurricanes. Most wetlands are less than one metre above sea -level. The particular problems of wetlands have been described and discussed in the NRCA Coastal Atlas and Coastal Manual (NRCA, 1997a, 1997b).
The continued existence of coastal wetlands depends on maintaining a delicate balance between sea level change, vertical accretion, and subsidence. Vertical accretion is attained partly by the influx of, usually, fine grained sediments from riverine floods, or sand deposited in the coastal margin of the wetland from surges, and partly through the growth and decomposition of the wetland vegetation.

The mangrove forest is a salt water wetland dominated by mangroves which are halophytic, evergreen woody plants, tall and shrubby, belonging to several related families that share common habitat preferences, physiognomy, functional and structural adaptation (Plate 4.1-4.2). They are found along the shores of estuaries, sheltered creeks, lagoons, deltas and the brackish water zones. The mangrove ecosystem is a complex comprising invertebrate and vertebrate fauna, micro-organisms and the interacting biotic factors such as temperature, salinity and chemical constituents of the muddy deposits. Such a system is noted for its high productivity.

Plate 12 A typical Mangrove Swamp

Mangrove woodland in Sierra Leone occupies 47 per cent of the Sierra Leone coastline, covering a total area of 171,600 hectares (Chong, 1979). In Sierra Leone the mangroves occur along the Scarcies River, Sierra Leone River, along creeks and bays in the Western area, the Yawri Bay and along the Sherbro River. The areal extent of the mangroves in these locations is summed up in Table below. The rich mangrove forests of Sierra Leone are exploited by the local populace of the coastal areas whose main preoccupation is fishing. The mangroves forest and trees have been used basically for fish smoking which is an indigenous traditional way of preserving fish caught for sale, and also as an important sources of fuel wood (Chong, 1987, Johnson and Johnson, 1991,1992). The environmental role of this natural resource include, coastal barriers in storm protection, flood and erosion control, and as habitat nursery ground for fish, shrimps and other marine fauna.

In Sierra Leone, which is dominated by a semi-diurnal tidal environment, the small range of the tide tends to promote relatively stable boundary conditions within the wetland. Thus the more saline parts of the wetland will be dominated by mangroves, while the more interior, freshwater parts will grow mixed forest and sea -grass. Erosion by storm impacts is widespread and recovery generally slow or absent.

Wetlands in particular are threatened by accelerating sea -level rise. Supratidal flooding causes salinity changes affecting the wetland vegetation and may adversely affect spawning fish stocks which grow in wetland areas. Most wetlands will shrink and eventually disappear unless the rate of sedimentation within the wetland can keep pace with sea -level rise.

Saline Intrusion

Saline intrusion will increase with sea -level rise but the effects of such an increase are likely to be small.

Saline intrusion is already a major factor in some parts of Sierra Leone due to over -pumping of groundwater wells. In the study localities used for this V&A assessment, water supplies were not drawn from wells sited near the coast, but from river systems. Water supplies are more likely to be affected by drought as populations increase into the future.

Anthropogenic factors

Although environmental stresses to coral reefs and other coastal ecosystems are both "natural" (i.e., not directly related to human activities) and anthropogenic in origin, human activities consistently amplify the impacts of naturally occurring stresses such as the passage of hurricanes and rising sea surface temperatures (Hallock et al. 2004). For example, the impact of a natural event such as a hurricane on coastal ecosystems is greatly and progressively amplified through time by deforestation, agriculture runoff, and coastal development leading to increased population pressures on the coastline.

The main anthropogenic stresses on the coastal zone, not directly related to climate change, arise from population increase and migration to the coastal zone, leading to:

- Informal settlements (squatting);
- Increased chemical pollution of coastal aquifers and the near -shore area from sewage and agricultural runoff;
- Increasing proliferation of hardened engineering structures along the coastline, leading to progressive beach erosion;
- Insufficient planning and siting of critical facilities, overburdened by population pressures; and
- Private ownership of coastal land which restricts public access to the coastline.

The long -term goals of Integrated Coastal Zone Management for conservation of coastal resources and sustainable development are often incompatible with the desire for a short -term economic gain by interests in the tourist and other industries.

4.5.4 V&A Case Studies

Konakridee

Vulnerability

What Conakry Dee community perceived as the impacts of Climate Change included: storms in Coastal Islands constituted a natural disaster as many people fell victims to storm conditions every year. Women were differently vulnerable than men due to various physical and social reasons. Two separate Female Group Discussions (FGDs) were conducted to get the perceptions of women on climate-change-related vulnerabilities. A number of climatic hazards were identified by the FGD participants, including rainstorm, flood, salinity, seawater intrusion, water logging and thunder storm.

Konakridee has been undergoing periodic bouts of coastal erosion since the 1960s during periods of heavy rainfall and stormy weather associated with the monsoon period.

The erosion has placed beachfront residences in jeopardy, with at least one home completely lost to the sea. The coastline has a tendency to retreat and prograde seasonally. The passage of storms has retarded the recovery of the beach after major erosive events. The community is also subject to Flooding from the stream which lies behind the village. These flood events occur after heavy rains when water from the stream floods homes and the main thoroughfare. During storms, Floodwaters which usually find their escape to the beach are backed up by storm surge cutting the main cliff face.

Socio-economic

Although Konakridee is located in the Port Loko District in northern Sierra Leone, it is much closer to the Western Area. Fishing is the dominant economic activity for men whereas farming and petty trading are the main source of livelihood for women. With over 300 fishing vessels in the community, some are large (30 crew) boats and some canoes are purely for transportation. The average size of the fishing community is estimated at 2,000, plus 1,000 others (mostly women) in fish handling, transactions and product transformations. There are strong women & fisheries associations dedicated to smoking fish using mangrove wood. Recently, FAO built a small fish-smoking house, but serious concerns emerged on the use of the facility as mangrove combustion emits polycyclic aromatic hydrocarbons (PAH), extremely hazardous carcinogenic compounds when inhaled, or eaten as smoke stock on fish. This required the development of alternative solutions in the community. Additionally, a significant number of people depend on riverine farming and vegetable gardening.

The women also depend on vegetable gardening as another main source of income. Huge quantities of vegetables are consumed in Freetown and this is a good source of earning. Vegetables are largely grown in December through May, followed by rice. Among the challenges is land ownership and control, which are decided by community heads and the men folks. The role of women in the community was not formally recognized or accounted for in any mitigation, adaptation or relief efforts. Women are knowledgeable about the ecosystem and have strategies, experiences and skills to cope with natural disasters and water shortages, which qualities are grossly ignored

Tombo Fishing Community

Tombo a coastal fishing town located in the peninsula plains in the Western Area Rural District of Sierra Leone with a population of 33,979 (16,823 male and 17,156 female). It is some 30 mi (49 km) east of Freetown (the capital city), with fishing as the main industry.

Vulnerability

The main hazards affecting the community of Tombo are similar to those facing the Konakridee community. Tombo also suffers from wave and surge activity caused by storms linked to the monsoon period and coastal erosion and also from locally intense rainfall. The beach area is particularly vulnerable to shoreline changes.

Although fishing goes on every day except Sundays, the best season is between January and June, July, August and September which bring in strong winds and with them the south-westerly waves, The highest waves occur for about a month, in spells within this period and according to local estimates, are about 4ft (1m) in height.

Socio-economic

The main economic activities are fishing, ecotourism, construction, rearing small ruminant and domestic poultry, vegetable gardening, quarrying, petty trading, charcoal production and migration. Tombo has its own local radio station — Radio Tombo on MHz 96.0. Coastal erosion, rainstorm, seaweed bloom, high temperature and flooding were the impacts of climate change on the community. Women are mainly engaged in fish processing and trading, but petty trading was the leading activity in which women are engaged.

Other industries in the town include coal production and farming. Cosmopolitan Tombo is a major fishery trade and transport hub with good mix of ethnicity (e.g. Temne, Sherbro, Krio and Limba). With a predominantly Muslim population, Tombo is known for its deep Islamic faith. The town has its own local radio station (Radio Tombo, MHz 96.0). Although a part of the larger Western Area District Council, Tombo is locally governed directly by an elected town council headed by a Town Head.

Although fishing is the main alternative strategy that has gained importance, respondents of the study highlighted that fishing activities have been weakened by decreasing fish sizes; a result of seaweed bloom and salinization. Due to climate change, the communities were facing increased environmental problems.

Subsistence agriculture is another income-earning activity in the community, second to fishing and livestock production. Rain-fed agriculture is done during the wet season (April to November), when maize, beans, groundnut and cassava are cultivated. During the dry season, watermelon, tomato, lettuce, etc. are cultivated. The natural vegetation is degraded savannah, with less than 10% tree cover and no grass layer. Fruits, construction materials (stakes and thatches) and firewood are collected from the degraded savanna. Additionally, the savanna is used as forage for domestic animals (ruminants). Bust as the area is facing considerable levels of desertification; resources gathered from the savannah are dwindling.

Rural Western District (Lakka)

Lakka is a coastal resort town around the peninsular in the Western Area Rural District of Sierra Leone. The town lies about ten miles west of Freetown (the capital). The major industries in Lakka Town are tourism and fishing. Lakka is known for its large beaches and therefore tourist attraction. It is a small community of about 5,000 people, over 50% of who are women.

Vulnerability

A high percentage of the interviewees in the focus groups and key informants faced several climatic and environmental challenges in the past few years.

The identified challenges included:

Prolonged wet season, experienced two years in a row now; High speed winds; Sea weed blooming.

Irregular seasonal variation in air temperature, salt water intrusion, Mangrove wood cutting and charcoal production: Over-fishing and illegal fishing   Coastal Erosion, Sea level rise, heavy windblown, flood and land slides.

Socio-Economic Issues

Lakka Town is ethnically diverse, as it is inhabited by several ethnic groups, although the Sherbro and Krio remain the principal inhabitants. The people are mainly engaged in fishing. Lakka Town has a famous hospital, several hotels and primary schools, and a secondary school. The inhabitants are largely of the Christian denomination. Although part of the Western Area Rural District Council, Lakka has its own directly elected Local Town Council that is headed by a Town Head.

Subsistence fishing is the main activity in the Lakka community (almost all the interviewees fished and processed fish for sale). Rain-fed agriculture is done between May/October and April, during which period maize, beans, groundnut and squash are cultivated. The natural vegetation has degraded due to improper human activities. Alternative livelihood strategies in the town include charcoal production, sand mining, tourism, and other informal jobs like construction and farming. Both women and men are fully engaged in these livelihood activities.

Adaptation Measures

Adaptive measures for coastal zone management are normally classified into three categories (IPCC):

- retreat,
- accommodate,
- protect

Using a major, low -lying Lumley beach highway as an example, the options in the face of rising sea -level are: (1) to relocate the highway on higher ground away from the coast, (2) to raise the roadbed above the expected elevation of future sea -level rise to accommodate the rise, (3) build a sea -wall to protect the highway at its existing elevation.

Setbacks

The currently available guidelines on setbacks (Land, Country Planning and the Environment) specify three categories of setback distance, based on shoreline slope categories referenced to the high water line:

- For slopes equal to or steeper than 1:1 (45 degrees), a setback of 7.6m (25 ft) is required;
- For slopes between 1:4 and 1:20, the required setback is 15.2m (50 ft), implying, at 1:4, a backshore elevation of 3.8m (12.5 ft); and at 1:20, a backshore elevation of 0.76m (2.5 ft);
- For slopes less than 1:20, the required setback is 30.5m (100 ft), implying a backshore elevation of 1.5m (at 1:20) or less.

All -weather roads

There is need to re -engineer sections of several major highways that serve coastal and other areas in Sierra Leone.
There is limited entry to and exit from the Greater Goderich area, considering the size of the population. Evacuation in the event of an extreme weather event is via three main access roads that include low -lying and floodable stretches, especially the northern route into Freetown Goderich road. As at 2008, prolonged heavy rains flood both the highway and some of the approach roads leading into Freetown. In particular the road is frequently flooded along the stretch that is below 1.5m above sea -level.

Draining the wetland adjacent to the Goderich-Hamilton road is unlikely to bring relief. The more likely result will be accelerated compaction due to the muddy and clayey nature of the substrate. With sea -level rise and possible continued subsidence, there is urgent need to re -engineer the highway by raising the level of the road bed to convert what is perhaps the most heavily used arterial road in Freetown into an all-weather road.

In Sierra Leone,there are other areas where the road bed needs to be elevated at least to 2 -3m above sea level to avoid increasing incidence of periodic flooding in the future. Long -term planning should incorporate this policy for all primary roads that service and provide access to with coastal communities, especially where emergency evacuation may be necessary.

Early warning systems in emergency management

Inhabited structures near the coastline, particularly along the Freetown coastline (such as hotels) should be required to have emergency procedures in place for storm surges, and other possible sudden events (such as explosions or accidents releasing noxious gases, flash floods, and beach contamination with oil). A rising sea -level will make built structures increasingly vulnerable to sudden flooding events.

Beach nourishment

With the likelihood that natural sand supplies to carbonate beaches will be severely curtailed before 2050, there is need to identify suitable sources of sand for beach nourishment if the tourist industry plans to continue to base it’s advertising on the prestige of the coastal environment. The cost of nourishment is high and is an ongoing process, requiring repeat nourishment at intervals. Thus offshore sand reserves near to the tourist and public beaches should be a priority target.

Constraints and Gaps

Coastal Vulnerability

A scheme embodying the principles used in constructing the Coastal Vulnerability Indices should be extended to the whole coastal area. This can be done relatively quickly and at relatively low cost. A country wide application of a Coastal Vulnerability Index would provide planners with a technical baseline for

considering the merits of the various development schemes that will surely be suggested in the future.
Preliminary research to perfect the most appropriate parameters would be a first step. Additional, nonphysical parameters should be added as, for example, in the comprehensive scheme published by Meur -Ferec et al. (2008)

Setbacks

In addition to revising setback guidelines to accommodate a risk -based approach, research is needed into how the guidelines may be designed to accommodate sea -level changes through time because progressive sea -level rise risks are likely to change. Setback guidelines should take into account the expected degree of rise and be subject to revision at frequent intervals (perhaps every 15 -20 years), as new data on sea -level rise rates are generated. As part of setback guideline revision, a country/coastal-wide survey procedure of assigning an Erosion Hazard Area to the coast, based on estimated erosion rates projected 60 years into the future should be implemented (Crowell and Leatherman, 1999).

Sources of beach sand

A research programme to carry out a country -wide survey of the country's shelf and upper slope to identify suitable alternative sources of carbonate sand for beach nourishment is needed, as the potential for natural beach replenishment decreases over time. This should be carried out before indiscriminate sand mining develops in response to the needs of the construction and tourist industry.

CHAPTER 6: Technology Transfer and Development

6.2.1 Background

Throughout the UNFCCC process, the need for technology transfer and environmentally sound technologies has been recognized as critical in averting the threat of climate change. Article 4.5 of the Convention states that:
"the developed country Parties and other developed Parties included in Annex II shall take all practicable steps to promote, facilitate and finance as appropriate, the transfer of, or access to, environmentally sound technologies and know how to other parties, particularly developing countries Parties, to enable them to implement the provisions of the Convention. In this process, the developed country Parties shall support the development and enhancement of endogenous capacities and technologies of developing country Parties. Other Parties and organizations in a position to do so may also assist in facilitating the transfer of such technologies."
Through the consultative process, a framework for technology transfer was developed and formally adopted at the Seventh Conference of Parties in 2001 by decision 4/CP7 to enhance the implementation of Article 4, para 5 of the Convention by increasing and improving the transfer of and access to environmentally sound technologies (ESTs) and know-how.

The successful development and transfer of ESTs and know-how require a country-driven, integrated approach, at national and sectoral levels and this should involve cooperation among various stakeholders. Activities include technology needs assessments, technology information, enabling environments, capacity building and mechanisms for technology transfer.

It is against this backdrop that a workshop on Technology Needs Assessments and Technology Information for Sierra Leone was held in October 2015 at the Climate Change Project Office in Freetown.

The main objectives were to;

- discuss national concerns and priorities in assessing technology needs, including information tools and resources relevant for Sierra Leone,
- discuss a framework to assist Sierra Leone in conducting comprehensive technology needs assessments including addressing adaptation issues and concerns.

Among the key recommendations and outcomes of the workshop were that;

- adaptation issues are inherently cross -sectoral and are often interrelated with mitigation options
- the Technology Needs Assessment process and activities should not be conducted in a vacuum but ensure links with national development priorities and needs.

6.2.2 The Technology Needs Assessment Process

Technology transfer is concerned with the flow of experience, know how, and equipment between and within countries. Decision 4CP/7 noted that technology transfer has five key elements connected within an integrated framework. These elements are:

- the technology needs assessment,
- improving access to technology information,
- improving and strengthening local capacity,
- creating enabling environments, and
- instituting technology transfer mechanisms.

A technology needs assessment process is defined as a set of country -driven activities that identify and determine national mitigation and adaptation technology priorities, which can form the basis for a portfolio of environmentally sound technologies projects and programs. To conduct the technology needs assessment, Sierra Leone adopted the six -step process outlined by UNDP below:

Activity 1: Prepare a preliminary overview of the sectors

Activity 1 is a preliminary overview or assessment of the sectors which are to be analyzed. The assessment involves collecting and analyzing the various data and information which exists on this sector, so that a comprehensive overview of the sector is complete.

Activity 2: Identify technology criteria for assessment

Activity 2 involves the identification of technology criteria for investment. This depends on a number of factors as it relates to the technology. Key questions such as the contribution to development goals and the possible market potential of technology have to be considered.

Activity 3: Prioritise sectors and select key technology (ies)
Activity 3 is the identification of priority sectors and key technologies, which will be based on the key criteria for the technology and the importance of the sector. The availability and the possible access to the technology should be considered.

Activity 4: Identify barriers and policy needs
Activity 4 allows the identification of barriers to applying specific technologies, and the identification of policy needs which are required to improve technology transfer.

Activity 5: Define and select options
Activity 6: Prepare a synthesis report
Activities 5 and 6 involve selecting technological options for the short and long term, and the preparation of a report for review. The entire technology needs assessment process should involve stakeholder consultation and engagement along with barrier analysis.

For Sierra Leone, the technology needs assessment process consisted of a series of expert workshops with key sectoral experts present to discuss issues relating to technology in Sierra Leone. The first workshop held on the 12th May, 2016, focused on mitigation and energy issues, while the second workshop looked at adaptation issues as they relate to the coastal zone and water sectors in Sierra Leone. Both workshops used the SNC of Sierra Leone as the document of reference.

6.2.3 Mitigation Technologies for the Energy Sector
Criteria for Mitigation Technologies
A number of issues were considered with regards to criteria for the transfer and development of technologies for mitigation for Sierra Leone. These included the overall integration with the current energy policy, and the linkage to development goals. In order for a technology to be suitable for Sierra Leone, it was agreed there a number of key criteria which have to be met.

These are:
- affordability and low cost,
- environmental and economic impact,
- social acceptability, and
- job creation potential.

The identification of these key criteria was done utilizing expert judgment and stakeholder analysis. It was noted that any technology which is to be transferred to Sierra Leone should aid in reducing the amount of foreign exchange which is utilized to purchase energy or fuel, in addition the technology should be durable, be commercially proven and aid in the development of Sierra Leone. Further, the proposed technology should be in line with future projected energy scenarios.

Table 6.1 A Possible Future Energy Scenario for 2015 Fuel Sources MW

Fuel Sources	MW
Heavy fuel oil and diesel	380
Natural gas and coal	700
Wind	35
Hydropower	70
Solid waste	10
Bagasse and fuelwood	35
Ocean energy	5
Solar photovoltaics	9.8
Fuel cells	0.2
Total	1,245

Mitigation Technology Requirements
Natural Gas Technology
Natural gas is the cleanest burning fossil fuel, and is available for transport in the form of liquefied natural gas (LNG) or compressed natural gas (CNG). Since the 1990s, natural gas has been one of the fastest growing sources of energy for electricity generation, with combined cycle gas technology increasing levels of competition and efficiency. The problem for Sierra Leone is that LNG is far away from the source. Natural gas has to be transported in specialized LNG ocean tankers and thus a terminal to receive natural gas is required so that Sierra Leone could benefit from its importation. This has not been identified as a priority for Sierra Leone for now. Given the considerable energy requirements for the mining sector, this natural gas could be considered in the future to generate electricity which will be shared among the major mining companies to remove their dependence on fuel oil.

Technology to extract methane from landfills and generate electricity is also considered as a priority. This has the potential to generate at least 10MW of electricity in Sierra Leone and plans should be put in place to pursue the generation of electricity from dump sites.

Transport
With increase in the number of motor vehicles in Sierra Leone, the transport sector was also considered as priority sector where new technologies may need to be applied. There is a need to examine the mass transit possibilities in the country, especially the possibilities for light rail transit. This needs further consideration given the large amounts of foreign exchange which is spent on the importation of petroleum fuels for vehicles; there is a need to look at alternative fuels and vehicles for Sierra Leone. CNG can be used in vehicles, and there are a number of manufactures of natural gas engine vehicles which could be used in Sierra Leone as the sector is modernized.

Utilizing natural gas vehicle in Sierra Leone would have a number of benefits including promoting energy security, and reducing the amount of particulate matter and oxides of nitrogen (NOx) which are emitted. Fuel cell vehicles could also be utilized in Sierra Leone, but there are a number issues related to fuel storage and facilities which would need to be addressed, such as establishing a number of retail points and increasing the numbers as vehicle numbers increase.

Diesel is cheaper than gasoline and there have been many developments in diesel engine technology which the country could benefit from. An increase in the number of vehicles utilizing low emission diesel engines would be affordable and beneficial to Sierra Leone. Electric vehicles and hybrid vehicle would also be desirable in Sierra Leone in the future, as these vehicles have little emissions and will help reduce the dependency on gasoline. However sustainable uninterrupted energy/electricity access will have to be significantly scaled up.

Renewable Energy Technologies

The country possesses vast potential in renewable energy in the form of biomass from agricultural wastes, hydro and solar power, which remain virtually untapped. Oil exploration activities are being undertaken. Petroleum Policy and Laws are in place to ensure accountability and transparency of its administration.

With the increasing amount escalating fossil fuel prices and the ever increasing amount of foreign exchange being spent on fossil fuels, the development of a vibrant renewable energy sector will help in improving energy independence. Like many other LDCs, Sierra Leone has an abundance of resources for renewable energy projects. The value of renewables lies in their ability to respond simultaneously to the two challenges which confront the energy sector, which are sustainable development and security and economic growth. Renewable energy technologies options for Sierra Leone are highlighted below.

Wind Energy:
Data on winds for Sierra Leone is rare. Existing data on wind velocities indicate a country-wide average of between 3m/s and 5m/s. wind speeds up to 12m/s are possible in some parts of the country. Currently there is no wind energy system in Sierra Leone.
Research into wind energy potential in Sierra Leone is poor and the country has no wind farm. There may be several sites where the wind is in excess 8 meters per second and thus suitable for the generation of electricity by wind. However feasibility studies need to be carried out. Generation of electricity by wind is very competitive with conventional mechanisms. Wind has not yet been identified as priority technology for Sierra Leone.

Small Scale Hydro Power:
As stated in chapter five under the water resources sector, Sierra Leone has nine major river systems. The Rokel/Seli, Pampana/Jong, Sewa and Waanje systems originate from within the country, as do the numerous coastal streams and creeks; the Great and Little Scarcies and Moa Rivers originate from the Fouta Jallon Plateau in the Republic of Guinea, and the Mano River originates from the Republic of Liberia. These rivers range in length from 160 km for the Great Scarcies to 430 km for the Sewa River; their catchment areas range from 2,530 km^2 for the coastal streams and creeks, to 14,140 km^2 for the Sewa River. The total mean annual runoff from the river basins is of the order of 160 km3, with monthly runoff following rainfall variability. Sierra Leone has over 20 hydro

potential sites of which the Bumbuna Dam is the only one that has been tapped. This dam, which has been completed, has a capacity of 50MW. This was considered as the most viable mitigation option for the electricity sector. If five of these hydro potentials including Bumbuna are utilized, it will result in almost zero emission from the electricity sector.This presents a huge opportunity for small scale hydro power particularly during the rainy season. Already a number of sites are being exploited.

Cogeneration and Biomass:

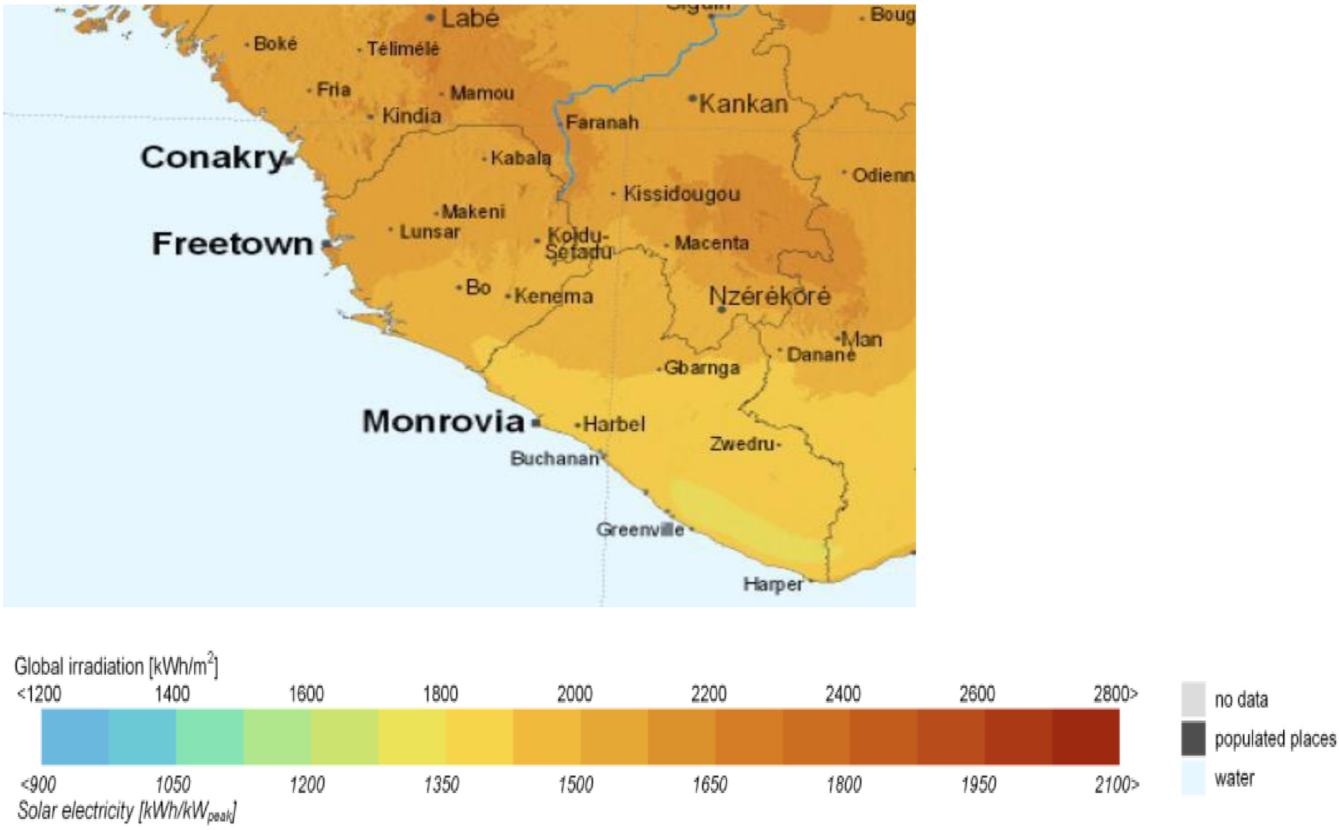
Ethanol is being produced by the ADDAX bioenergy project (the only CDM project) using sugar cane as feed in Sierra Leone. Ethanol can be used for a variety of purposes which includes replacement of octane enhancers in gasoline, as a transport fuel as is done in Brazil. The ethanol which is produced can also be exported. Technology for this ethanol production should therefore be encouraged. An ethanol production plant can be established in Sierra Leone.

Solar Energy:

Sierra Leone is ideally suited for the application of solar technologies. Many areas in Sierra Leone have solar insulation of 8kWh per sq. metre per day, which is excellent for utilizing solar energy for the supply of electricity.
While there are a number of photovoltaic systems scattered across the country, there is room for improvement with regards to solar energy. There are many street lighting systems which use photovoltaics, but there is a need for more photovoltaics to be used throughout the country. Some countries have developed solar hot water heating technologies and these needs to be transferred to Sierra Leone.

The Ministry of Energy and Water Resources (MEWR) estimates that approximately1460 kWh/m of solar radiation can be expected annually in Sierra Leone. A study by the Joint Research Centre (JRC) of the European Commission indicates a solar potential for the country at 2200 kWh/m.
A project for the installation of 10,000 solar street lights in Freetown, Lungi and twelve district capitals have been implemented with finance from the ECOWAS Bank for Invest and Development and Government of Sierra Leone. Two pilot projects in two rural communities at Tombo and Konta Line have been completed. A training center has been established for training for illiterate women in rural communities to build solar photovoltaic (PV) lanterns and installation of solar panels. In addition the United Nations Industrial Development Organization (UNIDO) has provided solar photovoltaic facilities at five growth centers and the United Nations Development Programme (UNDP) and three private companies facilitated the installation of 30 PV solar panels and equipment in a number of secondary schools in rural areas between 2010 and 2011.

Figure 5.15 Map showing potential for solar energy in Sierra Leone



The potential for solar crop drying has not been fully realized in Sierra Leone although it is a means of preventing spoilage which affects as much as 30 per cent of crop production. Crops such as bananas, papaya, sweet potato, yam, ginger, nutmeg, grasses and leaves can be dried by solar dryers, which range from the simple wire basket dryer to approximately two square meters of roof solar collectors.

Ocean Thermal Energy Conversion (OTEC):

OTEC is an energy source that basically utilizes the differences in the temperature gradients in between the warm surface water and the cold deep waters to drive a turbine to provide electricity. OTEC uses only seawater as energy resource. It provides an inexhaustible energy resource which is stable, with zero GHG emissions.

Exploration needs to be carried out to find out if there are deep water sites around the Sierra Leonean coast with sufficient temperature gradients which can be used for OTEC. OTEC technology may be suitable for Sierra Leone, and there can be many commercial spins such as Mari culture.

Technologies for Adaptation in the Coastal Zone and Water Resources Sectors

Current Situation (2005)

Coastal zones were identified as a critical sector for Sierra Leone in the Second National Communication. The Environment Protection Agency-Sierra Leone (EPA-SL) suggested that about 55 per cent of the GDP was produced within the coastal zone. Sierra Leone's coastline is approximately 503km in length and has diverse ecosystems, including sandy beaches, rocky shores, estuaries, wetlands and sea -grass beds.

Critical infrastructure located within Sierra Leone's coastal zone, includes port facilities, tourism resorts, and dense population centers. The coastal zone of Sierra Leone is very susceptible to sea level rise, which would cause increased beach erosion rates and higher incidences of coastal flooding. Permanent inundation could occur in some areas.

Climate change could also compound and amplify the effect of thunder rainstorms. Sierra Leone has suffered in recent times from extreme weather events notably the intense rainfall of the 16th of September 2015 and 14th of August 2016 which resulted in a devastating mudslide with over 500 lost lives in Regent. The potential for damage from climate impacts to the biodiversity of the coast and the coastal infrastructure is very high. The economic value of all the resources in the coastal zone will also be adversely impacted as a result of sea level rise and a changing climate. A fairly large percentage of Sierra Leone's population (approximately 15 per cent) is concentrated near to the coastline, thus a rise in the sea level will cause a displacement with regards to coastal settlements.

Sierra Leone's freshwater reserves come from a variety of sources. There are surface sources in the form of river and streams, and underground sources in the form of wells and springs. There is some rainwater harvesting in Sierra Leone, however groundwater meets most of the water demands in the rural areas. The second national communication noted that water demand distribution is based population concentrations, tourism development, and other water consuming industries.

The demand in the north of Sierra Leone is high, due to the extensive agriculture in the areas of little rainfall. Rutile and Bauxite and sugar cane processing industries located in the south, east and north of the country also consume large amounts of water.
Demand in the south and east of Sierra Leone is relatively low because there is greater rainfall and more cultivable land.

Changes in rainfall patterns could cause a decreased surface and groundwater supplies. Climate change will present additional water management challenges in Sierra Leone. There are predictions of increased short intense rain events under certain climate change scenarios. This would cause low percolation and recharge of aquifers and high run off. Reductions in rainfall as a result of climate change will affect water sources and supply. The reductions in rainfall will mean that less water will be available for domestic demand. Decreasing rainfall will mean that there will be an increase in irrigation requirements for agriculture. Water resources are important for all aspects of the economy, thus with a changing climate, key sectors such as tourism, and agriculture will be affected negatively.

Criteria for Technologies for Adaptation
A number of issues were considered when criteria for the transfer and development of technologies for adaptation were considered. Stakeholder consultations and expert judgment were used to determine the criteria. It was noted that technologies for adaptation should be: cost effective, proven, flexible,

aid in vulnerability reduction, and easy to use. Technologies for adaptation should also look at technologies in the broadest sense.

Adaptation Technology Requirements
A number of technologies for adaptation were suggested to aid in improving coastal zone management, in order to reduce the overall vulnerability of the coast to sea level rise. It was noted that beach protection measures such as groynes and revetments may be required. However, the reinstating of the tidal gauge network was highlighted as a priority for obtaining data, coupled with improved data collection for the geographic information system.

Improvement in the geographic information systems will aid in planning and project designs, thus ensuring that vulnerability reduction will occur. Beach profiling also needs to be expanded in Sierra Leone to aid the improved data collection. The regeneration of mangroves was another a priority identified.

In the Climate sector, the need for technology transfer in the field of earth data collection cannot be over emphasized. This includes the hardware setup of the stations, the operating software and the necessary training of personnel in working with the supplied tools.

In the water sector, the following needs were noted: an improvement and rationalization of the hydrometric network; additional river gauges and more automatic weather stations to aid in data collection and planning to reduce vulnerability; additional flood warning systems; and additional software such as water ware, river ware, and mike basin to aid in improvement of water management.

Barriers to Technology Transfer in Sierra Leone
The main barrier to the transfer of technology to Sierra Leone is the high initial capital cost of technologies.
There is a need for flexible financial measures in order for new technologies to be adopted.
Low capacity in terms of skilled personnel to absorb and repair the technology in breakdown situations was also noted.
Attitudes, perceptions, and lack of information were also highlighted as a key barrier. In particular, lack of understanding about specific technologies and lack of political will prevent the transfer and adoption of potential technologies.
Lack of data is a constraint, particularly with regards to vulnerability issues which prevents adoption and applications of technologies for adaptation. The lack of a central decision making entity to handle issues with regards to technology was also noted as a barrier.

6.2.2 Capacity development

At various sessions of the Conference of Parties COP and its subsidiary bodies, the issue of capacity building has been extensively discussed and decisions taken. By its Decision 2/ CP.7, the COP adopted the framework for capacity building in developing countries. The framework sets out the scope of, and provides the basis for action on capacity building related to the implementation of the Convention and preparation for the effective participation of developing countries in the Kyoto Protocol and post Kyoto Protocol process.

6.2.3 Activities Undertaken

Since 2003, the capacity of the task forces of the NCCC has been built through training workshops. These workshops covered the development of National inventories of Greenhouse Gas emissions, assessment of greenhouse gas mitigation measures, assessment of vulnerability of the national economy and ecosystems to projected climate change, and development and evaluation of CDM projects,. These were executed and funded by the GEF through UNDP, and the IPCC under the INC and SNC communications. The task forces of NCCC are, however, constrained in the capacity to execute methodological concepts of cost assessment of Mitigation and adaptation measures and to develop full projects in these areas.

Institutional capacity development is limited to procurement of computer hardware and software through projects funded by the UNFCCC and GEF through UNDP. This has particularly improved access to global environment information and communication between the UNFCCC Focal Point. IPCC and other multilateral environment organizations.

The GEF has provided financial and technical resources to Sierra Leone to enable the Task Forces of the MEAs of biodiversity, Desertification and Climate Change to undertake country-level capacity needs assessments and to develop specific capacity-building activities consistent with the Conventions. The EPA-SL which is the GEF Focal point is coordinating these activities. The NCCC will pay particular attention to the capacity development framework annexed to decision 2/CP-7 of the UNFCCC. The NCCC would identify the specific needs, options and priorities for capacity building for Sierra Leone and this will be achieved through the participation of a wide range of stakeholders, including government, national and international organizations, civil society and the private sector.

During the past ten years. Sierra Leone has promoted and encouraged the shift to more environmentally friendly technologies based on the awareness of the consequences of environmental degradation after the war which lasted from 1990-2000s. The shift has been from fossil fuel to renewable (solar) energy. Penetration of solar energy technology is high in the Administrative (District and City councils), Health, Communication, Water Resources, Commercial and Residential sectors of the economy.

In the Health sector most of the facilities at the District Health Centre's are powered by solar-photo-voltaic technology. Water lifting and supply systems are powered by diesel, and solar generators. The diesel generators should be replaced by solar generators because of reduced operational cost in addition to environmental benefits of reduced pollution. The penetration of wind energy is lower than solar energy due to lower wind speeds as one move further inland from the ocean. The commercial (mostly hotel) and residential sectors have also embraced solar technology through the use of Solar Home systems for lighting and heating. Penetration of solar systems in the residential sector is lower due to the attached initial cost of acquisition and installation of facilities. There is a potential move to the use of LPG for cooking in the residential sector to displace biomass (wood and charcoal) fuel although the issue of pricing and security are major concerns. Sierra Leone is therefore aware and receptive of clean technologies. There are a lot of opportunities and avenues in Sierra Leone for collaboration in the transfer and diffusion of climate friendly technology.

6.2.4 Activities to be undertaken

Activities that need to be undertaken include, among others:

- Technology needs assessment;
- Establishment of an efficient information system in support of technology transfer; and
- Capacity building in the promotion of the widespread dissemination, application and development of environmentally sound technologies and know-how.
- Improving the quality of activity data for future GHG inventory studies;
- Improving the quality of agricultural data for climate change impact analysis;
- Abating CO_2 emissions in the energy sector;
- Sequestering carbon and improving on the CO_2 sink base of the country; and
- Adapting to possible climate change effects on water resources, coastal zone and agriculture;

It is envisaged that the international community will select and fund these projects to allow Sierra Leone attain sustainable development whilst contributing effectively to global initiatives in addressing climate change.

Conclusions and Recommendations

The technology needs assessment process should be continued and there is a need to revisit this issue. Technology issues as they relate to agriculture have not yet been examined and an in -depth analysis of the technology requirements for the agricultural sector is needed, given the critical role of the sector to the country's economy. There should also be a specific consultation with the industrial sector so that the specific technologies for industry can be identified and transferred.

Public education, information and awareness with regards to new technologies need to be improved. Education and sensitization to new technologies should be targeted at every level of the society, and perhaps there is a need for a specific education and sensitization programme specifically tailored for policy makers. There may also be a need for a clearing house with regards to technology to be put into place, although raising awareness with specific stakeholders about the UNFCCC's TTClear website would aid information -sharing about potential useful technologies.

Improvements in the data which is collected was highlighted as concern by many stakeholders.

However, it was agreed that the lack of data should not prevent projects from proceeding.

CHAPTER 7: **Research and Systematic Observation**

Introduction

7.1 Based on an MOU signed between the project and the national Meteorological Agency, an initial assessment of Sierra Leone's systematic observation systems was conducted.
The assessment focused on the needs and the requirements of the Meteorological Agency, with a view to making recommendations for the improvement of the observation systems. More specifically, the following elements were planned:

- A detailed assessment of the coastal, marine, and hydro meteorological systematic observation systems in Sierra Leone, describing: the types and locations of the equipment; the agencies responsible for the maintenance of the equipment; the scope of climate related data stored, including climate variables observed; the years for which data is available and frequency of data collection.
- An assessment of the current coastal, marine, and hydro meteorological systematic observations systems in Sierra Leone.
- An identification of the technological and capacity building requirements for the upgrade and improvements of the current systematic observation systems.
- It was recommended that 15 automatic weather stations be added to the existing system. Along with some other required upgrades, the total cost of improvements would be US$ 795,000.

7.1.1 **Current status of systematic observation systems in Sierra Leone**

The Meteorological Department (now Agency) is organized into five branches:
The **Administration and Support Services** branch provides efficient and effective administration in the areas of personnel, office management, accounting services. There used to be a library and a training school which are no longer in operation since the time they were destroyed by the rebel war.
The **Weather** branch provides weather, hydrologic, and climate forecasts and warnings for Sierra Leone, its territories, adjacent waters and ocean areas, for the protection of life and property and the enhancement of the national economy. The **Weather** branch data and products form a national information database and infrastructure which can be used by other governmental agencies, the private sector, the public, and the global community. Data for forecasts are obtained locally from observation points at the surface with no upper air stations as well as radar stations since the department has not been able to replace them from the time they were destroyed by the rebel war. Data was supposed to be communicated via internet but due to lack of resources only eight stations out of the sixteen stations that are currently available have been put online.
The **Climate** division manages the country wide network of automatic weather stations. The branch compiles data generated and processes requests for clients.
The Global Observation System
The Global Observation System on Climate (GCOS) is a body which aims to achieve in the long run a good network of systematic climate observation system

to collect the necessary data for various investigation for the proper understanding of the climate for proper climate predictions.

7.1.2 Sector Policy

The Meteorological Sector is the sole institution enacted by the government for the collection, analyses, dissemination and storage of meteorological data for the country.
The Sierra Leone government signed and ratified the United Nations Framework Convention on Climate Change (UNFCCC), as the country's clear manifestation of concern for climate change issues.

7.1.3 Developments since the last communication

In Sierra Leone's SNC, there were a series of identified issues that were recommended for the strengthening of the Meteorological Agency.
Since then, the following have been accomplished by Government to address some of the concerns raised.

- The government has upgraded the meteorological department into an Agency through an act of Parliament.

- The UNDP through the facilitation of the World Meteorological Organization (WMO) supported a project for the digitization of the country's existing meteorological/climatological data. The project ended on the 31st December, 2010. However as there are still more data to enter, even after an extension of the contract was accepted for a limited period of three months.

- The Department received in 2006 the European Meteorological Satellite (EUMETSAT) reception station (PUMA System) together with the joint African Monitoring of the Environment for Sustainable Development (AMESD) of Ministry of Agriculture and Food Security and other line ministries and organizations. The equipment has now been installed at the forecast office and have greatly improved service delivery to end-users.

  The installation of the MESA equipment that will be replacing the PUMA . is already operational at the Meteorological Forecast Office.

- From the NAPA assessment, the Department came out with the Meteorological component master plan for the rehabilitation of dysfunctional stations and for possible expansion of the network of stations and other logistics.

- Some five (5) automatic weather stations from the Spanish Government has already been installed. These stations are currently faulty and need maintenance. The International Fund for Agricultural Development (IFAD) through the NAPA project that they were implementing in the Agriculture sector, provided eight Automatic Weather Stations (AWSs), two in each of their four districts of operation in Sierra Leone. The data are simultaneously received by a centralize saver at the MET station in Kenema for their respective processing for end users.

- Over the past three years, the Meteorological Department trained four (4) forecasters and two(2)meteorologists in WMO Nigeria Regional Training Centers and the University of Reading respectively.

- The Department collaborated with the Ministry of Agriculture and Food Security in FEWSNET/CILSS Food security monitoring and early warning.

- The Department's service to the Aviation, Marine, environment, disaster management sectors etc. cannot be overemphasized. The department is also involved in the Climate Information and Early Warning System (CIEWS) and the Quality Management System (QMS) project that is currently ongoing.

- The Department involvement in the last year's PRESAO July, August and September (JAS) forecast exercise prompted the department to introduce the Early Warning Systems and Seasonal Forecasting Mechanism (Planning/ Training stage). It is hoped that as the Meteorological Department's appeal to Planning and NGO Offices for assistance will be heeded, and the Department will get the necessary sponsorship for at least one person for the training session in Niamey, Niger in February, 2018 for the continuation of this vital service of seasonal forecasting.

New Monitoring Environment Security Africa (MESA) equipment is used to access weather product via satellite. It can perform numerous analyses and can also manipulate data to yield forecast projections.

Status of Other Observing Systems in Sierra Leone

Observing Systems	**Status**
Radiosonde Network	Currently Sierra Leone is without any radiosonde.
The Doppler RADAR	The Doppler RADAR located at Tower Hill in Freetown has been out of order for decades. It was noted, however, that the radar could provide a number of additional products which could be used to enhance operations of the Meteorological Service but this no longer applicable since it has been out of service.
Automatic Weather Stations	At the moment, there are sixteen automatic weather stations located at various parts of the country of which only twelve are in good working order.

Cloud Observation	The rehabilitation of these stations together with the setting up of the remaining stations will greatly capacitate weather department.
Observation of Greenhouse Gas Composition	There is none at the moment but the setting up of such stations will help to determine their respective concentrations in atmosphere above Sierra Leone. This will include Carbon Dioxide (CO2), Methane (CH4), water vapor and Ozone (O3).

Climatological Network

The country's climatological network consists of a mix of conventional and AWS stations. These stations record rainfall, temperature, evaporation and sunshine duration.

The network is maintained by the Data Acquisition Section of the Climate Division. The main instruments used are the Stevenson Screen, thermometers, rain gauges, rainfall loggers, evaporation pans and sunshine recorders.

Data Collection

Prior to 2005, there were no automatic weather stations for the collection of data in Sierra Leone although the standard meteorological data was always collected. Wind direction, speed, air temperature, relative humidity, atmospheric pressure and rainfall data are collected by the Meteorological Service.

Rainfall Observation

Each synoptic station measures rainfall.

Atmospheric Data Collection

WMO international data collection and dissemination mechanism is referred to as the Global Atmospheric Watch (GAW). There at the moment no component in either the GAW or GCOS for measuring the atmospheric composition and chemistry. The bridging of this gap will help us to contribute to our obligation of atmospheric chemical composition determination over our country.

Ozone Observation

The presence and use of this layer in the stratosphere in the absorption of the high energy ultra violet (UV) radiation cannot be over emphasized. Thus the setting up of an ozone monitoring system will expand the sparse data collection on ozone around the globe.

Aerosol Measurement

The role played by aerosols in the atmosphere has long been documented in the Inter-Governmental Panel on Climate Change (IPCC) report of 1996. There is still the task of expanding the limited knowledge on the extent of its impact on the climate system. The establishment of monitoring stations for these parameters will greatly improve our understanding of their influence on the climate system. This will also be done with other line ministries and institutions like the water resource department, the university and other development partners.

7.1.4Technological Capacity Needs and Requirements

Currently there is a high need of trained personnel for all sectors ranging from meteorologists, observers and technicians to fill the existing gap in the department. The department is also faced with serious constraints in the area of instrumentation like radar, rainfall stations, climatological stations, Ocean buoys, radiosonde, cloud height and amount measuring equipment, visibility measuring equipment, NWP forecasting model, Flood and climate forecasting models. More automatic weather stations are needed.

Plan for Systematic Observation

The 2000 assessment found that the number of automatic weather stations needed to be improved to obtain a comprehensive coverage of meteorological data so as to improve the ability to monitor the micro climates within Sierra Leone and to understand climate change and its possible impacts in Sierra Leone. An increase in the amount of weather stations would also aid with provision of agricultural data so that there is better understanding of the climatic conditions. Finally, an increase in the number of automatic weather stations would also assist in providing data for ground trothing radar systems.

Equipment Needs

In terms of the improving the Sierra Leonean climatological network, the assessment identified the following equipment needs: (i) an additional 100 rain gauges and measuring cylinders to provide at least 97% coverage of the country; (ii) an additional 40 rain -loggers to complement the rain gauges with intensity and duration information; (iii) fifty full climatological stations for greater spatial coverage – 30 along the coast and 20 at the higher elevations; and (iv) thermometers, evaporation pans, and sunshine recorders for each climatological station.

The total budget for the improvements of current AWS was estimated at US$ 795,000. Table 5.1 below depicts additional equipment needed by the agency (including the above 15 AWS request).

Table 5.1: Estimated Budget and Costs for Improving Sierra Leone's Systematic Observation Systems

Equipment	Estimated costs
200kw Radar	US$1,500,000
15 Automated Weather Stations and spare tower (shipping)	US$795,000

Training	
Technicians(10) and top levels(2)	US$395,500
Doppler Radar -Spares parts	US$95,000
Signal Processor Board (ESP -7) (part of the radar package)	
Thyratron	
Thyratron Trigger Module	
Lightning Protection (part of the radar package)	
Equipment Calibration and Maintenance Training	US$95,000
Radar Operation and Data interpretation Training	US$50,000
Upper Air Station	US$195,000
Filters for Hydrogen Generator Filtration System	US$5,000
Standby Power Generator	US$4,000
Synoptic Sub Station	
Hydothermometer (back - up temperature)	US$3,000
Aneroid Barometer (atmospheric pressure back - up	US$15,000
AWS Spares	US$35,000
TOTAL	US$3,382,000

Articulation of NAPA options in terms of Technological Options

This will include the cross-cutting activities that the Meteorological Department will implement in collaboration with other institutions in addressing the adaptation needs to climate change.

Table 7.1 Technological options in the NAPA

NAPA options	Development Sector of Concerned	Type of technology	Availability	Observation
Observation Network	Agriculture Water Resources	Real-time data transfer Complete data availability and storage	Could start crop modeling Water resource mapping done	Farmers could get more yield
Production and Dissemination of Agro/Hydro-Meteorological	Agriculture/ Water Resources	Radio, TV, Internet and RANET	Technology developed by ACMAD and AGRHYMET	Coupling with community media network

information				
Fight against some crop prone to climate-sensitive disease	Human health	The integration and use of the RANET System for issuing warnings in development planning	The management of both the rural and urban areas using the ACMAD/ AGRHYMET technology eg. AMSED crop and vegetation monitoring	The integration of Climate issues in the management of major endemic diseases
Extreme weather/climate events e.g. the dense haze of February, 2012 in the country	Human Health	The integration of clinical diagnosis of certain outbreak of diseases and the extreme weather events for future forecast	The Medical record management integrated into the weather data management. We mostly use the ACMAD/AGRHYMET technology	Medical Doctors and other practitioners working with the Meteorological department and the university
Popularization of animals and plant species with weather suitability	Agriculture and Livestock Production	Seeds resistant to Climate, Fight against parasites, promotion of crops adaptable to climate change as well as similar animal production	Work with MAFFS and Sierra Leone Agricultural Research Institutes (SLARI) of Njala and Rokpur	High economic gain and enhancement of Public research previously done in the country

The need to fast-track development and poverty reduction of the government Agenda for Prosperity(2012-2017) which is about to end this year since it was a four years development plan.
The overall development of the meteorological and other climatic issue related institutions is therefore critical.

Conclusions

It was concluded that the proposed additional automatic weather stations connected by satellite would have a number of advantages for Sierra Leone.

First, it will improve information on local conditions and could provide important climatic information for a number of uses such as agriculture and disaster management. Second, it would also improve the accuracy of Sierra Leone's contribution to the international observation systems and databases such as the Global Climate Observing System and the provision of more accurate meteorological data for inputting into Global Circulation Models.

Chapter 8 Education Training and Public Awareness

The general public needs to be adequately informed about issues relating to climate change and the consequences of climate change. This will help them play their different roles in influencing policy and decision making processes in implementing the UNFCCC.

Formal Education

The formal education system plays a pivotal role in mainstreaming Climate Change studies into our educational system. Currently, Climate Change studies are treated as subsections in subjects like Geography, Marine Science Environmental studies and Energy studies etc. Weather, climate and all other related environmental issues have been incorporated into the university curricula and are treated to such depths as to reveal the consequences of anthropogenic activities on climate change. The necessary adaptation and mitigation measures should also be incorporated in the curricula.

Informal Education

The Informal Education sector is less capacitated for climate change education. Thus should be treated as a universal problem and therefore be incorporated into the informal sector activities. Special awards can be awarded to communities and recognized bodies for their respective roles in climate change activities. Important figures and opinion leaders should be encouraged to act as propaganda machines for issues on climate change. Youths and women who are key figures on the ground should be encouraged to participate in climate change activities. Mass media techniques such as video/television, radio, print media, traditional communicators and extension agents are already being used in well designed campaigns aimed at achieving favourable results on climate change related issues. These activities should be scaled up.

Training

A series of workshops and seminars was held by the Climate Change Secretariat in collaboration with the Climate Change Project Office at Tower hill, Freetown to train the members of the different technical teams (GHG Inventory, Vulnerability and Adaptation and Mitigation) in the implementation of the project. These trainings need to be formalized and scaled up.

Training on Assessment of Greenhouse Gas Mitigation Options.

A National Consultant/Trainer was recruited to provide services to GOSL/GEF/UNEP project on the development of the Third National Communications for Sierra Leone, with particular reference to training on Mitigation tools (LEAP, COMAP etc.). This training lasted for about five (5) days and consisted of lectures, discussions and hands on deck exercises. Data requirements for each software package were treated in some detail based on available data.

The Consultant/Trainer, in conducting the training, explained the Basic Methods and concepts of Mitigation assessment for the Energy Industrial, residential, commercial transport and transport, agriculture, rangelands and grasslands, land use and forestry and waste management sectors. The national task forces were also introduced to the basic steps in the analysis of Mitigation options.

These steps include:

- Determination and collection of the data and information needed for the assessment
- Screening to identify mitigation options significant to the country.
- Development of baseline and climate change scenarios of the options.
- Development and projection of future GHG net emissions and cost scenarios.
- Evaluation of the cost-effectiveness of mitigation options.
- Development and evaluation of policies, institutional arrangements and incentives necessary for the implementation of the cost-effective mitigation options;

The experts were able to easily identify data requirements for each software and the results of the analysis were reported in Mitigation Chapter of this Third National Communications report.

The Consultant advised that the models for now should not be included in the report due to data and time constraints. They will hopefully be included in the fourth Communication Report pending improvement in both quantitative and qualitative data.

Public Awareness

During the implementation of the TNC various studies, sensitization and public awareness campaigns were carried out by the project throughout the country. These campaigns took the form of workshops, seminars, panel discussions and question and answer sessions. These deliberations were mostly conducted in the lingua franca, Krio, with relevant translations depending on the type of audience. This encouraged members of grassroots communities to participate actively. The workshops and seminars were organised by the project, EPA-SL with participation of Local Councils and attended by Government Ministers, high level Government officials, representatives of NGOs, CBOs, farmers, teachers, students, Heads of Government , Civil Society Organisations, etc.

Development of sensitization materials to enhance public awareness of climate change.

Bill boards carrying messages related to Climate Change were erected at key sites in and outside major cities.

Translation of the sensitization material into the various local languages.

Jingles and short skits highlighting the causes and effects of Climate Change are aired on both national and private radio stations nationwide.

As a sign of Government's continued commitment and support to the climate change process, the Deputy Minister of Transport and Aviation of the Republic of Sierra Leone launched the project early in 2013. The Resident Representative of the United Nations Development Programme, the UNEP programme officer George Manful, Government Ministers and other important dignitaries graced the occasion.

The now annual national status reports were produced detailing Sierra Leone's achievements and aspirations in implementing the UNFCCC from COP 15 - date.

CONSTRAINTS

One of The main constraints in enhancing public awareness is the inadequate human and institutional capacity within the Climate Change Committee of EPA –SL to develop sensitization materials to enhance public awareness on climate change.

In many fora country wide, the perception of most participants is that they viewed climate change as a change or variation in global climate accompanied by changes in temperature and weather patterns.

It is clear that there is misunderstanding about climate change, its causes and its impacts based on the definition of the IPCC.

In order to address many issues highlighted previously the following response actions have been proposed:

- The education of the policy and legislative authorities on the climate change issues for possible policy implementation.
- The education of the media on climate change and how to report on them.
- The training of the civil Society and local government authorities on the adverse effect of climate change, its contributing actions and how to disseminate the climate change information to the grassroots people.

- The formulation of policy on CDM undertakings and tailoring development paths through renewable energy resources.
- Diversification of our educational system to involve the school children in knowledge on climate and environmental matters.
- Getting producers involve in using alternative environmentally friendly products. e.g., using re-circled paper for packaging instead of plastics.
- Development of a Newsletter and Website for greater dissemination of information to the general public. With the installation of Internet facilities and training provided to the members of the NCC this objective could be achieved in the very near future.

Strategy for the future implementation of education, training and public awareness in Sierra Leone.

The programme and strategy will contain activities such as review of school curricula with the concept of including climate change issues, strengthened human, scientific, technical and institutional capacities, development and dissemination of outreach materials.

Recommendations

A key component for any climate change programme is public awareness and education; however funding may be a constraint. Thus, in designing the fourth National Communication, sufficient funds must be put aside for public awareness. There is a need for greater collaboration with agencies who have an interest with climate change to ensure an integrative approach to climate change, particularly as it relates to public awareness.

For the climate change education and awareness programme to be effective, there will also need to be synergies with other issues. For example, the linkage with disaster management should be exploited, particularly given the fact that Sierra Leone has been affected by a number of natural disasters. A joint strategy could be developed between the Meteorological Department and the Disaster Management Department of the Office of National Security with regards to climate change and disaster management. Linkages also need to be made with the energy sector for the development of joint programmes.

There will be also a need to sensitize the corporate sector as to the importance of climate change. A consultation with the corporate sector on climate change issues may be required. Corporate sponsorship could be sought for the development of these climate points.

The development of a short documentary on climate change should also take place. This could discuss the issue of climate change, highlight the vulnerable areas in Sierra Leone, adaptation options and required changes in behaviour, as well as focus on energy issues. Such a project should be a joint venture with the respective offices responsible for disaster management, water, energy, agriculture, and the Meteorological Service. Corporate sponsorship may have to be obtained to facilitate such a venture.

Funding for public awareness may have to come from external sources. All climate change related projects, however, should include substantial funds for public awareness.

With vulnerability being a key issue, it is clear that there is room for the development of vulnerability projects in Sierra Leone.

There are two possible projects which could be put forward.

- The first relates to the vulnerability of the tourism sector and climate change. The coastal areas could be used as a pilot site, and social economic issues considered, given the annual seaweed invasion and amount of persons employed by the industry.

- The second project can relate to the vulnerability of health sector. The health infrastructure could be considered as pilot sites. Thus issues related to temperature increases and disease outbreaks and health implications can be addressed. The projects should include funds for public awareness and should be submitted to the GEF for funding.

Conclusion

Article 6 of the convention is specific in addressing the capacity needs especially the LDCs in Training, Education (awareness raising) and research. The country has various laws and policies on some matters of concern in environmental matters, but they were formulated outside the convention. There is need to mainstream all these isolated legislations/ordinances into a more coherent one that will help us to address some of the key issues of our mitigation and adaptation measures to climate change events.

CHAPTER 9: Capacity Building and Strengthening

A Cross-cutting Task Force of the National Climate Change Committee reviewed all activities conducted on capacity building and assess information contained in the National Self Capacity Assessment and the Stocktaking and Stakeholder Consultations conducted in preparation of the TNC.

The sub-committee determined all the capacity building gaps and data and information requirements of Sierra Leone to implement the TNC project and also implement the Climate Change Convention.

The sub-Committee also compiled the gaps (technical and institutional capacities), data and information gathered, including any risks and barriers arising from legal and institutional frameworks; The outcome of all of the above was the development of a programme and strategy for the future implementation of capacity building needs for the implementation of the Convention in Sierra Leone.

The programme and strategy contained activities such as:

a) Development of capacity and expertise in participation in the Kyoto

Protocol/NDC process and development of appropriate implementation strategies.

b) Development and strengthening of the institutional and human capacity of the Climate Change Focal Point and secretariat to undertake sustained coordination of the implementation of the UNFCCC in Sierra Leone.

c) Develop and implement an enabling activity, specifically tailored to develop a comprehensive climate change action plan and integrated implementation strategy with emphasis on:

- development of education and training programmes, and specialized skills or expertise;
- development and strengthening of scientific institutions with the necessary equipment and scientific information;
- re-orientation and development of appropriate policies and regulations leading to improved decision- and policy-making and integration of climate change in national development.

The Capacity Building Needs

Least Developed Countries (LDCs) like Sierra Leone must fill the wide data gap faced by African scientists and its impacts on the climate modeling capacities of Africa. Thus improving the systematic observation system of Sierra Leone will help address specific challenges faced by the country regarding:

- The general observation of the present climate bringing out its inherent extreme events and variability
- Getting the necessary information that will assist in the determination of climate change and its effect
- The provision of observation that will help us determine the specific climate forcing caused by the specific Green House Gases present (GHGs) in the atmosphere of Sierra Leone.
- The establishment of a good network of systematic observation will help to not only provide climate modelling data but also help to validate them and other models previously developed.

In order to be able to manage data information and other activities the following capacity building needs must be addressed;

a. The provision of the necessary financial resources is key for the sector charged with the responsibility of data collection such as the Meteorological Agency and the Water Resource Directorate of the Ministry of water resources.
b. The streamlining the roles of various state actors in the different engagements in climate investigations and activities.

c. The provision of a structured institutional body charged with the implementation of systematic observation and research as Article 6 of the Convention hopes to address.
d. Enhancing the already existing structure for the enhancement of the exploitation of satellite data for climate studies and services.
e. The sensitization of the general public of Sierra Leone and other stakeholders on the climate issues at all levels ranging from local to central government.
f. The strengthening of the institutional capacity of both the data collection departments and the university for undertaking climate research.
g. The training of the relevant personnel of the various institutions for them to carry out their respective roles.
h. Enhance both the government and respective institutions in mainstreaming these activities in the governance structure of the country such as necessary legislation on water catchment areas, ready provision of the needed counterpart funding for the projects identified below
i. Enhancement of a permanent sustainable structure for systematic observation strategies and policies.
j. The harnessing of the socio-economic and meteorological data should also be complemented with the assimilation and management of the knowledge gained for the country's sustainable development

CHAPTER 10: Networking and, Knowledge and Information sharing

This chapter presents the assessment results of the information technology needs of the country in the area of climate change and other development and environmental areas.

In carrying out this assessment, information technology, particularly the internet/electronic media were used to assess and catalogue all national, regional and global institutions and agencies that keep relevant climate, climate change and other environmental information;

Linkages between the web site already and located at the Climate Change Focal Institution were developed with important and relevant national, regional and global web sites of institutions identified in (b) above;

An assessment and catalogue of all national, regional and global institutions and agencies that promote, encourage and offer networking (staff exchange visits, internship, industrial training and attachments, etc.) programmes were done;

Contacts have been established with these institutions and agencies and interest indicated in networking with them.

A programme and strategy for establishing and enhancing these networking activities on a continuous and sustainable basis has been developed.

Global institutions and agencies that keep relevant climate, climate change and other environmental information;

World Resources Institute (WRI)

Local institutions and agencies that keep relevant climate, climate change and other environmental information;

- Meteorological Agency-SL
- EPA-SL
- Petroleum Agency-SL
- Ministry of Agriculture Forestry and Food Security
- Freetown City Council
- University of Sierra Leone

CHAPTER 11: Constraints and Gaps, and Related Financial, Technical and Capacity Needs

11.2 Introduction - Implementation Strategy of the UNFCCC

For Sierra Leone, Climate Change is viewed as a development path. Hence, the UNFCCC is being implemented with the Sustainable Development Goals (SDG 13) guiding all future activities and programmes. Based on the identified Mitigation and Adaptation measures in the preceding chapters of four and five, the following strategy was developed for the future implementation of the Convention in Sierra Leone. The successful implementation of the strategy and the Convention is conditioned upon the availability of the human and financial capacities in the country, and the required International Cooperation. The identified financial resources will need to be met by Government and Donors contributions.

Constraints and Gaps

Constraints and gaps have been articulated in every chapter of this communication. However additional concerns are also stated here.
The major area of constraint is the weak scientific basis, based on poor data availability to make sound judgments for project development and also in the economic analysis and presentation of the cost of the activities and their implementation. The first task therefore is have a sustainable data collection system in place. The stakeholder institutions are constrained by inadequate human and variable institutional capacity.
The specific needs to implement the sectors plans are given below.

11.3 Capacity Building Needs

Adequate human and institutional capacity is a necessary condition for the implementation of the UNFCCC. To build on the limited national capacity developed over the years the following will be required.

1. The current capacity of the National Climate Change Secretariat under the Environment Protection Agency of Sierra Leone (EPA-SL) is limited in relation to facilitating the successful coordination of the implementation of the convention. Thus, it is a high priority in establishing and strengthening of the capacity of the national climate secretariat to enable the effective participation in the implementation of the Convention. This will involve:

    - An implementation of the already developed comprehensive climate change Strategy an Action plan (NCCSAP) that took into account the capacity building needs of the various institutions participating in climate change activities particularly in research, development and training.

    - Development of its capacity to implement the recently developed NAMA and NDC.

    - Enhancement of public awareness on climate change at all levels with the ultimate objectives of improving decision – and policy-making through re-orientation and development of appropriate policies.

2. In the area of development of inventory of national GHG emissions the members of the national Task Force assigned the study will need capacity to move beyond the mechanical use of the 1996 and 2006 Revised IPCC Guidelines and the emission factors contained in those guidelines. The Task Force should be capacitated and involved in the development of national and/or regional specific emission factors with the ultimate objective of reducing uncertainties in the national inventory statistics. This is likely to be achieved through the involvement of Sierra Leone in the UNDP/UNEP/GEF emissions factor project in West Africa in collaboration with the University of Sierra Leone.

3. Technical expertise of some members of the Task Forces has been developed to execute climate change scenario development tools and biophysical models (DSSAT, WATBAL) in the assessment of vulnerability (impact and adaptation) of the economic sectors to climate change. However, these members have very limited expertise in influencing the source codes of these models so as to "fine tune them to the Sierra Leone's environment. For a comprehensive vulnerability assessment the technical capacities and skills of experts need to be developed and enhanced beyond those acquired through workshops. The experts need to be trained on modeling at institutions of higher learning through fellowships and/or internships. There is need for the leading global climate modeling groups to collaborate with the University of Sierra Leone in building the capacity of members of the Task Forces in the development and execution of climate change biophysical models. The collaborative efforts should include the transfer of the model technology to Sierra Leoneans.

4. Understanding and participating in the climate change debate and development and implementation of climate change programmes is a

process that depends on access to a reliable body of scientific information. The information is developed from raw data acquired from national, regional and global system of observation networks. Sierra Leone has limited historical climate data (less than 50 years) and the meteorological and hydrological networks established in the late 1970s and 1980s have deteriorated and gaps in data have been realized from the mid-1990s.

5. Inadequate or non-availability of equipment for systematic collection of long-term instrumental observation of climate system variables has the consequence of limiting vital data required in the development of adequate and accurate input variables to model and simulate climate and climate change. Currently the observation networks in Sierra Leone, the future contribution of data for national, regional and global climate change simulation is still limited. It is thus a priority in Sierra Leone to reverse this situation of the observation networks and improve the data and information availability. Improvement will entail acquisition of additional automatic recording equipment with concurrent financial support and establishment of hydrological networks and their expansion to get more representative coverage of the country.

11.4 Information on Financial Resources and Technical Support Provided for the preparation of the TNC

The Global Environment Facility

The Global Environment Facility (GEF) provides financial assistance to non -Annex I Parties to prepare their national communications under guidance from the COP. This financing is made available under projects called **'**enabling activities for the preparation of National communications to the United Nations Framework Convention on Climate Change (UNFCCC)'.

Sierra Leone received up to $480,000 from the GEF. For Third National Communications and $ 20,000 from Government of Sierra Leone in kind. The TNC was executed through the United Nations Environment Programme (UNEP).

The Secretariat of the United Nations Framework Convention on Climate Change

One function of the UNFCCC Secretariat is to facilitate the provision of financial and technical assistance to non -Annex I Parties as they prepare national communications.

The UNDP/UNEP National Communications Support Programme

The Global Support Programme (GSP) is a UNDP/UNEP project, funded by the GEF, which provides technical and policy support to non -Annex I Parties for the preparation of national communications. The GSP is based in Istanbul, Turkey. The governments of Switzerland and the USA have co -financed GSP activities. The GSP is sustaining capacity -building efforts through technical and policy support, knowledge management, reviews and communications outreach. The GSP offers an integrated package of technical and policy support to enhance capacity in non-Annex I countries and to better meet the needs of countries, such as targeted, in-depth and issue-specific workshops and technical backstopping. The GSP also promotes the quality and comprehensiveness of national communications and the timeliness of their submission, and assists non-Annex I Parties to better incorporate climate change into national development policies.

Other Resources

The resources and support outlined below are not directly related to the development of the Third National Communication but rather to the overall goal of implementing the convention.

Mainstreaming Adaptation to Climate Change into National Development Planning.

In Sierra Leone, the European Union is to implementing a project, *Mainstreaming Adaptation to Climate Change into National Development Planning*, which aimed to integrate climate change and variability into the agendas of the tourism, agriculture, fisheries and infrastructure sectors.

The European Union in 2015 has also funded the development of the INDC for Sierra Leone through the UNDP country office in Freetown.

11.5 Information on Implemented Adaptation Measures and/ or priority areas for adaptation

The following adaptation measures from Sierra Leone NAPA are currently on-going.

UNDP-UNEP project "Strengthening Climate Information and Early Warning Systems in Africa for Climate Resilient Development and Adaptation to Climate Change"

Ongoing with UNDP Establishment of National Early Warning System.

Ongoing with UNDP, IFAD and AfDB Rehabilitation & Reconstruction of meteorological/climate Monitoring stations throughout the country.

Ongoing with UNDP Capacity building of the Meteorological Department through training of personnel for the country's adaptation to climate change.

Ongoing with UNDP and EU Project Sensitization and awareness raising campaigns on climate change impacts on women relating to the three conventions of biodiversity, desertification and UNFCCC.

Concluded IFAD project. Development of Inland Valley Swamps for Rice Production in some districts of Sierra Leone. (Hoping for Extention)

Ongoing with UNDP Institutional Strengthening of the Water Resources Sector in Sierra Leone.

Ongoing with UNDP Promotion of Rain Water Harvesting and Development of An Integrated Management System for Fresh Water Bodies.

Priority areas for Adaptation

Some priority areas from the NAPA include but not restricted to:-

- Promotion of the use of renewable energy (Solar Energy) in Sierra Leone and improvement of energy efficiency and conservation of energy resources
- Réhabilitation of degraded coastal habitats in the Northern Province/Kambia district and elsewhere.
- Health sector adaptation projects
- Upscaling of city roads to all weather roads.
- Reconstruction of key drainage system for Storm water removal.

Table 11.1 - Prioritized Adaptation options and their ranking according to NAPA Classification[21]

Project Number	Name of Option and Option Description	Rank
Technical Projects on Network of Observation and capacity building		
Project 1	Strengthening the assessment and monitoring of underground water measurement, and the country' Water Resources	1
Project 2	Establishment of Network of Applied Meteorology and Climate Study with Higher Educational institution in the country and sub region	2
Project 3	Establishment of Network with Local Grassroots organizations, International Non-Governmental Organizations, Line ministries for the enhancement of development and use of Climate information and services.	5
Project 4	Undertaking Various Climate Researches in our universities that will address different Climate Concerns for Development	6
Project 5	Building the capacity of policy makers on Climate issues and legislation that will enhance compliance of the convention and its accompanying protocol(s)	7
Project 6	Capacity building for the activities of Article 6 coordination team	8

Project 7	Sensitization of the general public on Climate and Climate Change issues and the use of Climate Information and Services in National Development	9
Project 8	Observation of Aerosols and its measurement in various parts of the country	10
Project 9	The initiation of Ozone observation in the country	11

11.8 Information on Projects for Financing

11.9 Data Gaps and Suggested Improvements to the National GHG Inventory

Energy Sector

- Compile fuel use and other activity data (production) by at least four digit ISIC codes. Where quantities are small and not readily or cost effectively compiled or disaggregated, the data collection should be geared to providing aggregates based on ISIC codes.

- Data collection should be improved in order to allow better distinctions of diesel fuel use to be made between on -road and off road transportation activities and other fuel combustion activities by sector.

- Fuel consumption data for some mining activities (bauxite mining by third party companies) and for lime production should be captured.

- Fuel consumption for aircraft registered in Sierra Leone (if any) should be compiled.

- Production data for lime production should be reported for all manufacturing facilities.

- The vehicle fleet data base should be improved over time by implementing quality assurance and quality control procedures to avoid data entry errors (weights, vehicle age, manufacturers etc.) and minimize other errors (fuel type, VIN numbers).

Industrial Processes and Product Use Sector

- Although the uncertainty in emissions from cement manufacture is low, some enhancement could be made by using chemical analyses for clinker produced.

- Import data for HFCs did not always identify all items in shipments. Because of the wide variation and relatively high global warming potentials for HFCs, such identification is essential for obtaining more reliable estimates.

- HFCs have been and are being used in fire suppression systems but data on the systems in place are lacking.

- Paint production data that are compiled and reported and paint specifications do not allow the key environmental issue regarding paints to be addressed. The current specifications include volatile matter which includes water – instead of isolating volatile organic compounds. Revision of the standards based on paint types such as those used in North America or Europe (but adapted to Sierra Leone's market) is recommended.

Agriculture, Forestry and Other Land Use Sector

- The assignments of land use and changes in land use categories are based on outdated satellite imagery. Updated satellite imagery data complemented by suitable ground based surveys and permanent sample plots to measure growth rates are needed in order to improve the quality of the land use change data and to develop country -specific growth rates. This information will significantly improve the accuracy of the inventories as well as inform land -use policies and forestry management.

- Agricultural census data should be compiled approximately every 10 years and mechanisms should be established to allow estimates in the intervening years for those data that are important but not currently compiled. These include data for goats and sheep as well as manure management practices for all animals and the amounts of crop residues remaining in the fields.

- Information on the wood conversion (i.e., removals for various purposes such as fuel wood, timber, and agriculture) on privately owned lands is lacking. The design of suitable, viable solutions to obtain such data is challenging but options that should be considered include legislation and well designed, periodic surveys.

Waste Sector

- Reliable data on the loading (volume and BOD or COD) of releases from sewage treatment and industrial wastewater plants are lacking. The development, enactment and enforcement of Wastewater and Sludge Regulations should be piloted by EPA-SL to remedy this situation. For instance, flow meters could be required at sewage treatment facilities and/or facilities required to regularly submit information.

- Reliable data for the types and quantities of industrial waste generated and disposed of in municipal and industrial waste disposal sites are lacking.

- Data for municipal waste should be compiled by the city and town councils, but ongoing and additional determination and estimates of waste stream disposal methods (collected, uncollected, treatment methods including open burning) will assist in making more reliable inventory estimates as well as inform waste reduction and other waste management strategies.

- Additional information on population according to income groups and the degree of utilization of sewage treatment systems (sewered, not sewered, pit latrines) by cities and urban and rural areas is needed. Statistics Sierra Leone and sectors need to collect and present data in the same format annually.

- Data on the quantities and disposal and treatment methods of clinical and industrial solid wastes are lacking. Air Quality Regulations needs to be included under the EPA-SL Act to improve some of the data availability (e.g., when waste is incinerated) for future inventories.

- While challenging, EPA-SL needs to ensure that small facilities which do not fall within the licensing system use the best available technology and /or best practices to operate their facilities.

11.10 Shortcomings, Constraints, and Priority Needs

The Agenda for Prosperity (A4P) or PRSP 3 document together with this present Third National Communication brought the focus on Climate Change effects. This led to the creation of the Disaster Management Department (DMD) under the Office of National Security (ONS) which is supervised by the Vice President. During the past years, weather/climate disasters such as flooding (resulting in fatalities and crop damage) on the one hand and shortage of water at the GUMA Dam (GUMA Water Company supplies water to the City of Freetown), show the importance that extreme events have on and the need for collaborative actions to address some of the perceived effect through mitigation and adaptation.

Despite this effort, the limited resources of the government in the post war and post ebola (EVD) reconstruction have made some of these vital issues to be temporarily shelved. Thus the following constraints need attention which some of the projects will address if implemented.

- The concept of Climate Change is relatively new. Many do not understand the issues (even the educated) and as such, some stakeholders first of all need to be educated before using them to sensitize the general public.
- In Sierra Leone, more that 60% of the people are illiterate and therefore need other means of information dissemination.
- The high cost of learning materials hinders learning.
- The resources put into Climate Change issues is not commensurate with the task that needs to be addressed.
- Most players act in isolation as various Ministries, Departments and Agencies (MDAs) are responsible for different aspects of Climate Change. The civil society organizations have not shown the due interest in the implementation of the UNFCCC as is done for Health and Education.
- There is problem with information dissemination both within the country and between similar institutions in the sub region.
- The funding mechanism of UNFCCC (especially GEF) and other multilateral organization are so complex that access to them has not been easy for most countries. e.g. very few countries have accessed the LDC special Adaptation fund, Somalia representative at the June, 2012 Article

6 planning workshop in Bonn said "that they have never accessed GEF yearly grant".

- In most LDCs the cost of media service (from newspaper to TV through radio and advertisement) is very high which prevent the use though regrettably powerful.

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