FINAL DRAFT

Initial National Communication under the United Nations Framework Convention on Climate Change

Sri Lanka

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Foreword

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ABBREVIATIONS

AP	**Agriculture Policy**
AIT	**Asian Institute of Technology**
BD	**Buildings Department**
BAP	**Biodiversity Action Plan**
CEB	**Ceylon Electricity Board**
CoP	**Conference of Parties**
CZMP	**Coastal Zone Management Plan**
CA2AP	**Clean Air 2000 Action Plan**
CHPB	**Centre for Housing, Planning & Building**
DSM	**Demand Side Management**
EPSL	**Energy Policy of Sri Lanka**
FO	**Forest Ordinance**
FRP	**Fibreglass Reinforced Plastic**
FMP	**Forestry Master Plan**
GHG	**Greenhouse Gas**
GEF	**Global Environment Facility**
GIS	**Geographical Information Systems**
ICTAD	**Institute for Construction, Training and Development**
IPCC	**Intergovernmental Panel on Climate Change**
LPG	**Liquid Petroleum Gas**
MPCE	**Master Plan for Coastal Erosion Management**
MSL	**Mean Sea Level**
NBRO	**National Building Research Organization**
NERD	**National Engineering & Research Development Centre**
NAPCC	**National Action Plan on Climate Change**
NEAP	**National Environmental Action Plan**
NFP	**National Forestry Policy**
NFDP	**National Fisheries Development Plan**
NTP	**National Transport Policy**
NPWC	**National Policy for Wildlife Conservation**
NLUP	**National Land Use Policy**
OECD	**Organization for Economic Cooperation and Development**
PV	**Photo Voltaic**
RS	**Remote Sensing**
SLT	**Sri Lanka Telecom**
SIDA	**Swedish International Development Agency**
TOE	**Tonnes of Oil Equivalent**

EXECUTIVE SUMMARY

The National Communication comprises, the National Circumstances; Greenhouse Gas Inventory; Impacts and Vulnerability; Mitigation Options and Adaptation Responses; Policies and Measures; Education, Training and Awareness Programmes; Constraints and Technological Needs and Recommended Research Studies and a Portfolio of Projects.

National Circumstances

Sri Lanka with an areal extent of about 65,610 square kilometres lies between 6° and 10°n latitude and between 80° and 82°e longitude. The island consists of a mountainous area in the south-central parts and a vast coastal plain, which surrounds it. Despite the relatively small size of the country, there is considerable variation in climate over time and space. The annual average rainfall varies from below 1000mm (39") over a small region in the arid parts of the north-west and south-east of the island to over 5000mm (197") in a few places on the south-western slopes of the central hills. There is little seasonal variation of temperature. The mean annual temperature in the coastal areas below 150m in elevation ranges from 26.0°c to 28.0°c while in the hill country above 1500m, it ranges from 15.0° c to 19.0° c.

Sri Lanka's population which at the last census taken in 1981 was 14.8 million, is projected to reach 19.0 million by the year 2001 and 23.1 million by the year 2031. The population is unevenly distributed across the country. Nearly 60.0% is concentrated in the wet zone, which includes both the maritime provinces with higher levels of economic development and the areas given over to the cultivation of plantation crops. Over 75% of the country's population live in rural areas.

Until the 1960's, the Sri Lanka's economy depended heavily on the export-oriented plantation crops of tea, rubber and coconut. By 1998 the major sector of the growing economy was the services sector contributing 53.0% to the Gross Domestic Product (GDP). This was followed by the agriculture, fisheries and the forestry sector with 21.3% and the manufacturing sector with 16.5%. The three major economic activities in the country are agriculture and livestock, manufacturing and fishing. Together they contribute 37.0% towards the Gross National Product and provide employment to 53.0% of the total employed. The agricultural sector comprises two sub-sectors, one producing mainly for the domestic market and the other mainly for the export market. Paddy is the main crop within the domestic sector. The export sector is dominated by tea, rubber and coconut. A variety of animals are raised in the country including neat cattle, buffaloes, sheep, goats, pigs and poultry. The dairy and the poultry industries represent the more prominent and organized sectors of the country's livestock industry. Fish production which includes both marine fish production (coastal, offshore and deep sea) and aqua culture fish production (inland, coastal brackish water prawns and cultured prawns), contributes on the average 3.0% to the Gross National Product. The manufacturing sector consists of three sub-sectors, i.e. factory industry, processing of plantation crops and small industries. Together they contributed 17.1% of the G.N.P. in 1998. Factory industry is the most important of the three sub-sectors accounting for 78.0% of the value added in the manufacturing sector in 1997. The tourism sector makes a significant contribution to the national economy, by earning valuable foreign exchange, functioning as a source of revenue to the government and generating both direct and indirect employment. The income distribution in the country remains uneven. The lowest 30.0% of the households receive less than 10.0% of the household income while the highest 30% receive 65.0%.

Energy supply in Sri Lanka is mainly based on three primary sources, namely hydroelectricity, biomass and petroleum. In 1996, hydro-electricity accounted for approximately 780 thousand Tonnes of Oil Equivalent (TOE) (11.4%), biomass for 3,930 thousand TOE (57.1%) and petroleum and crude oil products for 2,169 thousand TOE (31.5%) giving an aggregate primary energy supply of approximately 6880 thousand TOE. The other energy sources include wind energy, micro hydro power and solar power. The contribution from these sources is negligible. The energy supply is expected to increase to approximately 11.5 million TOE by year 2010 at an annual growth rate ranging from 4% to 8% in different sub-sectors.

The climate of Sri Lanka is conducive to forest growth and the entire land area with a few exceptions was once covered with forests. Over the last century much of this forest cover, rich in diversity, has been destroyed and today less than 1/3 of the area is under forest. Deforestation has seriously diminished timber supplies, made soils less productive and affected the natural water supply.

Sri Lanka has reasonable endowments of mineral resources in relation to its size. The most economically valuable are the gemstones, which accounted for more than 90% of all mineral exports in 1994.

Surface water from the high watersheds is transported by 103 distinct natural river basins that cover 90% of the island; the remaining 94 small coastal basins contribute only marginally to water resources. River basins originating in the wetter parts of the hill country are perennial while the majority of those in the dry zone are seasonal. Annual surface water estimates vary from 4.0 to 5.13 million hectare metres. A part of this is used for irrigation and hydropower projects, and the balance discharged to the sea.

The education system in Sri Lanka comprises three sub-systems, i.e. (i) General Education, (ii) Higher Education, and (iii) Technical and Vocational Education. General education is provided by over 10,000 government schools and by a number of officially approved private schools, private tutories and pirivenas or temple schools. At present, higher education is provided by 12 national universities, 6 post-graduate institutes and 5 other institutions. Technical education and vocational training which caters directly to the labour market is handled by the Department of Technical Education and Training and other similar institutions.

Health care is provided by both the public and private sectors. The public sector provides preventive, curative and rehabilitation health care for nearly 60% of the population. The private sector provides mainly curative care, which accounts for nearly 50% of the out-patient care of the population and is largely concentrated in the urban and sub-urban areas. Ninety five percent of in-patient care is provided by the public sector.

The Democratic Socialist Republic of Sri Lanka is a unitary state whose legal and administrative structure is based on its republican constitution. The national constitution of 1978 forms the supreme law under the Executive Presidency and a single House of Parliament. At present there are 33 Ministries each headed by a Minister and assisted by one or more Deputy Ministers. The country is divided for administrative purposes into nine provinces. The provinces are divided into 25 districts, each headed by a Government Agent and districts are divided into 280 divisions each headed by a Divisional Secretary. The 13th amendment to the Constitution in 1987 provided for the devolution of power to the provinces and provinces are now the fundamental administrative units of regional governance. Local government is in the hands of Municipal Councils, Urban Councils in urban areas and the Pradeshiya Sabhas at the Divisional level.

The subject of climate change has not been directly addressed in almost all the existing policies. However, there are a number of environmental policies, legal enactments and plans that contain provisions that could contribute in reducing or mitigating the effects of climate change. There are also many acts which deals with the subject areas dealing with climate change. These however have not been effectively implemented due to enforcement weaknesses.

Greenhouse Gas Inventory

Greenhouse gases are found naturally in the atmosphere in trace quantities. These contribute significantly to global warming through their accelerated generation as a result of anthropogenic activities. The main areas of greenhouse gas generation are energy industries, livestock, agriculture, forestry and waste. The gases comprise Methane, Nitrous Oxides, Carbon Monoxides and Carbon Dioxide.

The largest contribution to GHG emissions in Sri Lanka is through the change in forest and woody biomass stocks, forest grassland conversion, liming and organically amended soils.

Domestic livestock are diverse and some fall into the category of ruminants, which mainly depend on roughage diets. When such diets are ingested by ruminants, methane is produced. In addition, microbiological activity on the stockpiled animal waste, submerged rice soils and field burning of crop residues also result in methane emissions. The largest source of methane is from treatment and handling of waste while energy sector also contributes in a small scale through incomplete burning of fossil fuel.

Fuel combustion in energy industries, manufacturing industries and construction, transport and other sectors is also another large contributor to GHG emissions in the country.

Impacts and Vulnerability

Global warming, is expected to lead to a rise in the sea level, higher temperatures, more frequent and prolonged droughts, high intensity rainfall and increased thunder activity. These anticipated changes in the global context represent a significant threat to the coastal areas of Sri Lanka, the different sectors of the national economy and human health. A range of major impacts can be expected from the changes. The phenomenal activities which will be affected are summarized in the Table given below.

Impacts

Impacts in the wider context	Phenomena / hazards / activities / industries affected
Sea level rise (4.1)	• Inundation of low lying coastal settlements and coastal wetlands • Coastal Erosion • Flooding and Storm Damage • Salt Water Intrusion affecting low lying agriculture and fresh water intakes • Fishery Industry • Coast Protection and Port Structures • Nearshore Infrastructure – Land based infrastructure and Land reclamation • Tourist Industry
Temperature rise (4.2)	• Power Generation • Agriculture output • Human Health • Transport Infrastructure
Droughts (4.3)	• Ground and Surface Water Supply • Power Generation • Forest Resources • Agricultural Output • Human Health • Transport Infrastructure
High intensity Rainfall (4.4)	• Floods • Land Degradation • Agricultural Output • Human Health • Transport Infrastructure • Power Generation
Increased thunder activity (4.5)	• Damage to Infrastructure • Human Health

Mitigation Options and Adaptation Responses

Sri Lanka's response strategy to anticipated climate changes includes the implementation of both mitigation and adaptation measures. The country's contribution to the emission of greenhouse gases is considered negligible. Even so, every effort has to be made to maximize the country's potential contribution towards controlling the amount of gases being emitted to the atmosphere. Adaptation measures are required to address the potential impacts of climate change. A few measures have already been adapted in some sectors such as agriculture and energy to promote improved environmental management. The Mitigation Options and Adaptation Measures recommended for the different sectors are summarized in the Table given below. Detailed descriptions are made available in sections 5.1 and 5.2 in Chapter 5.

Relevant Sector	Recommendation of Mitigation Options	Recommendation of Adaptation Measures
Energy Sector	✓ (5.1.1)	
Industrial Sector	✓ (5.1.2)	
Transport Sector	✓ (5.1.3)	✓ (5.2.2)
Agricultural Sector	✓ (5.1.4)	✓ (5.2.3)
Forestry Sector		✓ (5.2.4)
Water Resource Sector		✓ (5.2.5)
Coastal Zone		✓ (5.2.1)
Health Sector		✓ (5.2.6)
Human Settlement and Public Utilities Sector		✓ (5.2.7)

Policies and Measures

General measures that would increase resilience to climate change include - the protection of arable soil, improvement of water management, enhancement of agro-technology, formulation of land use policies, maintenance of food reserves and provision of emergency disaster relief. Several major policies have been formulated up to date. These are the Agricultural Policy, National Land Use Policy (Draft), Transport Policy, Forestry Policy, and Energy Policy. There is a need for revising these policies taking into account the climate change impacts. When strengthening the policies and preparing new policies it is important to bear in mind - the need for (a) building up a database, (b) to provide incentives/disincentives, (c) to consider the cost-effectiveness of policies, (d) need to adopt an integrated approach, (e) to promote stakeholder collaboration and (f) to increase the awareness of climate change.

Education Training and Awareness

Sri Lanka has already launched a number of programmes to educate, train and promote awareness on climate change and related issues. At school level, basic concepts of meteorology, climatology, environment, biodiversity and climate change have been included into the respective curricula. At the university under-graduate level, climate change has been included as one of the subjects in the field of climatology whereas special subjects in post-graduate courses include environment, oceanography and climatology.

A number of training workshops and seminars have been conducted by the Ministry of Forestry and Environment and the Department of Meteorology with the assistance and cooperation of the National Institute of Education to train master teachers. Sri Lanka also hopes to undertake capacity building programmes to train scientists from the universities, research institutions and implementing agencies to (a) undertake relevant research and (b) to formulate and implement projects and research programmes on a priority basis. These programmes will be coordinated by the recently established Centre for Climate Change Studies with the assistance and cooperation of the Ministry of Environment and other relevant institutions.

Since the early 1990's, Sri Lanka has also been conducting awareness programmes on climate change and related issues for the benefit of school children, teachers and others. These have been sponsored by the Ministry of Forestry and Environment and organized by the Department of Meteorology.

Recommended Research Studies and Portfolio of Projects

A detailed list of research studies and a portfolio of project proposals is given in Chapter 7 of the report. Some of the important research studies and projects suggested are:

Research Studies

Coastal Zone

Preparation of a coastal data base both referral and relational at a suitable resolution and linking the same with an appropriate environmental monitoring system.

Undertake studies on the impact of rise in temperature and sea level on coral reefs and marine species.

Energy Sector

Conducting a study on the use of Natural Gas as an option for the future plants as well as the conversion of existing plants especially the large number of combustion turbines that will be in the system and undertaking in-depth Integrated Resource Planning study on Energy Conservation and other Demand Side Management (DSM) measures.

Industrial and Transport Sectors

Developing and enforcing emission standards related to GHGs in the industrial sector and representative emission factors for different fuel and vehicle types.

Agricultural Sector

Estimating the change in production rates with carbon dioxide fertilization of different crops – rice, field crops, vegetables, plantation crops and identifying agro-ecological zones particularly sensitive to climate change impacts.

Forestry Sector

Examining the potential for Carbon sequestration and evaluating socio-economic benefits form Carbon offset projects.

Water Resources Sector

Studying by hydraulic monitoring the extent of intrusion of salinity wedge along waterways for different scenarios of sea level rise and the impact of climate variability and climate change on river flow regimes in Sri Lanka.

Health Sector

Conducting studies on epidemiological forecasting and early warning systems using RS/GIS technology applicable in high risk areas for malaria, dengue, Japanese Encephalitis, diarrhoeal disease and nutritional disorders and undertaking prospective and retrospective studies on identified disease patterns such as eye and skin disorders relevant to climatic change in sentinel stations.

Human Settlements

Studying the impact of climate change on existing sewerage and drainage systems and urban water supply schemes, including reservoirs and developing, storm, wind and cyclone resistant building standards and guidelines for different building categories (NBRO, CHPB, ICTAD, BD, NERD, SLT, CEB).

Others

Developing rainfall and temperature scenarios for Sri Lanka.

Projects

Coastal Zone

Studying the influence of increased salt water intrusion in a selected river estuary and undertaking a vulnerability assessment in a selected region along the coast.

Investigating the impacts of sea level rise and temperature rise on coral reef systems around the coastal belt.

Energy Sector

Harnessing the total maximum identified potential of hydropower, based on a study of the economic and environmental impacts and introducing DSM measures such as luminairs, refrigerators, air-conditioners and motors, etc.

Industry Sector

Adopting energy efficient building codes and standardization and labeling of energy consuming end use equipment and promoting proper solid waste management with methane recovery.

Transport Sector

Improving traffic management systems and integrating bus-rail operation through proper network planning.

Agricultural Sector

Promoting rainfed farming and the efficient utilization/conservation of water and developing integrated farming systems in relation to climatic change.

Forestry Sector

Preparing a database to achieve a greater understanding of the linkages between climate change and forest eco-systems and quantifying the role of forests, forest soils and reservoirs, sinks and sources of Carbon.

Water Resources Sector

Introducing permit/monitoring systems for groundwater extraction and water quality assessment in vulnerable areas and assessing extent of land that will be affected by sea level rise.

Health Sector

Establishing work environment standards for local conditions.

Human Settlements

Mapping flood plain and flood hazards, especially for Kelani Ganga, Kalu Ganga, Gin Ganga, Nilwala Ganga, Attanagalu Oya, Mahaweli Oya, Heda Oya and Lunu Oya and identifying the prioritize vulnerable areas for human settlements.

Constraints and Technological Needs

The major constraints faced by the project were: (1) the inability to recruit experts on a full time basis, (2) the limited availability of specific studies and relevant research and (3) the inadequate time available for undertaking specific studies and research on impacts of climate change. The major technological needs include, the assessment of vulnerability of the different sectors to climate change impacts, adaptation of measures to reduce GHG emissions in the industrial, transport and agricultural sectors and introducing the adaptation measures that have been identified.

CHAPTER 1

INTRODUCTION

The United Nations Framework Convention on Climate Change (UNFCCC) was ratified by Sri Lanka on 23 November 1993 and entered into force on 21 March 1994. Sri Lanka, being a developing country and a non-annex 1 country party to the UNFCCC, has to prepare a National Communication to the Conference of Parties (CoP) within three years of the entry into force of the Convention or of the availability of financial resources in accordance with article 4 paragraph 3 of the Convention. The National Communication has been prepared in response to this obligation.

The guidelines for the communications of non-annex I countries were adopted by the CoP in July 1996. In accordance with the Article 12 of the UNFCCC, detailed guidelines for the preparation of communications were presented in the document FCCC/CP/1996/L.12, to parties not included in Annex I. These guidelines have been followed in the preparation of the National Communication.

Global Environmental Facility (GEF) made available to Sri Lanka a grant of US $110,000 through UNDP to prepare its National Communication on Climate Change in 1997. The Enabling Activity Project on Climate Change commenced its activities in February 1998 under the Ministry of Forestry & Environment. A Steering Committee comprising of experts from different fields was appointed to provide the necessary guidance and direction to the project.

Sri Lanka's contribution to the emission of green house gases is considered negligible. Nonetheless the adverse impacts of the anticipated changes arising out of global warming are likely to be significant. The most affected areas are agriculture, coastal regions and hydro-electricity supplies.

The National Communication incorporates the updated (1994) inventory of greenhouse gases in Sri Lanka and the potential measures to abate the increase and, the national action plan to address Climate Change. As a prelude to the preparation of the National Action Plan on Climate Change (NAPCC), the necessary background information was collected on the four major sectors, i.e. (i) Energy, Industry, Transport and Highways (ii) Agriculture, Forestry, Land Use and Water Resources (iii) Coastal Zone, Ports and Fisheries and (iv) Human Health, Human Settlements and Public Utilities. Ten core teams prepared the initial sectoral drafts of the NAPCC and these were consolidated at a workshop held in 1999. This formed the basis of the draft NAPCC which was presented at a series of participatory workshops.

The National Communication has been based on the guidelines provided by the Conference of Parties. It presents in several chapters, the National Circumstances; Greenhouse Gas Inventory; Impacts and Vulnerability; Mitigation Options and Adaptation Responses; Policies and Measures; Recommended Education, Training and Awareness Programmes and Constraints and Technological Needs. Research Studies and a Portfolio of Projects have also been identified.

CHAPTER 2

NATIONAL CIRCUMSTANCES

2.1 GEOGRAPHY

Sri Lanka is a tropical island situated to the south of the southern tip of India. It lies between 6° and 10° N latitude and between 80° and 82° E longitude and has an areal extent of about 65,610 square kilometres. The maximum length of the island is about 435 km and the maximum width is about 240 km. The coastline, which is about 1,585 km in length, is irregular, comprising sandy beaches, extensive lagoons and estuaries, mangroves, coastal marshes and dunes. The continental shelf, 26,000 sq.km in extent, is on average 20 km wide and 20 to 65 metres deep. It is narrowest at Kalpitiya, in the north-western province, where the width is only 2 km, while on the north-east, it is continuous with peninsular India. The near-shore zone is characterized by the occurrence of reefs, which are of three types, namely, coral, sandstone and crystalline rock (boulder).

Aligned with the UN Convention on the Law of the Sea which was ratified by Sri Lanka in July 1994, the country enjoys a total extent of approximately 489,000 square kilometres of maritime waters. The maritime zones consist of Internal waters, Historic waters, Territorial Sea, Contiguous Zone and an Exclusive Economic Zone (EEZ). A greater part of this area (437,000 square kilometres) belongs to the EEZ.

The island consists of a mountainous area in the south-central parts and a vast coastal plain, which surrounds it. The central mountainous region, rising to an elevation of 2,524 metres is the source of the major rivers of the country, numbering over a hundred, which flow across the lowlands into the Indian Ocean. Long parallel ridges cut by these rivers, their height increasing gradually from the coast, characterize the topography of the south-west. The northern and north-central parts of the island form one great plain and the maritime districts consist of similar level or undulating stretches (Fig. 2.1).

2.2 CLIMATE

For the most part, Sri Lanka is hot and humid. Despite the relatively small size of the country, there is considerable variation in climate over time and space.

Information regarding the National Circumstances is given in Table 2.1.

TABLE 2.1: NATIONAL CIRCUMSTANCES

Criteria	1994
Population (million)	17.90
Area (thousands of square kilometres)	65.6
GDP (US$ billion)	11.7
GDP per capita (US$)	656
Estimated share of the informal sector in the economy in GDP (percentage)	10
Sectoral shares in GDP %	
- Agriculture	20.5
- Mining & quarrying	2.5
- Manufacturing	19.7
- Construction	6.9
- Services	50.4
Land area used for agricultural purposes (thousands of square kilometres)	16.0
- Paddy	7.3
- Coconut	4.4
- Tea	1.9
- Rubber	1.6
- Others	0.8
Urban population as a percentage of total population	22.4 in 1981
Livestock population (million)	3.22
- Cattle	
- Buffaloes	1.70
- Goats	0.80
- Sheep	0.60
- Swine	0.02
	0.10
Forest area (thousands of square kilometres)	2.0
- Montane Forest	
- Rain Forest	0.1
- Monsoon Forests	0.2
- Others	1.3
	0.4
Population in absolute poverty (million)	4
Life expectancy at birth (years)	72.5
Literacy rate (percentage)	91.8

Figure 2.1

SOURCE: NATIONAL ATLAS OF SRI LANKA

2.2.1 Rainfall

The annual average rainfall varies from below 1000 mm (39") over a small region in the semi-arid parts of the north-west and south-east of the island to over 5000 mm (197") at a few places on the south-western slopes of the central hills (Fig. 2.2).

There are four rainfall seasons during the year. These are:

1. The south-west monsoon period (May to September)
2. The inter-monsoon period following the south-west monsoon (October to November)
3. The north-east monsoon period (December to February)
4. The inter-monsoon period following the north-east monsoon (March to April)

Rainfall is of three types – monsoonal, convectional and depressional. Rain during the south-west and north-east monsoon periods accounts for nearly 55% of the annual precipitation. Rainfall during the south-west monsoon is mostly over the south-western parts of the island while during the north-east monsoon, it is mostly over the eastern half of the island. South-west monsoon rainfall exceeds 3000 mm (118") on the south-western slopes of the hill country and during the north-east monsoon, the eastern half of the island receives about 200 mm (8") to over 1200 mm (47") of rain. Convectional rain occurs during the inter-monsoon periods, mainly in the afternoon or evening and is likely to be experienced anywhere over the island. Depressional rain occurs during the inter-monsoon period (October to November) and sometimes during the south-west monsoon. Rainfall during the period October to November is widespread and exceeds 500 mm (20") at many places. Taking the island as a whole, this is the rainiest period of the year.

2.2.2 Temperature

There is little seasonal variation of temperature in Sri Lanka. The mean annual temperature in the coastal areas below 150 m in elevation ranges from 26.0°C to 28.0°C while in the hill country above 1500 m, it ranges from 15.0°C to 19.0°C (Fig. 2.3).

A noteworthy feature in many parts of Sri Lanka is the small variation in the mean monthly temperatures throughout the year. On average, the mean temperature of 25.0°C during the coolest months from November to February, is only 2.4°C lower than that during the warmest months, April to May. Higher temperatures are generally experienced in the northern, north-central and eastern regions of the island and range on the average between 33.3°C and 34.7°C.

The diurnal variation of temperature is well marked, its magnitude depending on the season. There is a gradual increase in the range with altitude as well as with distance from the sea.

2.2.3 Relative humidity

Relative humidity generally varies from about 70% during the day to about 90 to 95% at night. In the dry zone, however, these values are lower by about 5%. In the driest areas in the north-west and south-east, relative humidity drops to about 60%.

2.2.4 Hail

Hail is experienced occasionally during intense thunderstorms. It occurs mainly in the hill country but there have been reports on the occurrence of hail in low country stations too.

2.2.5 Ground frost

Ground frost occurs in hilly areas over 2000 m on a few days of the year during the months of January and February.

Figure 2.2

SOURCE: DEPT. OF METEOROLOGY

Figure 2.3

SOURCE: DEPT. OF METEOROLOGY

2.2.6 Climate change

Temperature, rainfall and other meteorological data have been collected by the Department of Meteorology over a period of more than 100 years. Statistical analyses of the temperature data have shown an increasing trend in the annual mean air temperature over the entire island, particularly during the period 1961-1990. This increase was found to be approximately 0.16°C per decade. Rainfall trends were found to be complex. During the period 1961-1990, a decreasing trend was evident over most of the island except in some isolated areas in the north-west, where an increasing trend was indicated. Thunder activity, which showed an increasing trend, was found to be positively correlated with air temperature.

2.2.7 Agro ecological regions

Sri Lanka has been traditionally divided into three zones, namely (a) the Wet Zone, (b) the Intermediate Zone and (c) the Dry Zone. The Wet Zone receives a mean annual rainfall of over 2500 mm (98") and comprises the south-west quadrant of the island whereas the Dry Zone receives a mean annual rainfall of less than 1750 mm (69") and comprises mainly the Northern and Eastern sectors of the island. The Intermediate Zone receives a mean annual rainfall between 1750 mm and 2500 mm.

For agro ecological purposes the country is divided into three sub-divisions based on elevation, i.e. Low country (below 300 metres), Mid country (between 300 and 900 metres) and Up country (above 900 metres). The Dry Zone falls wholly within the low country, whereas the Wet and Intermediate Zones fall within all three sub-divisions.

24 Agro ecological regions have been identified based on climate, soils, land forms and agricultural practices. Ten of these regions are in the Wet Zone while 9 are in the Intermediate Zone and 5 are in the Dry Zone (Fig. 2.4).

2.3 POPULATION AND HUMAN SETTLEMENTS

Sri Lanka's population at the last census taken in 1981 was 14.8 million. Island-wide censuses have not been undertaken since then due to civil disturbances, but according to mid-year estimates, the population had increased to 18.8 million by mid-1998. Population growth during the eighties was at an average annual rate of 1.5%, but this has declined slowly and now stands at 1.2%. The population is projected to reach 19.0 million by the year 2001 and 23.1 million by the year 2031.

The population is unevenly distributed across the country. Nearly 60.0% is concentrated in the Wet Zone, which includes both the maritime provinces with higher levels of economic development and the areas given over to the cultivation of plantation crops.

Sri Lanka is one of the world's most densely populated countries. The population density on the basis of the current estimated population is nearly 300 persons per square kilometre. Regional variations however are quite marked, with the Wet zone having a density of nearly 650 persons per square kilometre compared to 175 persons per square kilometre in the Dry zone.

Over 75% of the country's population live in rural areas in settlements ranging in size from small hamlets with a population of less than 1250 persons to large villages with over 4000 persons. Rural settlements comprise traditional villages distributed throughout the country where the majority of the inhabitants depend on farming, fishing and animal husbandry; agricultural settlements in the Dry zone based on irrigation works; plantation settlements in areas of tea and rubber cultivation and unplanned settlements where landless persons have encroached on state land. A number of rural settlements also function as small service centres providing goods and performing services to the resident population as well as to the population in adjacent areas.

Figure 2.4

SOURCE: NATIONAL ATLAS OF SRI LANKA

Less than 25% of the population live in urban areas. Not only is the urban population low but it is also very unevenly distributed. Over 75.0% of the urban population is to be found within the Wet Zone and of this nearly half is concentrated within the city of Colombo and its immediate hinterland. There are approximately three hundred urban settlements in the country where the economically active resident population is engaged predominantly in secondary and tertiary occupations. These settlements range in size from small towns with a population of less than 20,000 to large towns with a population of over 100,000 (Fig. 2.5).

The urban and rural settlements are linked by a network of roads with a total length of around 100,000 km providing 90% of the demand for transportation and railway lines with a total length of about 1500 km. While Sri Lanka Railways maintains the railway network, Road Development Authority is responsible for maintenance and development of national highways of class A and class B totalling about 11,300 km of road length while Provincial Councils are responsible for 15,000 km of class C and class D roads. The remaining road length comprising local roads, estate roads and agricultural roads is under the local governments and other public and private institutions (Fig. 2.6).

2.4 THE SRI LANKAN ECONOMY

Until the 1960's, the Sri Lankan economy depended heavily on the export-oriented plantation crops of tea, rubber and coconut. The manufacturing sector was relatively weak and most of the industries were government operated monopolies. The adoption of open economic policies in the 1970's and the liberalization programme started in the late 1980's increased the market orientation of the economy emphasizing export led growth and the development of the private sector. Despite the severe civil strife, these economic reforms have resulted in an average annual growth rate of around 5.0% since 1990. Per capita income has reached US dollars 837 and Sri Lanka is now recognized as a "lower middle-income" country moving up from the "low income" group.

By 1998 the major sector of the growing economy was the services sector contributing 53.0% to the Gross Domestic Product (GDP). This was followed by the agriculture, fisheries and the forestry sector with 21.3% and the manufacturing sector with 16.5%.

The volume and value of exports have increased rapidly in recent years and export earnings reached US dollars 4639 million in 1998. The composition of exports has also changed. Agricultural exports have declined in relative importance and in 1998 contributed only 22.0% towards export earnings compared to 79.9% in 1978. Industrial exports on the other hand led by textiles and garments have increased in importance accounting for 75.0% of the total value of exports in 1998 as against 14.0% in 1978.

There has been a declining trend in unemployment with the unemployment rate falling from 16.0% of the labour force in the early 1990's to 9.1% by the end of 1998. The key areas of employment generation have been manufacturing, construction and services. The average annual inflation rate has also continued to decline and stood at 8.6% in 1998 as against 11.7% in 1993. The domestic savings rate has increased steadily from 16.0% in 1993 to 18.9% in 1998, reflecting the country's growing ability to finance a higher level of investment out of its own resources.

Despite the positive developments the income distribution in the country remains uneven. The lowest 30.0% of the households receive less than 10.0% of the household income while the highest 30% receive 65.0%. Nearly 40.0% of the population was below the poverty line in 1996. It is estimated that 20.0% live in absolute poverty.

Figure 2.5

SOURCE: NATIONAL ATLAS OF SRI LANKA

Figure 2.6

SOURCE: NATIONAL ATLAS OF SRI LANKA

2.5 ECONOMIC ACTIVITIES

The three major economic activities in the country are agriculture and livestock, manufacturing and fishing. Together they contribute 37.0% towards the Gross National Product and provide employment to 53.0% of the total employed.

2.5.1 Agriculture

The agricultural sector comprises two sub-sectors, one producing mainly for the domestic market and the other mainly for the export market.

(i) *Domestic Sector:*

Paddy is the main crop within the domestic sector. It is also the staple carbohydrate of the Sri Lankans. Cultivation is widespread and approximately 850,000 hectares are set apart for paddy. This is surpassed in extent only by the area under coconut. Over three-fourths of the paddy land is located in the Dry Zone.

Paddy which is essentially a small-holder's crop is grown under irrigation as well as under rain-fed conditions. Over two-thirds of the paddy lands are irrigated and much of this land is in the Dry zone. Rain-fed cultivation on the other hand is relatively more important in the Wet zone. The total production in 1998 amounted to 2,692,000 tonnes.

The domestic sector also produces other field crops, vegetables, fruits and sugar. Other field crops include grain legumes, coarse grains, oil seeds and condiments grown in rain-fed upland areas and under minor irrigation schemes mainly in the Intermediate zone and in the Dry zone. The total area under cultivation in 1998 amounted to approximately 131,000 hectares. These generate high incomes, but profit margins have gone down in recent years because of low market prices and high input costs and labour costs. Total production in 1998 amounted to 185,000 tonnes. Vegetables include both low country vegetables and up country vegetables. Low country vegetables are grown on un-irrigable upland areas in the Dry zone as well as in the paddy fields in the Wet and Dry zones. Up country vegetables are the temperate species grown intensively on sloping lands in the hill country. A wide variety of fruits are also grown in different parts of the country, but fruit production largely takes place in a non-commercial manner. Except for bananas and pineapples and to a lesser extent strawberries, there are no organized orchards. Much of the sugar cane is grown on a few large scale plantations and on small peasant sub-grown holdings in the Dry zone. Although sugar cane cultivation and the processing industry provides direct and indirect employment opportunities to a large number of persons in the production areas, Sri Lankan sugar production is sufficient to meet only about 10-12% of the domestic consumption requirements.

(ii) *The Export Sector:*

The export sector is dominated by tea, rubber and coconut. In 1998, tea and rubber accounted for 194,736 ha and 158,140 ha respectively. The three crops accounted for 21.0% of the value of exports in that year. Much of the coconut lands are confined to the lowland areas in the Wet and Intermediate zones while most of the rubber and tea lands are on the wetter western slopes of the hill country. Production takes place partly on large estates and partly on small-holdings. These crops, because of their high dry matter content and long life span may have a role to play in carbon sequestration.

The other crops within the export sector include spices such as cloves, cardamoms, cinnamon, pepper and nutmeg, beverage crops such as cocoa and coffee and essential oils such as citronella. All of these crops are confined to the Wet zone, where they are grown as mixed crops on home gardens with the exception of cinnamon which is cultivated in a less organized manner in larger holdings. The extents cultivated are small relative to tea, rubber and coconut and hence production remains low. In 1998 their contribution to the value of exports amounted to only 2.6%.

2.5.2 Animal Husbandry

A variety of animals are raised in the country including neat cattle, buffaloes, sheep, goats and pigs. Cattle and buffaloes are raised for draught, dairy purposes and for slaughter. Pigs and sheep are raised exclusively for slaughter while goats are raised both for slaughter and the supply of milk. The poultry industry is dominated by the private sector and consists of a multitude of small producers and a few large producers. The dairy and the poultry industries represent the more prominent and organized sectors of the country's livestock industry.

2.5.3 Fishing

The fisheries sector contributes on the average 3.0% to the Gross National Product. Fish production includes both marine fish production (coastal, offshore and deep sea) and aqua culture fish production (inland, coastal brackish water prawns and cultured prawns). Marine fish production accounted for 89.0% of the total fish production in 1998. Both marine fish production and aqua culture food production has increased in recent years, the former because of the facilities provided to encourage and strengthen the off-shore fisheries sector and the latter because of the supply of inputs, better management of aquatic resources and proper monitoring.

2.5.4 Manufacturing

The manufacturing sector consists of three sub-sectors, i.e. factory industry, processing of plantation crops and small industries. Together they contributed 17.1% to the G.N.P. in 1998. Factory industry is the most important of the three sub-sectors accounting for 78.0% of the value added in the manufacturing sector in 1997.

Textiles, wearing apparel and leather products, food, beverages and tobacco and chemicals, petroleum, rubber and plastic production are the more important industries today contributing 83.0% to the total industrial production in 1998.

Some of the industries are domestic market oriented while others are export oriented. Industrial exports led by textiles and garments is today the largest contributor to export earnings. They accounted for 75.0% of the total exports in 1998. A few of the industries are public sector enterprises. The majority however, belong to the private sector. Private sector industries accounted for 93.0% of the total industrial production in 1998.

Most of the industries are concentrated in the hinterland of Colombo, the commercial capital, because of the availability of relatively better infra-structure facilities and the proximity to the harbour and the airport.

2.5.5 Tourism

The tourism sector makes a significant contribution to the national economy (Fig.2.7). In 1997, the foreign exchange earnings amounted to approximately 216.0 million U.S. Dollars and the revenue from different sources such as taxes, entrance fees to tourist sites, etc., to approximately 9.0 million U.S. Dollars. The tourist sector also generates both direct and indirect employment. Direct employment which is provided by tourist sector enterprises such as hotels, restaurants, airlines, tourist shops and transport agencies amounted to approximately 35,000 persons in 1998. In the same year, indirect employment which is generated in sectors supplying goods and services to the tourist establishments was estimated at approximately 49,000 persons.

Figure 2.7

SOURCE: SURVEY DEPARTMENT

2.6 ENERGY PRODUCTION AND CONSUMPTION

2.6.1 Primary Energy Sources

Energy supply in Sri Lanka is mainly based on three primary sources, namely hydroelectricity, biomass and petroleum. In 1996, hydro-electricity accounted for approximately 780 thousand Tonnes of Oil Equivalent (TOE) (11.4%), biomass for 3,930 thousand TOE (57.1%) and petroleum and crude oil products for 2,169 thousand TOE (31.5%), giving an aggregate primary energy supply of approximately 6,880 thousand TOE (Fig. 2.8). Commercial use of renewable energy sources such as wind power and solar electricity is negligible while the import and use of coal accounted for only 0.54 thousand TOE of the total energy supply in 1996.

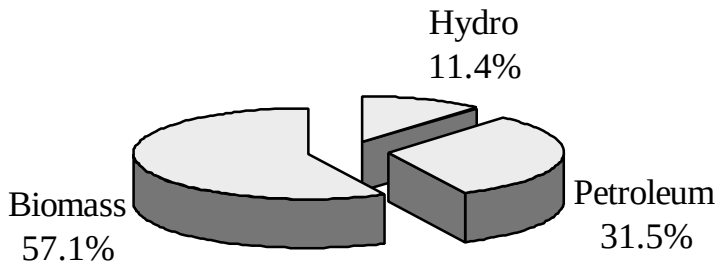

Figure 2.8: Primary Energy Supply in Sri Lanka (1996)
SOURCE: SRI LANKA ENERGY BALANCE-1996, ENERGY CONSERVATION FUND, SRI LANKA.

The energy supply is expected to increase to approximately 11.5 million TOE by the year 2010 at an annual growth rate ranging from 4% to 8% in different sub-sectors. Hydro power and biomass based energy supply will remain virtually fixed during this period as the development efforts pertaining to these primary energy sources are only very modest. Petroleum oil and coal consumption on the other hand will gradually increase necessitating a greater emphasis on mitigation of environmental impacts.

2.6.2 Electricity

DEMAND

The demand for electricity has increased over the years (Fig. 2.9). The overall annual electricity demand grew from 823 million units in 1972 to 3,588 million units in 1996 at an annual compound growth rate of 6.8%. The growth however has been uneven. The growth rate which amounted to 4.7% during the period 1972-1977 rose sharply to 10% per annum in the early 1980s, dropped to 4.9% between 1982-1989 and increased again to 8.9% from 1989 to 1994.

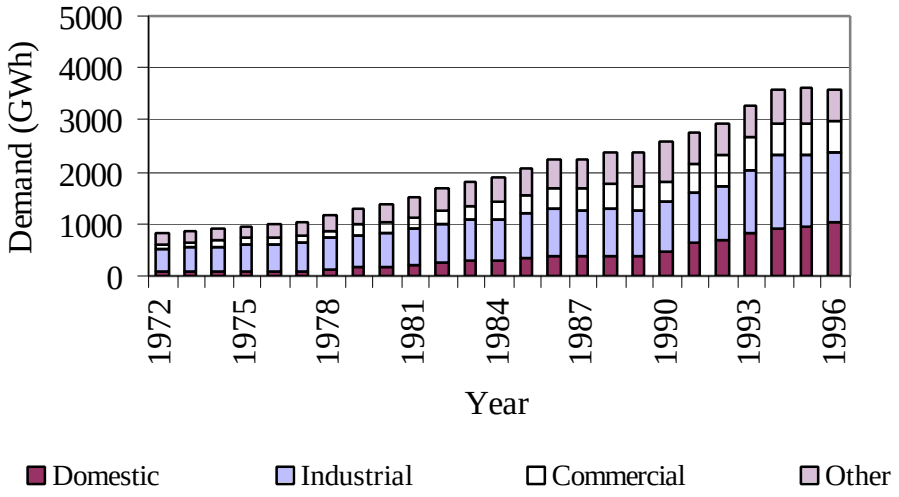

Figure 2.9: Growth of Electricity Sales 1972-1996
SOURCE: LONG TERM GENERATION EXPANSION PLANNING STUDIES 1996-2010, CEYLON ELECTRICITY BOARD, 1996

The countrywide electrification level stands at approximately 50% of the households with a relatively large percentage of rural households not being connected to the national grid.

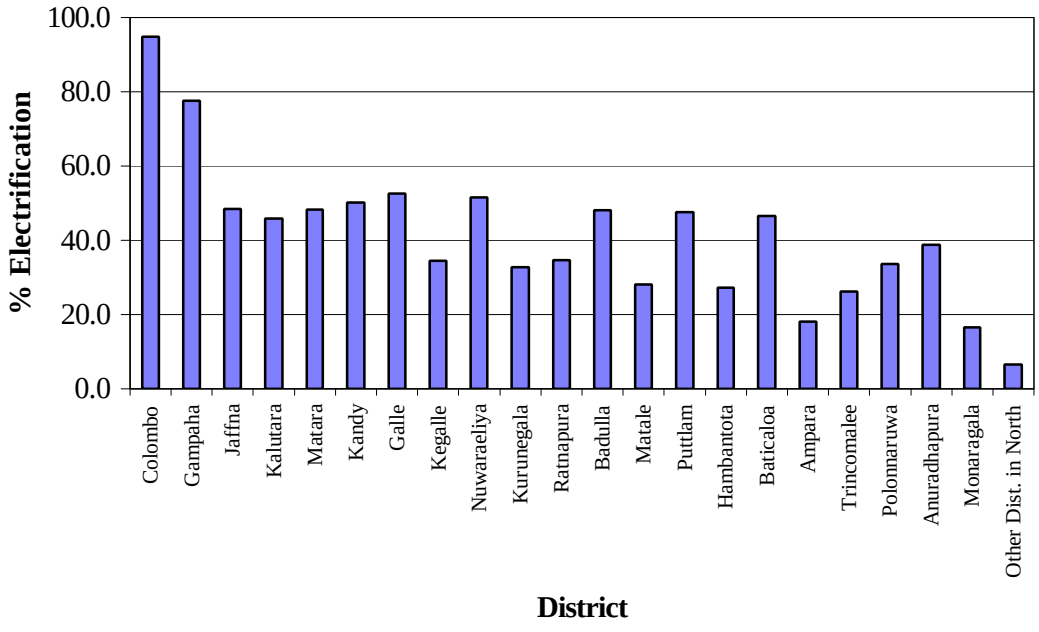

Figure 2.10: Electrification Level in Different Districts
SOURCE: PRE-ELECTRIFICATION UNIT, CEYLON ELECTRICITY BOARD, 1998

Figure 2.10 shows the districtwise distribution of electrification level in 1998. There are wide regional variations in the distribution of electrification. In the Colombo district where the national electricity grid has penetrated to all of the areas, the electrification level stands around 98%. Rural districts such as Ampara and Monaragala are poorly electrified with less than 20% of the households being connected to the grid.

The per capita electricity consumption in Sri Lanka which stood at 208 units a year in 1995, is relatively low in comparison to other countries in the region. The average annual increase in per capita consumption during the last 15 years is also the lowest in the group.

GENERATION

Electricity generation is 15–20% higher than the electricity sales figures because the generators also have to meet the inevitable power losses in the transmission and the distribution of electricity.

The use of hydroelectricity in a given year depends entirely on the extent of effective installed capacity and the rainfall in hydro catchment areas. At present, hydroelectricity is the primary source and any deficit is supplied by oil-fired thermal plants.

The total hydroelectricity generation from existing power stations in 1996 amounted to approximately 3,250 million units per annum which is equivalent to 300 thousand TOE. There are other potential hydroelectric sites, but their development will be constrained by economic factors. Hence, the amount that can be added to the annual supply will be limited to approximately 3,500 million units.

Installed capacity and energy supply from hydroelectric stations in Sri Lanka have been progressively increased through the commissioning of hydropower stations. The total installed capacity of hydropower stations in 1999 was 1,135 MW providing an average generation capability of approximately 3,500 million units. Since the demand in 1999 was for 6,481 million units, the shortfall of approximately 3,000 million units had to be provided by thermal power stations.

The forecasts of Annual Electrical Energy Generation required, for the period 1998 to 2017 are given in Figure 2.11. The expansion of hydroelectric system during this period will be limited to 70MW and 305 million units. This implies that there will be a significant gap between the demand and hydropower output, which needs to be bridged by thermal plants. Additional thermal electricity sources as presently planned by the Ceylon Electricity Board (CEB) are all either oil or coal based.

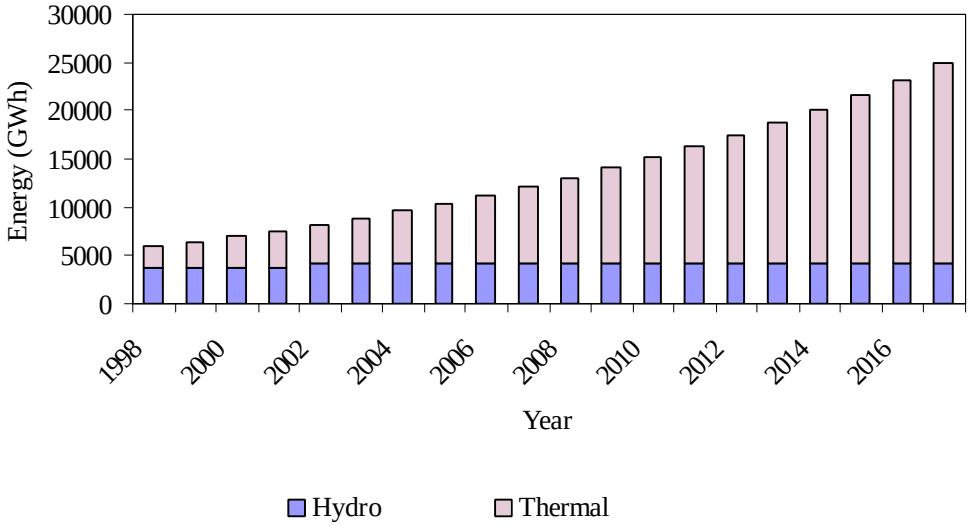

Figure 2.11: Growth of the Electricity Generation Sector 1998-2017
SOURCE: LONG TERM GENERATION EXPANSION PLANNING STUDIES 1996-2010, CEYLON ELECTRICITY BOARD, 1996

2.6.3 Petroleum

Petroleum oil products amounting to approximately 2 million TOE, contributed to 31.5% (1996) of the primary energy supply in Sri Lanka at a cost of Rs.18.3 billion. The products are supplied either through the output of the local refinery with an annual refining capacity of 2 million tonnes of crude oil or from direct importation of refined products.

Figure 2.12 shows that the major user of petroleum products is the transport sector. This is followed by the industrial and electricity sectors.

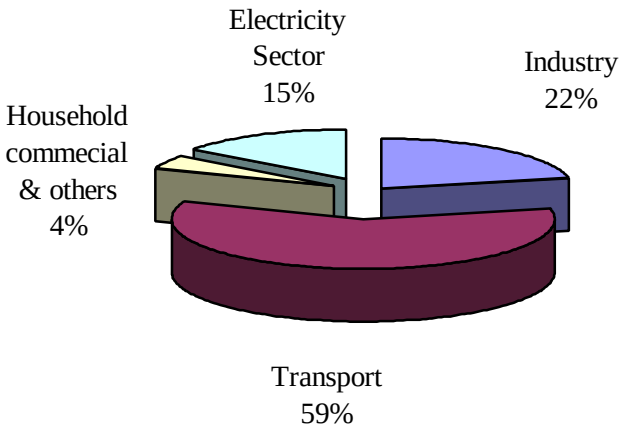

Figure 2.12: Composition of Petroleum Product Consumption (1996)
SOURCE: SRI LANKA ENERGY BALANCE-1996, ENERGY CONSERVATION FUND, SRI LANKA.

During the period 1972 to 1977, the consumption of all petroleum products except liquid petroleum gas (LPG) and auto-diesel declined due to low economic growth coupled with the near trebling of prices (Fig. 2.13). Since 1977, demand for most petroleum products has been increasing, particularly that for auto-diesel and LPG. In dry years when hydro-power generated capability is at its minimum, the heavy demand on thermal electricity also increases the demand for heavy diesel and fuel oil.

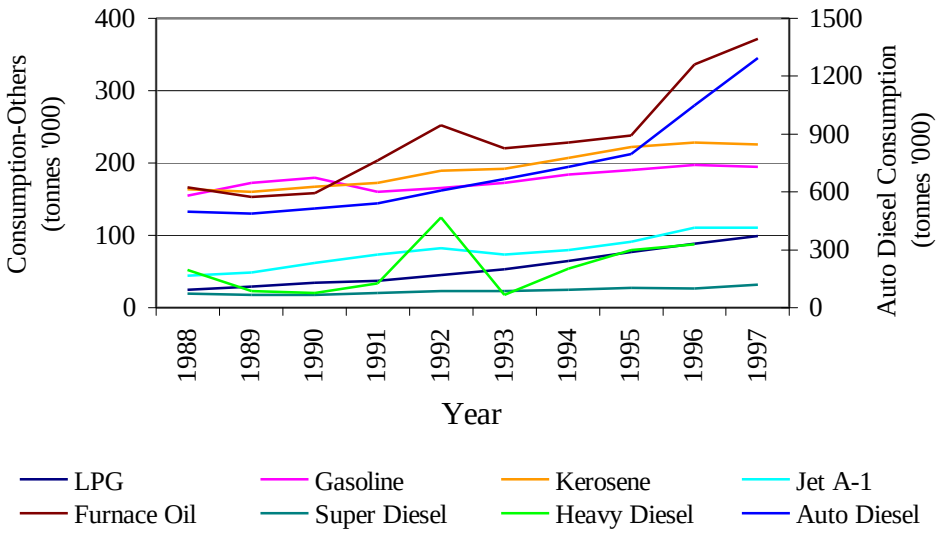

Figure 2.13: Historical Growth in Petroleum Product Consumption
SOURCE: ANNUAL REPORT 1997, CENTRAL BANK OF SRI LANKA

In the year 2000, the local annual refining capacity at the only local oil refinery is expected to saturate at 2.2 million tonnes of crude oil. Further, the present annual consumption of 2 million TOE of petroleum is expected to grow at an average annual growth rate of 7% up to 4.9 million TOE by the year 2010, mainly as a result of increased direct consumption in the transport and industrial sectors. The expected growth in consumption is shown in Figure 2.14.

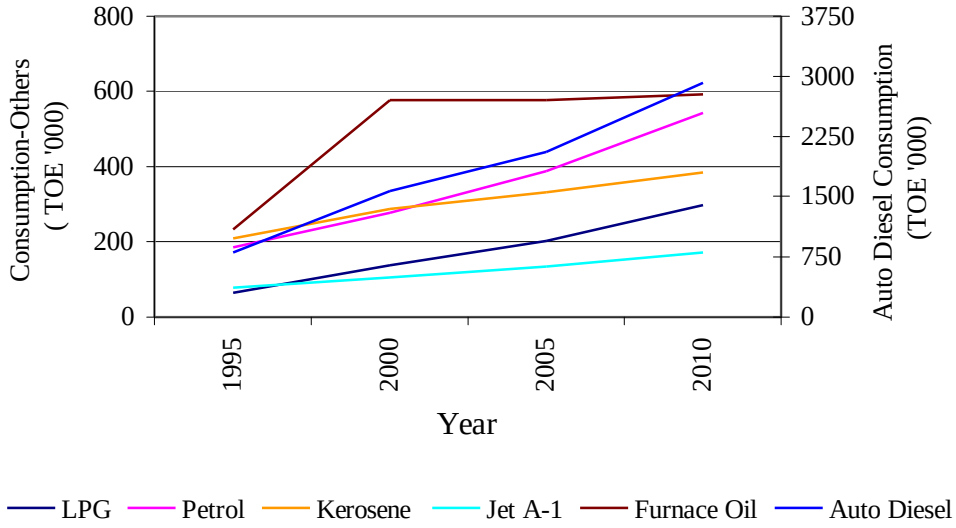

Figure 2.14: Expected Growth in Petroleum Product Consumption
SOURCE: DRAFT ENERGY POLICY FOR SRI LANKA, MINISTRY OF IRRIGATION, POWER AND ENERGY, 1997

2.6.4 Biomass

Biomass generally implies fuel-wood, agro-waste through forest and non-forest sectors including twigs, branches and roots. Biomass, though generally classified as "non-commercial" has a market value and is traded freely (Fig. 2.15).

As in the case of many other developing countries, biomass is the most widely used source of primary energy in Sri Lanka. The total biomass consumption stood at approximately 10 million metric tonnes in the year 1996, the demand being shared between domestic, commercial and industrial sectors.

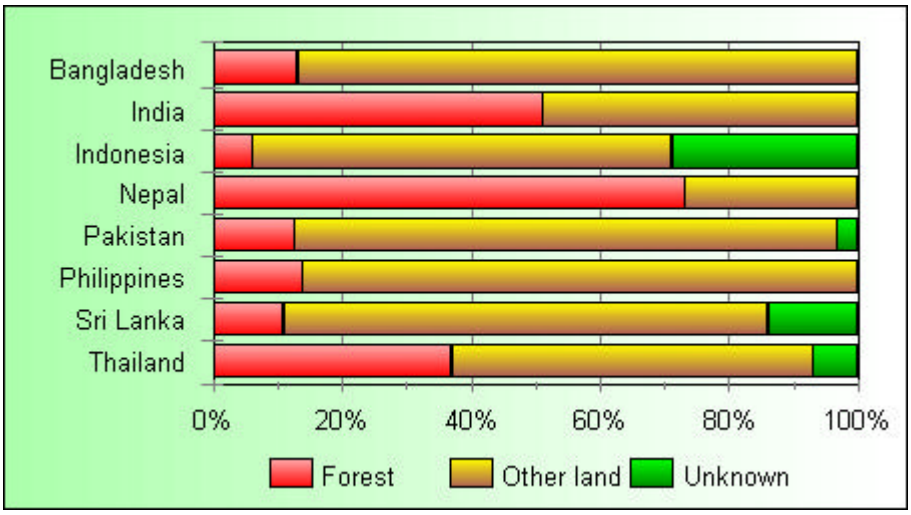

Figure 2.15: Fuelwood Supply in the Region from Different Sources
SOURCE: SOURCES OF WOOD ENERGY, FAO-RWEDP, 1999

Fuelwood and other biomass such as coconut residues, paddy husk and saw dust are largely used for domestic cooking. Small manufacturing industries such as bakeries and tile and brick making use mainly fuelwood as their source of energy supply. Bagasse resulting from sugar production is almost completely utilized for electricity generation within the sugar factories themselves. Rice husk is being increasingly used in rice mills and in tobacco barns as a major energy source of energy during processing.

The annual biomass availability is estimated to be between 10,900 to 16,500 kilo tonnes corresponding to 4,142 thousand TOE and 6,270 thousand TOE respectively. Although the biomass supply is greater than the demand for the country as a whole, nonetheless there are some regional deficits.

The Forestry Master Plan has identified 1.6 million hectares of scrub land and chena land, which urgently need some form of "cover" to prevent further degradation. This can be done by introducing energy plantations on some of these lands. Fuel-wood plantations on 0.5 million hectares of this marginal land can provide 10 million tonnes of fuel-wood annually which is equivalent to 3.8 million tonnes of oil. This quantity of fuel-wood could effectively supply more than the entire energy being supplied from oil at present.

Presently there are 10 experimental plots of land being cultivated by the Ministry of Science & Technology, with the assistance of the Energy Conservation Fund and the Department of Forests, under an European Commission funded Energy Forest pilot project in Sri Lanka. This is mainly to determine the optimum parameters such as species types and planting distances associated and other aspects of energy plantations. Also another study has been recently completed to ascertain the feasibility of fuelwood based electricity generation and the use of short rotation plant species.

2.6.5 Other Energy Sources

WIND ENERGY

In Sri Lanka, systematic studies involving the development of wind energy were commenced in 1988 by the CEB. These studies revealed that the southern coastal belt from Hambantota to Kirinda offer an exploitable wind turbine capacity of 200 MW with an annual yield of 350 million units. In addition, it is expected that a substantial wind energy potential is available on the north-western coastal belt from Puttalam to Jaffna and on the east coast from Jaffna to Trincomalee. Certain areas of the hill country such as Ambewela and Uva basin also experience strong winds.

In most locations in the southern coastal belt, only an annual average wind speed of around 6 m/s to 6.5 m/s is experienced. There is also a mismatch between the wind speed variation and the daily, as well as the annual demand for additional generation.

CEB has now embarked on a pilot wind farm of 3MW capacity consisting of five 600kW turbines in Hambantota. This was commissioned in early 1999 and connected to the national grid. Some private sector institutions also have already expressed their interest in establishing grid-connected wind turbine plants in the southern coastal belt.

MICRO-HYDRO POWER

The highlands in Sri Lanka experience rain for about 9 months in the year, leading to the formation of a number of small streams. These streams join to form rivers, which are utilized for large scale hydropower generation. Since these small streams flow through vast areas of tea cultivation, they were used in the early part of the century for power generation to fulfill the electricity requirements of the tea industry. Later, most of these micro-hydro plants were abandoned with grid electricity penetrating into the tea estates. The records reveal that there had been around 500 micro-hydro plants with capacities varying between 10 kW to 250 kW resulting in a combined capacity of around 20MW, during this period. The exploitable capacity at these sites can be as high as 40MW. When other possible larger scale sites are also considered, the total exploitable small hydro potential is estimated to be around 100 MW to 120 MW with an annual energy output of around 350 million units.

The CEB has now allowed grid connection of small hydro plants and offers to buy all the energy injected to the system by such plants at a pre-published power purchase tariff meant for small power producers. Since the initial capital investment required for micro-hydro plants has now come down making them more competitive with conventional electricity generating systems, a considerable interest among private investors has been generated in this area. Presently, studies are being carried out on the development of many identified sites. Twelve plants have already been connected to the national grid during the last three years.

SOLAR POWER

Solar insolation in Sri Lanka is high at an average annual rate of 1.86 TWh per square km. In Sri Lanka, traditionally solar power has been directly used in day to day activities associated with drying processes. The biggest users of solar drying are the various agricultural products such as rice and chilli. In recent times, solar hot water systems have also been designed to capture direct solar radiation for water heating. This has become popular among more affluent households and tourist hotels in the country mainly due to increasing electricity costs. Research and development activities concerned with the use of solar thermal systems in the industrial sector as a means of cheaper and cleaner energy supply are also being undertaken.

In 1980, with the formation of the Energy Unit at the CEB, Sri Lanka started the promotion of solar photovoltaic (PV) systems for rural domestic use. Since then many private sector companies have been involved in assembling and marketing solar PV systems in the country.

The main solar PV applications identified for Sri Lanka are in domestic lighting and the operation of radios and television sets in remote rural areas where there is no likely access to the national power grid within the foreseeable future. At present there are also about 20 solar PV based water-pumping schemes in the Monaragala and Badulla districts, established with grant funding from the Australian Government. There are also approximately 8,000 solar home systems installed in Sri Lanka.

2.7 NATURAL RESOURCES

2.7.1 Land Resources

Sri Lanka has a total land area of 65.6 thousand square kilometres, nearly 80% of which comes under some form of state control. About a third of this area is under forest cover and another third is under agriculture. Human settlements, home gardens, urban and industrial areas, transportation and a variety of other uses including undeveloped land account for the balance (Fig. 2.16).

A rough land "balance sheet" prepared in 1995 indicated that 51% was under agriculture, homesteads, pasture, chena and other sparse uses; 31% under forests and catchment areas and 9% under streams and their reservations, reservoirs and infrastructure facilities. The balance 9% comprised steep lands, barren lands, lands above 5,000 ft., marshes and mangroves.

Figure 2.16

SOURCE: NATIONAL ATLAS OF SRI LANKA

2.7.2 Forests

The climate of Sri Lanka is conducive to forest growth and the entire land area with a few exceptions was once covered with forests. Over the last century much of this forest cover, rich in diversity, has been destroyed. Deforestation has seriously diminished timber supplies, made soils less productive and affected the natural water supply.

Sri Lanka still has a variety of forest types. The wet south-western region and the central highlands are covered with tropical rain forests, sub-montane forests and wet evergreen forests particularly at higher elevations. Tropical semi-evergreen forests are present in the transition zone between the wet zone and the dry zone. The major part of the dry zone has tropical dry mixed evergreen forests. In the dry zone large-scale felling and chena cultivation has degraded the forest cover and today scrub or low jungle and dry pastures dominated by coarse grass types are widely present in the area. Tidal mud flats and mangrove forests are located along the coastal belt of the country, particularly influenced by the tidal lagoon environment.

Although Sri Lanka has a long history of wildlife protection and sustainable use of forests, severe deforestation and degradation have taken place. It is estimated that deforestation has occurred at the rate of 42,000 hectares per year over 1956-1983 increasing to 54,000 hectares per year over 1984-1994. Reforestation programmes have been implemented by the Forest Department to minimize the negative impacts of deforestation, protect environmentally sensitive areas and provide fuelwood and timber.

2.7.3 Minerals

Sri Lanka has reasonable endowments of mineral resources in relation to its size (Fig. 2.17 – Mineral Map). The most economically valuable are the gemstones, which accounted for more than 90% of all mineral exports in 1994. Other important minerals include clays, vein quartz, silica sands, feldspar, apatite rock phosphate, miocene limestone, dolomite, coral, monazite, ilmenite, zirconium, graphite and granite. A number of these minerals support important industries.

2.7.4 Water Resources

Sri Lanka is exposed to moisture-laden winds from the south-west and the north-east but despite this favourable position, Sri Lanka has extensive areas of water deficit. A greater part of the country at times experiences dry spells extending over several months.

The principal geographical determinant of water resources of the island is the highland massif in the south central region, located across the passage of monsoonal winds. The moisture laden monsoonal winds are intercepted by the hills in the central region leading to a unique rainfall pattern. Surface water from the high watersheds is transported by 103 distinct natural river basins that cover 90% of the island; the remaining 94 small coastal basins contribute only marginally to water resources. River basins originating in the wetter parts of the hill country are perennial while the majority of those in the dry zone are seasonal.

Water, which remains from rainfall after accounting for evapotranspiration and infiltration losses, is identified as available surface water. Annual surface water estimates vary from 4.0 to 5.13 million hectare metres. Much of this is used for hydropower projects and irrigation and the balance is discharged to the sea. Over 60% of the water that is discharged comes from the wet zone and often leads to floods and water logged lowlands. Development of river basins in the dry zone has considerably reduced dry zone run off.

Figure 2.17

SOURCE: NATIONAL ATLAS OF SRI LANKA

Information on the available ground water in different aquifer formations is incomplete. The largest and the most investigated aquifers lie in north and north-western regions. It has been reported that miocene limestones of the north-west extend over 200 km in the north-western and northern coastal areas with aquifers becoming increasingly thick as they approach the coast. For example in the Vanathavillu basin, in the north-western part of the country which spreads over 40 square km, the confined aquifer creates artesian conditions. Estimates of ground water resources available in this basin vary between 5-20 million cubic metres per year with the higher figure reflecting the maximum potential. Estimates of well yields outside the north and north-west point to relatively modest ground water potential.

2.8 SOCIAL PROFILE

2.8.1 Education

The education system in Sri Lanka comprises three sub-systems, i.e. (i) General Education, (ii) Higher Education, and (iii) Technical and Vocational Education.

(i) *General Education:*

General education is provided by over 10,000 government schools of which nearly 3% are National Schools administered by the Ministry of Education and Higher Education. The balance comes under the jurisdiction of the Provincial Councils.

General education is also provided by a number of officially approved private schools, private tutories and pirivenas or temple schools.

(ii) *Higher Education:*

At present, higher education is provided by 12 national universities, 6 post-graduate institutes and 5 other institutions.

All of the universities are autonomous institutions and are overseen by the University Grants Commission established in 1978. They offer degrees in the fields of Medicine, Engineering, Dentistry, Veterinary Science, Biological Sciences, Physical Sciences, Arts, Fine Arts and Law. The Open University established in 1980 also offers various degree courses on the basis of distance education.

(iii) *Technical Education and Vocational Training:*

Technical education and vocational training which caters directly to the labour market is handled by the Department of Technical Education and Training and other similar institutions. At present, there are 36 technical institutions with a staff of approximately 1,500 providing training to nearly 15,000 students.

2.8.2 Health

The responsibility for the protection and promotion of people's health lies with the Ministry of Health and Indigenous Medicine in the Central Government. Health care is provided by both the public and private sectors. The public sector provides preventive, curative and rehabilitation health care for nearly 60% of the population. The private sector provides mainly curative care, which accounts for nearly 50% of the out-patient care of the population and is largely concentrated in the urban and sub-urban areas. Ninety-five percent of inpatient care is provided by the public sector.

Western, ayurvedic, unani, siddha and homeopathy systems are practiced in Sri Lanka. Of these, Western medicine is the main sector catering to the needs of the majority of the population. The public sector comprises western and ayurvedic systems while the private sector includes practitioners in all types of medicine.

The network of curative care institutions ranges from sophisticated Teaching Hospitals with specialized consultative services to small Central Dispensaries that provide only outpatient services. Primary health care institutions include Central Dispensaries, Maternity Homes, Rural Hospitals, Peripheral Units and District Hospitals; secondary care institutions include Base Hospitals and Provincial Hospitals, and tertiary care institutions include Teaching and Special Hospitals.

2.9 POLITICAL PROFILE

2.9.1 Central Government

The Democratic Socialist Republic of Sri Lanka is a unitary state whose legal and administrative structure is based on its republican constitution. The national constitution of 1978 forms the supreme law under the Executive Presidency and a single House of Parliament.

The President of the Republic is elected by the people and holds office for a term of 6 years. Parliament consists of 196 members elected by the electors of the several electoral districts in accordance with the provisions of the constitution. Parliament continues for 6 years from the date of appointment.

The President appoints the Prime Minster and the Cabinet of Ministers and is the Head of the Cabinet. At present there are 33 Ministries each headed by a Minister and assisted by one or more Deputy Ministers.

The hierarchy of administration of the Government consists of Ministerial Secretaries, Additional Secretaries, Assistant Secretaries, Heads of Departments and Heads of Corporations at the Central Government level.

2.9.2 Provincial Government

The country is divided for administrative purposes into nine provinces. The provinces are divided into 25 districts, each headed by a Government Agent and districts are divided into 280 divisions each headed by a Divisional Secretary (Fig. 2.18 – Administrative Divisions).

The 13th amendment to the Constitution in 1987 provided for the devolution of power to the provinces and provinces are now the fundamental administrative units of regional governance. The unit of devolution is the Provincial Council comprising a number of members elected by the voters in each province. The province is headed by a Governor appointed by the President and the Provincial Council by a Chief Minister appointed from amongst the elected members. The Chief Minister is assisted by a Cabinet of Ministers.

Figure 2.18

SOURCE: NATIONAL ATLAS OF SRI LANKA

Under the 13th amendment, some subjects are completely devolved, e.g. Police and Public order, Planning, Education, Local Government, Provincial Housing, Social Services, Agrarian Services, minor Irrigation Services, protection of environment, etc., some are shared by the Provincial government and the Central government, e.g. Plan Implementation and Progress Control, Higher Education, Social Services, Health, Irrigation, Tourism, Drugs and Poisons, and some are handled by the Central government, e.g. Defence and National Security, Foreign Affairs, Posts and Telecommunications, Ports and Harbours, National Transport, Immigration and Emigration, etc.

2.9.3 Local Government

Local government is in the hands of Municipal Councils, Urban Councils in urban areas and the Pradeshiya Sabhas at the Divisional level. Each local authority is a corporate body having perpetual succession with a council elected for a period of 3 years and operate under powers vested in them under existing laws. At present, there are 12 Municipal Councils, 51 Urban Councils and 257 Pradeshiya Sabhas.

2.10 INSTITUTIONAL STRUCTURE

The present Ministry of Forestry & Environment (MFE) set up in 1997 has the mandate to provide leadership for formulating national environmental policy and its review.

The Ministry functions under a Cabinet Minister supported by a Deputy Minister. It is headed by a Secretary who is assisted by 2 Additional Secretaries, one of whom is in charge of Environmental Management and the other in charge of Forestry and Administration.

The Central Environmental Authority (CEA) was established in 1981 as the Agency responsible for the formulation and implementation of policies and strategies for the protection and management of the environment in Sri Lanka. It now functions as the implementing agency of the Ministry of Forestry and Environment and has the responsibility to protect the environment from air pollution, water pollution and industrial pollution. In addition to the MFE and its agencies, there are several other ministries and their agencies also concerned with the protection of the environment, e.g. the National Building Research Organization in the Ministry of Urban Development, Housing and Construction and the National Disaster Management Centre in the Ministry of Social Services.

Sri Lanka has an active NGO community and conservation related NGOs have existed and operated in Sri Lanka for many years. NGOs represent an active medium to address environmental problems and they perform a crucial role in ensuring effective public participation in decisions and actions that pertain to the conservation of the environment and natural resources.

2.11 POLICIES RELATING TO CLIMATE CHANGE

The subject of climate change has not been directly addressed in almost all the existing policies. However, there are a number of environmental policies, legal enactments and plans that contain provisions that could contribute in reducing or mitigating the effects of climate change.

2.11.1 Policies

The National Forestry Policy of 1995 (NFP), the National Policy for Wildlife Conservation (NPWC), the Agriculture Policy of 1996 (AP), the Energy Policy of Sri Lanka of 1997 (EPSL), The National Transport Policy (NTP) and the National Policy on Air Quality Management are the existing policies that have a direct bearing on climate change and associated impacts.

With the rapidly dwindling forest cover and associated issues arising as a result of excessive dependency on forest resources and its eco-systems, the objectives and strategies included in the NFP, are very important in minimizing climate change impacts. It places high emphasis on increasing the tree cover in the country through private sector and community participation, and the protection of bio-diversity, soils and water through the effective management of a Protected Area Network and a clearly defined National Forestry Estate.

With the reduction of the forest cover and the resultant losses of habitat due mainly to population increase, the NPWC places much importance on the conservation of bio-diversity, with special emphasis on fauna. The conservation of threatened species both in-situ and ex-situ, which may diminish as a result of climate change has been adequately addressed. The need for clearly defined management plans for the conservation of protected areas and the sharing of benefits with communities living around the protected areas is emphasized.

Sri Lanka is an agricultural country with nearly 40% of its land area under agriculture. Because of the need to have food buffer stocks in view of the possible climatic change impacts on food production, the AP has made provision for conducting research on increasing farmer yields through bio-technology or genetic engineering; the supply of high quality seeds to farmers, and the provision of credit, fiscal incentives, marketing facilities, etc., to encourage sustainable agriculture and to increase food production in the country.

The EPSL emphasizes the importance of bio-mass in meeting the demand for energy and the need to reduce the dependency on imported energy. Promotion of energy efficiency measures through introduction of new technology and correct pricing and the use of renewable energy on a large scale have also been highlighted. On the whole, the implementation of the policy would result in a reduction in total emissions.

The NTP highlights the need for energy conservation through reduced use of fossil fuels, and the expansion of mass transportation systems such as the railway services, preferably through electrification. A reduction in vehicle emissions through control via monitoring and surveillance mechanisms would in the long run assist in minimizing climatic change impacts.

National Policy on Air Quality Management requires to maintain good air quality in the environment and focuses on vehicle maintenance, fuel reformulation, pricing, emission inventory and standard setting.

2.11.2 Legislation

There are many acts which deals with the subject areas dealing with climate change. These however have not been effectively implemented due to enforcement weaknesses.

SOIL CONSERVATION

The Soil Conservation Act No.25 of 1951 amended in 1953, 1981 and 1996 is concerned with the control and mitigation of soil erosion, protection of soils from floods, and designating, regulating and protecting erosion prone areas. The Act empowers the Director of Agriculture to acquire environmentally sensitive areas which are prone to severe soil erosion, specify measures for control, and to prohibit certain land use practices that contribute to soil erosion. The latest amendment to the Act provides for a Soil Conservation Board consisting of all relevant agencies for co-ordinating soil conservation, watershed protection, prevention of land degradation, etc.

FLORA AND FAUNA PROTECTION

The Forest Ordinance No.16 of 1907 (FO), amended in 1966, 1979, 1982, 1988 provides for the protection of forests from illegal operations and prescribes penalties for those who violate them. The subsequent amendments provide for village forestry, community forestry operations and buffer zone activities in protected forests.

The Fauna and Flora Protection Ordinance No.2 of 1937 and amendments introduced in 1964 and 1970, make provision for the protection of wildlife and flora in national reserves, and provides for the establishment and management of National Reserves and Sanctuaries.

COASTAL RESOURCES

The Fisheries Act No.24 of 1940 provides for protection of fish in Sri Lankan waters, and the regulation of fishing.

The Coast Conservation Act No.57 of 1981 and amended in 1988, established the Coast Conservation Department. The Department was made responsible for carrying out coast conservation programmes, developing a coastal zone management plan, and carrying out regulatory permit programme for the coastal zone between 300 m landward and two km seaward, and the waters of rivers, estuaries and lagoons within two km of their sea entrance.

The National Environmental Act No.47 of 1980 and amended in 1988 established the Central Environmental Authority. The Authority has assisted in developing policies, setting standards, and carrying out educational programmes in relation to environment and natural resources. The Act has paved the way for initiating many pollution prevention measures, such as Environmental Impact Assessment.

WATER RESOURCES

The Water Resources Board Act No.29 of 1994 provides for integrated planning and conservation of water resources, the co-ordination of river basin surveys and studies and other measures to control economic uses of water.

2.11.3 Plans

The various sector plans related to the broader context of climate change acts as strategies for implementing the related policies. In the absence of a policy, these plans provide the necessary policy direction to the sector. The Coastal Zone Management Plan of 1997 (CZMP), National Environmental Action Plan (NEAP), National Fisheries Development Plan (NFDP) (1999-2004), National Biodiversity Action Plan of 1998 (BAP), the Forestry Sector Master Plan of 1995 (FSMP), the Master Plan for Coastal Erosion Management (MPCE) (1986) and the Clean Air 2000 Action Plan (1992) (CA2AP).

The **CZMP**, which spells out the strategy for coastal management, is the only document which directly recommends action towards minimizing climate change impacts.

The **NEAP** is a long term strategic plan which deals with all aspects of environmental conservation.

The **NFDP** is concerned with exploitation of aquatic resources within sustainable limits and the prevention of unauthorized exploitation of resources in Sri Lanka's exclusive economic zone.

The **BAP** emphasizes the need for protecting threatened forest ecosystems and species. A regular monitoring system on forest biodiversity and necessary timely remedial action to rectify negative trends is expected to conserve biodiversity.

The **NFP** is translated into action in the FSMP where eleven broad based development programmes have been suggested for implementation during a 25 year period. It has given prominence to conservation of natural forests and forest plantations in sensitive areas.

The **MPCE** was developed as a long term strategy for erosion control. The plan identified several areas that are prone to severe erosion along the coast and have recommended and given priority to structural solutions.

CHAPTER 3

GREENHOUSE GAS INVENTORY

Greenhouse gases are found naturally in the atmosphere in small quantities. These contribute significantly to global warming through their accelerated generation as a result of anthropogenic activities. The main areas of greenhouse gas generation are energy industries, livestock, agriculture, forestry and waste. The gases comprise Carbon Dioxide, Methane, Nitrous Oxide, Nitrogen Oxides, Carbon Monoxides.

The largest contribution to GHG emissions is through the change in forest and woody biomass stocks, forest grassland conversion, liming and organically amended soils.

Domestic livestock are diverse and some fall into the category of ruminants, which mainly depend on roughage diets. When such diets are ingested by ruminants methane is produced. In addition, microbiological activity on the stockpiled animal waste, submerged rice soils and field burning of crop residues also result in methane emissions. The largest source of methane is from treatment and handling of waste while energy sector also contributes in a small scale through incomplete burning of fossil fuel.

Fuel combustion, which is one of the largest contributors to GHG emissions in Sri Lanka, can be broadly categorized into four groups for emission assessment, i.e. energy industries; manufacturing industries and construction, transport and other sectors having emissions from energy consumption. Emissions from the fuel combustion activities are estimated according to the revised procedures published in 1996 by the Intergovernmental Panel on Climate Change. Conversion factors and Carbon emission factors used in all the calculations are given in Table 3.0.

TABLE 3.0: CONVERSION FACTORS AND CARBON EMISSION FACTORS FOR DIFFERENT TYPES OF FUELS IN SRI LANKA

FUEL	CARBON EMISSION FACTOR (tC/TJ)	NET CALORIFIC VALUE (TJ/kt)
FOSSIL FULES		
Crude Oil	20.0	42.16
Gasoline	18.9	44.80
Jet Kerosene	19.5	44.59
Kerosene	19.6	44.75
Gas/Diesel Oil	20.2	43.33
Residual Fuel Oil	21.1	40.19
LPG	17.2	47.31
Naphtha	20.0	45.01
Bitumen	22.0	40.19
Lubricant	20.0	40.19
Other Oil	20.0	40.19
Other Bituminous Coal	25.8	25.75
SOLID BIOMASS	29.9	
Wood (Air dried)	29.9	15.5
Charcoal	29.9	29.0
Bagasse (Air dried)	29.9	16.2
Agricultural Waters	29.9	15

3.1 ENERGY AND TRANSFORMATION INDUSTRIES

3.1.1 Public electricity and heat production

All fossil-based thermal generation stations in Sri Lanka depend completely on imported petroleum fuels as crude oil or as refined products. Main fuels used in power generation are furnace oil, residual fuel oil and diesel.

EMISSION FACTORS

Standard emission factors for the power sector of Sri Lanka have not been tested and established so far. Several references to emission factors have been made elsewhere, but because of the uncertainty of the representation, the lack of evidence of reproducibility of such emission factors and the wide variation of these emission factors with the IPCC standard/default values, the IPCC default values have been used in this estimate in order to retain uniformity and some degree of reliability of the estimates. The data used are shown in Tables 3.1 and 3.2.

TABLE 3.1: CARBON EMISSION FACTORS AND FRACTION OXIDIZED

Fuel	Carbon Emission Factor (tC/TJ)	Fraction Oxidized
Heavy Diesel	20.2	0.99
Auto Diesel	20.2	0.99
Furnace Oil	21.1	0.99
Field Fuel	21.1	0.99

TABLE 3.2: GHG EMISSION FACTORS

	Emission Factor (kg/TJ)				
	CO	CH_4	NO_x	N_2O	NMVOC
Corresponding to tier 1 method	15	3	200	0.6	5
Corresponding to tier 2 method					
Gas turbine simple cycle	32	5.9	188	NA	NA
Residual oil boilers	15	0.9	200	0.3	NA
Diesel engine	0.3	0.0	1.3	0.026	2.91
Fuel oil engine	0.046	0.003	2.1	0.002	0.067

TABLE 3.3: EMISSIONS FROM POWER STATIONS - 1994

Emissions (Gg)					
CO_2	CH_4	N_2O	CO	NO_x	NMVOC
257.794	0.0103	0.0021	0.052	1.06	0.017

3.1.2 Petroleum refining

Refining of crude oil at the country's only petroleum refinery at Sapugaskanda also contributes to GHG emissions. The main fuels used to drive machinery and to operate equipment during processing are diesel and fuel oil.

EMISSIONS DATA

The energy consumption data of the Ceylon Petroleum Corporation is presented in Table 3.4.

TABLE 3.4: CONSUMPTION OF FOSSIL FUEL BY REFINERY FOR OWN USE

Fuel Type	Use	Consumption (kt) – 1994
Auto Diesel	Vehicles	2.771
Fuel Oil	Refinery Use	34.929
Fuel Gas	Refinery Use	40.348
Petrol	Refinery Vehicles	0.043
Kerosene	Refinery Use	0.104
LPG	Refinery Use	0.014

EMISSION FACTORS

The relevant carbon emission factors and factor of Carbon Oxidized and the emission factors are given in Table 3.5.

TABLE 3.5: FUEL AND EMISSIONS DATA

Fuel	Conversion Factor (TJ/kt)	Carbon Emission Factor (tC/TJ)	Fraction Oxidized	Emission Factor (kg/TJ)				
				NO_x	CH_4	N_2O	CO	NMVOC
Diesel (Vehicle)	43.33	20.2	0.99	800	5	0.6	1000	200
Diesel (Other)				200	3	0.6	15	5
Furnace Oil	40.19	21.1	0.99	200	3	0.6	15	5
Fuel Oil	40.19	21.1	0.99	200	3	0.6	15	5
Gasoline (Vehicle)	44.80	18.9	0.99	600	20	0.6	8000	1500
Kerosene	44.75	19.6	0.99	200	3	0.6	15	5
Fuel Gas	48.15	15.2	0.995	200	3	0.6	15	5
LPG	47.31	17.2	0.995	200	3	0.6	15	5

TABLE 3.6: EMISSIONS FROM FUEL COMBUSTION WITHIN REFINERY - 1994

Emissions (Gg)					
CO_2	CH_4	N_2O	CO	NO_x	NMVOC
224.564	0.0107	0.002	0.186	1.839	0.044

3.1.3 Use of bagasse

Bagasse is widely used in sugar industries as a primary source of energy to generate electricity whenever it is available in large quantities. The total use of bagasse (Air Dried) in 1994 was 287.99kt.

Emission factors applicable to combustion of bagasse in the energy sector is shown in Table 3.7.

TABLE 3.7: EMISSIONS FACTORS FOR BAGASSE

CO	CH_4	NO_x	N_2O	NMVOC
1000	30	100	14	50

TABLE 3.8: EMISSIONS FROM USE OF BAGASSE – 1994

Emission (Gg)					
CO_2	CO	CH_4	NO_x	N_2O	NMVOC
450.11	4.61	0.139	0.466	0.018	0.233

3.1.4 Manufacturing solid fuels and other energy industries

Biomass such as wood is mainly used for charcoal production in Sri Lanka. Carbonization of these materials is generally carried out in open pits, kilns or metal retorts. The gas and particulate emissions in the process are allowed to escape into the atmosphere or burnt. In Sri Lanka, wood charcoal is produced by the official sector and by the State Timber Corporation. Charcoal is preferred to wood as it is easier to use than wood. Moreover, in urban centers, it is often less expensive than wood. Over 50% of the charcoal production is exported and another 25% used to produce activated carbon. The latter amount is not usually shown in the Sri Lanka Energy balance. As a result, data on production and consumption of charcoal had to be obtained from the data bank of the Ministry of Industrial Development. Even though the manufacture of activated carbon is an industry, the process itself is an energy process. Initially, coconut shells are converted to charcoal and thereafter, the heat and gases generated used to produce activated carbon. The quantity of charcoal produced in Sri Lanka during 1994 is shown in Table 3.9.

TABLE 3.9: PRODUCTION OF CHARCOAL IN SRI LANKA - 1994

Charcoal Consumed In (kt)	Charcoal Produced (kt)		
Activated Carbon Manufacture	Other	Activated Carbon Manufacture	Total Produced
4.42	13.52	15.48	29.00

EMISSION FACTORS

Values for fraction oxidized, and the emission factors for non CO_2 gases for the manufacture of charcoal are presented in Table 3.10. Table 3.11 shows the emissions from this process.

TABLE 3.10: EMISSIONS DATA FOR THE CONSUMPTION AND MANUFACTURE OF CHARCOAL

Conversion Factor (TJ/kt)	27.6	
Carbon Emission Factor (tC/TJ)	29.9	
Fraction of Carbon Oxidized	0.87	
	Consumption	**Production**
CH_4 kg/TJ of Charcoal consumed/produced	200	1000
NO_x kg/TJ of Charcoal consumed/produced	100	10
N_2O kg/TJ of Charcoal consumed/produced	4	4
CO kg/TJ of Charcoal consumed/produced	4000	7000
NMVOC kg/TJ of Charcoal consumed/produced	100	1700

TABLE 3.11: EMISSIONS IN CHARCOAL PRODUCTION – 1994

Emission (Gg)					
CO_2	CO	CH_4	NO_x	N_2O	NMVOC
80.22	5.89	0.841	0.008	0.003	1.429

3.2 MANUFACTURING INDUSTRIES AND CONSTRUCTION

Fuel combustion in the manufacturing and construction industries also contribute to GHG emissions.

3.2.1 Iron and steel

Manufacture of basic iron and steel as well as casting of iron and steel.

3.2.2 Non-ferrous metal

Manufacture of basic precious and non-ferrous metals are taken into consideration.

3.2.3 Pulp, paper & print

Manufacture of pulp, paper and paper board and publishing, printing and reproduction of recorded media.

3.2.4 Chemical

Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics of primary form, pesticides and other agro-chemicals, paints, varnishes, pharmaceuticals, detergents, perfumes, toilet preparations and other chemical products.

3.2.5 Food processing, beverages and tobacco

Production, processing and preservation of meat, fish, fruit, vegetables, oils, fats, dairy products, grain mill products, starches and prepared animal feeds, beverages and tobacco products.

3.2.6 Other industries

Industries not specified above are also included in this category.

The activity data for the sector concerned consists of fuel consumption by each industrial sector discussed above.

Data for each sector are available with the Department of Census and Statistics. However, due to the varied nature of the Food Processing, Beverage and Tobacco sector, the data were not easily available for compilation. Taking into account the total fuel consumption by the Industrial sector in Sri Lanka, it was possible to evaluate the energy consumption for the food, beverage, tobacco and all other industries as a unit sector. The fuel consumption data for 1994 for each category are shown in Table 3.12.

TABLE 3.12: FUEL COMBUSTION DATA FOR INDUSTRIAL SECTORS

	CONSUMPTION (kt)				
	Fire Wood	**Charcoal**	**Fuel Oil**	**Kerosene Oil**	**LPG**
Iron & Steel	0.004	1.541	29.27	0.002	3.737
Non Ferrous	0	0	0.223	0	0
Chemicals	0	0.005	46.919	0.189	0.357
Pulp & Paper	0.00345	0	31.195	0.162	0
Food & Other	150	0	113.5	0	35.3
Total	**150**	**1.5461**	**221.0**	**0.353**	**39.42**

EMISSION FACTORS

Emission factors for the respective fuels shown in Table 3.13 are based on the default values from IPCC and other sources.

TABLE 3.13: EMISSION FACTORS APPLICABLE TO THE INDUSTRIAL SECTOR

		EMISSION FCTOR (kg/TJ)				
Fuel		CO	CH_4	NO_x	N_2O	NMVOC
LPG	Furnace	10	1.1	47	NAV	NAV
Kerosene	Furnace	13	5	51	15.7	NAV
Fuel Oil	Boiler/Furnace	15	3	170	0.3	NAV
Fuel Wood	Boiler	590	15	65	NAV	NAV
Charcoal	Kiln	211	1	35	NAV	16

The IPCC worksheets 1-3 overview estimates the emissions by considering all liquid fuels into a single cell, and thereafter incorporating an average emission factor to cover all the liquid fuels in this sector. As a result of the mix of liquid fuels and the different proportions of the mix for each year, the average emission factor for the liquid mix varies with the year under consideration.

The estimated average emission factors are presented in Table 3.14.

TABLE 3.14: AVERAGE EMISSION FACTORS FOR LIQUID FUEL MIX FOR THE INDUSTRIAL SECTOR - 1994

CO	CH_4	NO_x	N_2O	NMVOC
14.13	2.67	148.52	2.72	0

TABLE 3.15: ESTIMATE OF EMISSIONS FROM FUEL COMBUSTION IN THE INDUSTRIAL SECTOR - 1994

Emissions (Gg)						
CO_2 Biomass	CO_2 Fossil	CO	CH_4	NO_x	N_2O	NMVOC
288.83	801.08	1.92	0.07	1.79	0.03	0.00

3.3 TRANSPORT

The transport sector of Sri Lanka, which is mainly dependent on Gasoline and Diesel, comprises both domestic transport and international transport. Each of these sectors could be further subdivided into passenger transport and freight transport. The domestic passenger transport consists of individual transport such as cars, vans, light duty vehicles and motor cycles, while public transport comprises mainly buses and railways. Domestic freight movement depends mainly on road and rail; the extent of coastal shipping is relatively small. The road freight transport fleet consists of trucks.

International transport comprises both air and sea transport. Air transport handles nearly all of the passenger transport and a relatively small amount of freight. Sea transport on the other hand handles the bulk of the freight dealing with imports and exports. A small amount of sea freight includes transport to the northern and eastern regions of the country.

GHG emissions from mobile sources consist of the gaseous product of engine fuel combustion (exhaust emissions) and evaporation and leaks from vehicles (Fugitive emissions). Carbon dioxide (CO_2) and carbon monoxide (CO) emissions are due to the oxidation of fuel during combustion. Other emissions from the transport sector include Methane (CH_4), Nitrous Oxide (N_2O), Oxides of Nitrogen other than nitrous oxide (NO_x), Non Methane Volatile Organic Compounds (NMVOC). NMVOC emissions are fugitive emissions due to evaporation and leaks.

3.3.1 Civil Aviation

Few private sector organizations operate the local air transport, which includes both passenger, and freight transport. The energy consumption consists of aviation turbine fuel and aviation gasoline.

3.3.2 Road Transportation

Sri Lanka had a network of approximately 10447.61 km of metalled and bitumen surfaced roads in 1990. Of the active road vehicle fleet only 25%comprise new imported vehicles, 75% comprise imported reconditioned vehicles. Petrol and auto diesel are the main fuels used for road transport in Sri Lanka. Buses and trucks are the main diesel consumers. Petrol is mainly consumed by cars and vans.

3.3.3 Railways

The railway sector of Sri Lanka has about 1450 km of railway track, most of which is limited to a single line. The 102 km of double track extends from Colombo up to Polgahawela on the main up-country line and from Colombo up to Wadduwa on the coastal line. The effective railway fleet of Sri Lanka consists of about 200 diesel locomotives and 46 power sets. Diesel is the major fuel type used. A small amount of coal is also used for steam railways.

3.3.4 Navigation

The Port of Colombo which is the main marine center for navigation in Sri Lanka handles most of the international marine transport. Two smaller ports in Galle and Trincomalee also handle some coastal shipping and fishing boats. The energy consumed consists of marine diesel and fuel oil.

ESTIMATION OF EMISSIONS

Tables 3.16 and 3.17 show the Fuel consumption values for the road vehicles in kilo litres and kilo tonnes respectively.

TABLE 3.16: FUEL CONSUMPTION (BY VOLUME) IN ROAD TRANSPORT SECTOR - 1994

Vehicle Type	Fuel Type	Consumption 000 Lit -1994
CAR	PETROL	114,692
PICK UP	PETROL	26,595
MINI BUS	PETROL	1,250.4
MOTOR CYCLE	PETROL	62,373
MOTOR TRICYCLE	PETROL	7,879.9
SUB TOTAL		212,791
CAR	DIESEL	17,241
MEDIUM BUS	DIESEL	143,796
DUAL PURPOSE	DIESEL	215,769
JEEP	DIESEL	12,809
HEAVY BUS	DIESEL	81,278
TRUCK	DIESEL	309,436
SUB TOTAL		**789,328**

TABLE 3.17: FUEL CONSUMPTION (BY WEIGHT) IN ROAD TRANSPORT SECTOR

Vehicle Type	Fuel Type	Consumption (kt) 1994
CAR	PETROL	84.378
PICK UP	PETROL	19.566
MINI BUS	PETROL	0.920
MOTOR CYCLE	PETROL	45.888
MOTOR TRICYCLE	PETROL	5.797
SUB TOTAL		**156.549**
CAR	DIESEL	14.751
MEDIUM BUS	DIESEL	123.029
DUAL PURPOSE	DIESEL	184.611
JEEP	DIESEL	10.959
HEAVY BUS	DIESEL	69.541
TRUCK	DIESEL	264.753
SUB TOTAL		**667.644**

Fuel consumption by railways amounted to 26.97kt of Diesel/Gas Oil and 0.55kt of coal; fuel consumption in local marine was 2.63kt of Diesel/Gas oil & 0.025kt of Fuel Oil while that in air transport was 78.34kt of aviation turbine fuel & 0.42kt of aviation gasoline.

Table 3.18 shows the amounts of fuel used by international bunkers.

TABLE 3.18: FUEL CONSUMPTION IN INTERNATIONAL BUNKERS - 1994

FUEL TYPE	CONSUMPTION (kt)
Marine Diesel	48.83
Furnace Oil	299.393
Aviation Gasoline	0.130
Aviation Turbine Fuel	146.9

EMISSIONS DATA

Standard emission factors for the transport sector of Sri Lanka have not been tested and established so far. Several references to emission factors have been made elsewhere, but because of the uncertainty of the representation, the lack of evidence of reproducibility of such emission factors and the wide variation of these emission factors with the IPCC standard/default values, the IPCC default values have been used in this estimate in order to retain uniformity and better reliability of the estimates. Default Carbon emission factors presented by the IPCC shown in Table 3.19 were used in the estimations.

TABLE 3.19: CARBON EMISSION FACTORS USED

Fuel Type	Carbon Emission Factor / (t C/TJ)
Gasoline	18.9
Diesel	20.2
Coal	25.8
Av Turbine Fuel/Jet Kerosene	19.5
Fuel Oil	21.1

The emission factors for the non-CO2 emissions applicable to road vehicles are presented in Tables 3.20 (A&B). As can be seen, road transport consists of different vehicles each having an individual emission factor for a given GHG. Depending on the extent of the fuel consumption by each vehicle category, an average emission factor for the road transport sector could be evaluated for each GHG and for each year. The values presented in the Table 3.21 under the road transport represents the average emission factor for the GHG for the whole fleet in a given year.

TABLE 3.20A: NON CO_2 EMISSION FACTORS FOR INDIVIDUAL ROAD VEHICLE TYPES

	EMISSION FACTORS (t/TJ)				
VEHICLE TYPE	CO	CH_4	NO_x	N_2O	NMVOC
PETROL					
Car	13	0.02	0.6	0.001	1.5
Pickup	8.3	0.02	0.7	0.001	1.4
Mini Bus	7.9	0.02	0.7	0.001	0.8
Motor Cycle	13	0.1	0.06	0.001	8.3
Motor Tricycle	12	0.1	0.2	0.001	2.4

TABLE 3.20B: NON CO_2 EMISSION FACTORS FOR INDIVIDUAL ROAD VEHICLE TYPES (DIESEL)

	EMISSION FACTORS (t/TJ)				
VEHICLE TYPE	CO	CH_4	NO_x	N_2O	NMVOC
DIESEL					
Car	0.3	0.002	0.3	0.004	0.07
Medium Bus	0.4	0.001	0.4	0.004	0.1
Dual Purpose	0.4	0.001	0.4	0.004	0.1
Jeep	0.4	0.001	0.4	0.004	0.1
Heavy Bus	0.9	0.006	1	0.003	0.2
Truck	0.9	0.006	1	0.003	0.2

TABLE 3.21: NON CO_2 EMISSION FACTORS

Mode of Transport	**CO**		**CH_4**		**NO_x**		**N_2O**		**NMVOC**	
National Navigation	1000		5		1500		0.6		200	
Rail Transport [a]	150	1000	10	5	300	1200	1.4	0.6	20	200
Domestic Aviation	100		0.5		300		2		50	
Road Transport 1993 [b]	8450	655	23	4	670	705	1	3.5	1140	150
Road Transport 1994 [b]	8550	650	24	4	660	700	1	3.5	1195	150
Road Transport 1995 [b]	8550	650	24	4	660	700	1	3.5	1195	150
Int. Marine Bunk.	1000		5		1500		0.6		200	
Int. Av. Bunk.	100		0.5		300		2		50	

Note: All the values are in kg of the gas/TJ **(a)** The first column represents the emission factors for coal and the second column the emission factors for oil. **(b**) The first column represents the emission factors for Gasoline and the second column the emission factors for Diesel

TABLE 3.22: CO_2 EMISSIONS FROM THE TRANSPORT SECTOR - 1994

Mode of Transport	**CO_2 Emission (Gg)**
National Navigation	8.34
Rail Transport	87.00
Domestic Aviation	248.56
Road Transport	2602.41
Transport Total	**2946.31**
International Marine Bunkers	1076.76
International Aviation Bunkers	464.06
Total International Bunkers	**1540.82**

TABLE 3.23: NON-CO_2 EMISSIONS FROM THE TRANSPORT SECTOR - 1994

Mode of Transport	CO		CH_4		NO_x		N_2O		NMVOC	
National Navigation	114.9		0.6		172.4		0.1		23.0	
Rail Transport [a]	2.1	1168.6	0.1	5.8	4.2	1402.3	0.02	0.7	0.3	233.7
Domestic Aviation	351.2		1.8		1053.6		7.0		175.6	
Road Transport [b]	59964.9	18803.8	147.3	115.7	4628.9	20250.2	7.0	101.3	8381.1	4339.3
Int. Marine Bunk.	14148		70.7		21220		8.5		2829.7	
Int. Av. Bunk.	655.6		3.3		1970		13.1		327.8	

a. First Column Coal based & second Oil based b. First column Gasoline based & second diesel based

3.4 OTHER SECTORS HAVING EMISSIONS FROM ENERGY CONSUMPTION

3.4.1 Commercial and Institutional Sector

The commercial sector consists of commercial organizations such as shops, markets, banks, and hotels. Although electricity is the main energy source in the commercial sector small quantities of fossil fuels and biomass are also used. Consumption of LPG, Charcoal and Fuelwood (air dried) in the commercial sector in 1994 were 11kt, 0.82kt, and 276kt respectively.

EMISSION FACTORS

Emission factors shown in Table 3.24 are the default values presented by the IPCC

TABLE 3.24: EMISSION FACTORS

Fuel Type	Emission Factor / (Gg / TJ)				
	CO	CH_4	NO_X	N_2O	NMVOC
Charcoal furnace / kiln	7000	200	100	1	100
LPG Furnace	20	10	100	0.6	5
Conventional Biomass Stove	5000	300	100	4	600

TABLE 3.25: ESTIMATE OF EMISSIONS FROM THE COMMERCIAL SECTOR - 1994

Emissions (Gg)						
CO_2 Biofuels	CO_2 Fossil	CO	CH_4	NO_x	N_2O	NMVOC
410.33	32.49	21.57	1.29	0.48	0.02	2.57

3.4.2 Residential Sector

Fuelwood and agricultural wastes are the traditional sources of energy used by the domestic sector of Sri Lanka. These fuels which are used as energy sources for cooking in many households are derived from forests, tree crops, home gardens, scrubs and waste land. However, with the introduction of LPG during the last decade, it has become a popular fuel for cooking, mainly in urban areas. Today, the entirety of the LPG consumed is used for household cooking. Kerosene is a main fuel used for lighting amongst rural households. Small quantities of kerosene and electricity are also used for cooking. Fuel consumption values in the residential sector are shown in Table 3.26.

TABLE 3.26: FUEL CONSUMPTION BY THE RESIDENTIAL SECTOR

FUEL TYPE	APPLIANCE	CONSUMPTION (kt) - 1994
Kerosene	Cooker	56.49
	Lamp	156.34
LPG	Cooker	53.0
Charcoal	Iron	0.448
Fuelwood	Stoves	8256

EMISSION FACTORS

Emission Factors for non CO_2 gases applicable to the residential sector are given in Table 3.27.

TABLE 3.27: EMISSION FACTORS FOR NON CO_2 GASES FOR RESIDENTIAL SECTOR

	EMISSION FACTOR (kg/TJ)				
	CH_4	N_2O	NO_x	CO	NMVOC
Oil	10	0.6	100	20	5
Biomass	300	4	100	5000	600
Charcoal	200	1	100	7000	100

TABLE 3.28: ESTIMATE OF EMISSIONS FROM THE RESIDENTIAL SECTOR - 1994

Emissions (Gg)						
CO_2 Biomass	CO_2 Fossil	CO	CH_4	NO_x	N_2O	NMVOC
15671.76	834.18	640.17	38.51	14.00	0.52	76.84

3.4.3 Agriculture and forestry

The agriculture and forestry sectors of Sri Lanka employ both traditional and modern technologies for operations such as land clearing, land preparation, harvesting, etc. Some of the operators depend either on cattle or manual labour. Others use tractors, water pumps and harvesters. Diesel is used for tractors and kerosene for operating water pumps.

This sector comprises of forestry, major export crops, such as tea, rubber and coconut; minor export crops such as pepper, cloves, cinnamon etc. and; products of domestic agricultural use such as paddy, sugar, maize and other minor food crops. Of the above crops, paddy is mainly responsible for the use of fuel in crop production compared with other crops. Fuel combustion activities in forestry have been more or less stagnant and insignificant during the years under consideration. The average growth rate in the paddy and other sectors in the years 1993 and 1994 has been 10%, 4% and 5% respectively. The fuel consumption for this sector for the year 1992 was available. Due to unavailability of fuel consumption data for the 1994, the fuel consumption values presented were estimated using the above growth figures. The fuel consumption figures estimated are given in Table 3.29.

TABLE 3.29: FUEL CONSUMPTION BY THE AGRICULTURAL/FORESTRY SECTOR

FUEL TYPE	APPLIANCE	CONSUMPTION (kt)		
		1992	1993	1994
Kerosene	Pumps	18.03	19.83	20.62
Diesel	Tractors	20.01	22.0	22,89

EMISSION FACTORS

Emission factors applicable to the sector are shown in Table 3.30.

TABLE 3.30: EMISSION FACTORS FOR NON CO_2 GASES FOR AGRICULTURAL/FORESTRY SECTOR

	EMISSION FACTOR (kg/TJ)				
	CH_4	N_2O	NO_x	CO	NMVOC
Kerosene (pump)	4	0.6	100	370	160
Diesel (tractor)	4	0.6	1200	370	160

3.4.4 Fisheries

As in the case of the agricultural sector, the fisheries sector also employs both traditional and modern methods for fishing. Traditional boats include Oru, which are outrigger canoes made out of hollowed log and provided with mast and boom for supporting a sail, and Vallams, Teppams and Kattamarans which are constructed either as a dugout canoe from a log or from planks on a frame. These have an outrigger and a sail for use when fishing outside shallow waters. Mechanical craft used include fibreglass reinforced plastic (FRP) boats, which are either open decked or close decked made out of FRP material and powered by kerosene. The traditional craft and the small, mechanized boats are day boats with no facilities for storing fish or carrying ice for storage purposes. Eleven ton multi-day boats were introduced in the early eighties and several hundred of these boats are presently in use in the off shore fisheries activities.

Details pertaining to the fishing fleet and the fuel usage are given in Tables 3.31 and 3.32 respectively.

TABLE 3.31: FISHING FLEET IN SRI LANKA - 1994

TYPE OF BOAT	1994
1. Multi Day inboard engines Craft over 32 ft	1543
2. Day inboard engines 28-32 ft	1272
SUB TOTAL (Inboard)	**2815**
3. Traditional Motorized with outboard engine	1016
4. 17.5-32 ft FRP boats fitted with Out Board Motors	8843
5. Traditional Non Motorized fishing fleet	12462
TOTAL	**25136**

TABLE 3.32: FUEL CONSUMPTION BY FISHING BOATS- 1994

TYPE OF BOAT	AVERAGE FUEL CONSUMPTION / YEAR / UNIT (kg)	ANNUAL CONSUMPTION (TONNES)
1. Multi Day inboard engines 2. Craft over 32 ft (DIESEL)	25380	39161.34
3. Day inboard engines 4. 28-32 ft (DIESEL)	3086.2	3925.646
5. Traditional Motorized with outboard engine (KEROSENE)	2356.5	2394.2
6. 17.5-32 ft FRP boats fitted with Out Board Motors + Traditional Out Board Engines (KEOSENE)	2356.5	20838.57
TOTAL: Kerosene **Diesel**		**23232.7** **43087**

EMISSION FACTORS

Emission factors applicable to the fisheries sector are shown in Table 3.33.

TABLE 3.33: EMISSION FACTORS FOR NON CO_2 GASES FOR FISHERIES SECTOR

	EMISSION FACTOR (kg / TJ)				
	CH_4	N_2O	NO_x	CO	NMVOC
Kerosene (boat)	5	2	1600	500	110
Diesel (boat)	5	2	1600	500	110

As can be seen from the above discussion, the combined Agriculture, Forestry and Fisheries sectors make use of kerosene for both stationary and mobile activities and diesel for mobile activities only. Hence for the combined activity, the average emission factors depending on the activity in each sector for a given year could be evaluated. The average emission factors for non-CO2 gases are given in Table 3.34 below.

TABLE 3.34: EMISSION FACTORS FOR NON CO_2 GASES FOR COMBINED AGRICULTURE, FORESTRY AND FISHERIES SECTORS - 1994

OIL	EMISSION FACTOR (kg / TJ)				
	CH_4	N_2O	NO_x	CO	NMVOC
Kerosene and Diesel *Boats and Tractors*					
MOBILE	4.770	1.687	1508.1	470.13	121.49
Kerosene *Pumps*					
STATIC (all years)	4	0.6	1200	370	160

Emissions from the sector were estimated using the IPCC procedure. The results are shown in Table 3.35.

TABLE 3.35: OVERALL EMISSIONS FROM AGRICULTURE, FORESTRY AND FISHERIES SECTORS - 1994

Emissions (Gg)						
CO_2 From mobile sources	CO_2 From static sources	CO	CH_4	NO_x	N_2O	NMVOC
283.59	67.66	2.17	0.024	5.97	0.0106	0.62

3.4.5 Fugitive Emissions

In addition to emission from the above four main groups there are fugitive emissions associated with fuels. These are intentional or unintentional releases of gases from anthropogenic activities. Such emissions may arise with the production, processing, transmission and storage of coal, oil and natural gas. Methane (CH_4), carbon dioxide (CO_2) and non methane volatile organic compounds (NMVOC) are some of the emissions reported to be fugitive.

Crude oil is imported to the country by the Ceylon Petroleum Corporation and refined at the Sapugaskanda refinery. Fugitive emissions due to the handling of crude oil are considered in order to account for this sector. Amount of Crude oil processed in the Refinery in the year 1994 was 1944.55kt.

The amount of crude oil amount shown above is generally unloaded via pipelines and transported to the refinery for processing. The refined products are thereafter stored in Storage tanks with secondary seals. There are no catalytic cracking or sulphur recovery plants operated during the refining process.

EMISSION FACTORS

Emission factors used for the estimation of emissions from fugitive activities in Sri Lanka are presented in Table 3.36.

TABLE 3.36: EMISSION FACTORS

ACTIVITY	EMISSION FACTOR	COMMENT
Oil Transport	745 kg CH4/PJ oil tankered	Only half of this value was taken as loading of crude oil to tankers does not take place in Sri Lanka and hence only half of the operation takes place.
Oil Refining	750 kg CH4/PJ oil refined	
	0.09 kg CO/t oil refined	
	0.06 kg NO_x/t oil refined	
	0.62 kg NMVOC/t oil refined	
	0.93 kg SO_2/t oil refined	
Oil Storage	140 kg CH_4 /PJ refined oil	
Oil Storage: Secondary Seals	0.2 kg NMVOC/t crude oil throughput	

TABLE 3.37: EMISSIONS DUE TO FUGITIVE ACTIVITIES - 1994

Emissions (Gg)							
Oil Transport	Oil Refining					Oil Storage	
CH_4	CO	CH_4	NO_x	NMVOC	SO_2	NMVOC	CH_4
0.03	0.18	0.06	0.12	1.21	1.81	0.39	0.01

3.5 INDUSTRIAL PROCESSES

MINERAL PRODUCTS

CEMENT PRODUCTION

Emissions of carbon dioxide during the production of cement is one of the most important sources of carbon dioxide emissions from the industrial sector in Sri Lanka.

Raw materials used for cement production are limestone and clay. The raw mixture is initially finely ground and fed into a kiln in order to obtain clinker. The clinker is thereafter ground with approximately 4%-5% gypsum in order to obtain finished cement. High temperatures in cement kilns chemically change raw material lime into cement clinker and thereby emit carbon dioxide.

CO_2 emissions from cement production are obtained by using of an emission factor expressed in tonnes of CO_2 released per tonne of clinker produced. The recommended emission factor for clinker is 0.5071 tonnes of CO_2 per tonne of clinker produced.

There are five main cement factories in Sri Lanka. They are, Puttalam Cement Factory, Ruhunu Cement Factory, Kankasanturai Cement Factory, Mahaweli Marine Cement Co. Ltd, and the Tokyo Cement Co (Lanka) Ltd.

The Puttalam cement factory is the only clinker producer in Sri Lanka, making its own clinker using limestone to produce cement. The other factories such as Ruhunu Cement, use imported clinker. The other cement factories such as Tokyo Cement Co. (Lanka) Ltd and Mahaweli Marine Cement Co. Ltd do not manufacture cement but repack imported cement for the local market. The Kankasanturai Cement factory has been closed after June 1990 due to civil disturbances in the northern province. Since direct cement imports and production of cement using imported clinker do not contribute to the national inventory of greenhouse gas emissions, the production of clinker from the Puttalam Cement factory is considered here for the greenhouse gas estimates. The clinker production data used in this estimation are given in Table 3.38.

TABLE 3.38: CLINKER PRODUCTION DATA OF THE PUTTALAM CEMENT FACTORY- 1994

ITEM	
Clinker Imports (kt)	52.5
Total annual Production of cement from Clinker (kt)	478
Total Clinker used for cement (kt)	457.4
Actual Clinker Produced locally (kt)	404.9
Total annual Production of cement from locally produced Clinker (kt)*	423.12

* Cement is assumed to contain gypsum equivalent to 4.5% by weight of Clinker

Clinker is generally mixed with gypsum and the average clinker/lime percentage is estimated to be 64.6%. Based on this figure, an average emission factor of 0.5071 t CO_2/tonne of clinker is recommended. It is also recommended that SO2 emissions from the clay raw material be included in the estimates. S content of lime in Sri Lanka is not readily available. Hence, the recommended default value of 0.3 kg of SO2/tone of cement produce is taken for the estimates.

LIME PRODUCTION

Four main types of limestones are reported to be available in Sri Lanka. These are

Miocene Limestone	(95% of $CaCO_3$)
Calcite	(100% $CaCO_3$)
Coral and shells	(95% $CaCO_3$)
Dolomite	($CaCO_3$, $MgCO_3$)

Pure limestone deposits are present only at a few locations. The magnesium varieties are reported to be more abundant . Miocene limestone is confined to the north and north-western regions of Sri Lanka and is found along the coastal belt from Puttalam to Jaffna Peninsula. Miocene limestone is exploited by the Puttalam cement factory and emissions from its use have been already considered in the previous section. CO_2 is a by-product of quick lime production.

The amount of lime produced is generally targeted to the demand. Therefore, the total amount of lime consumed per year could be approximated to the total annual production. The usage of dolomite for the production of lime stood at 4.546kt in 1994.

The average composition of dolomite in Sri Lanka is reported to be 30.4%CaO, 21.7% MgO and 47.9% CO_2. Based on this composition, the amount of lime produced could be estimated as 0.521 t lime/t of dolomite used and an emission factor of 0.919 t CO_2/ t of lime produced. The total production of lime for the construction industry in Sri Lanka amounted to 2.368kt in 1994.

LIMESTONE AND DOLOMITE USE

Industries such as iron and steel, glass manufacture; agriculture; construction and environmental pollution control make use of lime and dolomite in their processes. Use of dolomite and calcite in the ceramic, glass and other industries amounted to 2.022kt and 3.938kt respectively in 1994.

The emission factors recommended are 440fkg CO2/tonne of limestone used and 477f kg CO2/tonne of dolomite used (f -fractional purity of limestone or dolomite i.e. t CaCO3/t raw material). Default value of f=1 has been used because of uncertainty of the purity of calcite and dolomite produced.

SODA ASH PRODUCTION AND USE

Soda Ash is not produced in Sri Lanka; the requirements are imported. The quantity of soda ash used in Sri Lanka in 1994 was 3744.66t.

The default emission factor for the emission of CO_2 is 415 kg CO2 /t of Na2CO3 used.

ASPHALT ROOFING

Asphalt roofing is produced in Sri Lanka by a privately owned factory at Puttalam, based on a process of saturation without spray. The production of roofing was 589077kg in 1994.

The default values for the emission factors for the production of asphalt roofing used in the estimation of emissions are given in Table 3.39.

TABLE 3.39: EMISSION FACTORS FOR ASPHALT ROOFING PRODUCTION

Emission factors for Asphalt Roofing Production (kg/tonne of Product)		
	Emission factor (saturation with spray)	Emission factor (saturation without spray)
NMVOC	0.13-0.16	0.046-0.049
CO	NAV	0.0095
NAV= Not available		

ROAD PAVING WITH ASPHALT

The default factor of 100kg asphalt/m^2 road surface was used in order to estimate the asphalt used. The total paving area and corresponding asphalt used in 1994 amounted to 339.2x10^3 m^2 and 33.92kt respectively.

The default values for the emission factors for the production of asphalt and use of asphalt are given in Table 3.40 below.

TABLE 3.40: EMISSION FACTORS FOR ASPHALT USE ON ROADS

Emission factors for Road Paving with Asphalt (kg/tonne of Asphalt)					
	SO_2	NO_x	CO	CO_2	NMVOC
Asphalt Plant	0.12	0.084	0.035	0	0.023
Road Surface	NAV	NAV	NAV	0	320

GLASS PRODUCTION

Industries which manufacture glass emit NMVOC. The total production of glass in Sri Lanka in 1994 was 15103 tonnes. The emission factor for the NMVOC for the glass industry is 4.5 kg MVOC/t of glass produced.

CHEMICAL INDUSTRY

In the chemical industry, the production of Ammonia, Nitric Acid, Adipic Acid, Urea, Carbides, Caprolactam and Petrochemicals generate GHG emissions during processing. Sri Lanka does not have a facility for producing the above chemicals except for the Ceylon Petroleum Corporation which produces petroleum products. Greenhouse gas emissions from the chemical industry of Sri Lanka are therefore assumed to be insignificant in this analysis.

METAL PRODUCTION

Metal production includes the production of metals like Iron and Steel, Ferroalloys, Aluminium and others. Sri Lanka does not have a strong metal production industry. Only a moderate quantity of steel from intermediate metal is produced at the Ceylon Heavy Industries and Construction Co. Ltd., at Athurugiriya (formerly the Ceylon Steel Corporation) and iron is not produced at this factory. The quantity of steel produced in 1994 was 55.5kt.

Emission factors for the rolling mills used were the default values recommended by the IPCC. These are given in Table 3.41.

TABLE 3.41: EMISSION FACTORS FOR ROLLING MILS

Emission factors for rolling mills (g/tonne of steel produced)				
SO_2	CO_2	NO_x	CO	NMVOC
45	1.6	40	1	30

OTHER PRODUCTION

PULP AND PAPER

The National Paper Co. Ltd., manufactures paper in Sri Lanka at the Valachchanai mills and the Embilipitiya Mills. The total production in 1994 was 37500 tonnes. Emission factors for the process used were the default values given in Table 3.42.

TABLE 3.42: EMISSION FACTORS FOR KRAFT PULPING PROCESS

Emission Factors for Rolling Mills (kg/Tonne of Dried Pulp)			
SO_2	No_x	CO	VOC
7	1.5	5.6	3.7

FOOD AND DRINK

It is known that emissions of NMVOC are produced in some preparations within the food sector. Alcoholic beverages like wines, beer, spirits, production of bread, cakes and biscuits, sugar, animal feeds, meat and poultry, margarine and cooking fats etc., produce NMVOC emissions. Annual production data of these industries in Sri Lanka are presented in Table 3.43.

TABLE 3.43: ANNUAL PRODUCTION OF NMVOC EMITTING FOOD INDUSTRIES IN SRI LANKA

	UNIT	PRODUCTION – 1994
1. Beer	Hl	69620
2 Spirits including Arrack	Hl	510881.3
3. Bread	T	49097
4. Cakes and Biscuits	T	30178.2
5. Meat, Fish and Poultry	Kt	306.32
6. Sugar	Kt	73.53
7. Margarine	Kt	8.5
8. Animal Feed	Kt	73.95

Emission factors applicable to the industries are given in Table 3.44.

TABLE 3.44: EMISSION FACTORS FOR NMVOC: FOR FOOD INDUSTRIES IN SRI LANKA

	EMISSION FACTOR	UNIT MEASURED
1. Beer	0.035	kg/hl
2 Spirits including Arrack	15	kg/hl
3. Bread	8	kg/t
4. Cakes and Biscuits	1	kg/t
5. Meat, Fish and Poultry	0.3	kg/t
6. Sugar	10	kg/t
7. Margarine	10	kg/t
8. Animal Feed	1	kg/t

PRODUCTION OF HALOCARBONS AND SULPHUR HEXAFLUORIDE

HFC, PFC and SF_6 are not produced in Sri Lanka. Emissions due to this sector are therefore not considered.

CONSUMPTION OF HALOCARBONS AND SULPHUR HEXAFLUORIDE

Introduction of halocarbons to Sri Lanka commenced in 1997. Hence, there are no records of imports of these chemicals to Sri Lanka for the year 1994. A study of refrigeration and air conditioning manufacturers and repairers has revealed that HFC and PFC chemicals have not been used by them during the years 1993-1995. However, small quantities of SF_6, 6457kg have been imported to Sri Lanka in 1994.

Emissions of SF_6 per year are estimated using the default method recommended by the IPCC. Due to the unavailability of data of the total stocks of Gas Insulated switchgear (GGIS), the total emission per year is assumed to be equal to the consumption.

TABLE 3.45: SUMMARY OF EMISSIONS FROM THE INDUSTRIAL SECTOR PROCESSES - 1994

	Emissions (Gg)					
	SF_6	SO_2	NO_x	CO	CO_2	NMVOC
(A) Mineral Products						
1. Cement Production		0.13			205.32	
2. Lime Production					2.18	
3. Limestone And Dolomite Use					2.70	
4. Soda Ash Use					1.55	
5. Asphalt Roofing				0.00		0.00
6. Road Paving With Asphalt						10.86
7. *Glass*						0.07
(B) Chemical Industry						
(C) Metal Production (Tier 1b) Iron And Steel		0.002	0.002	0.000	88.80	0.002
(D) Other Production						
1. Pulp And Paper		0.26	0.06	0.21		0.14
2. Food And Drink: Beverages						7.67
Food						1.41
(F) Consumption of Sulphur Hexafluoride	0.007					
Total	0.007	0.392	0.062	0.21	300.55	20.02

3.6 LIVESTOCK SECTOR

From ancient times, the livestock industry has been in the hands of the small holder farmers. Ruminant livestock include cattle, buffalo, goat and sheep; non-ruminant livestock includes poultry and swine. In general, the ruminant livestock are freely grazed on natural pastures. Large ruminants, that is cattle and buffalo are native or introduced or they are crosses. Cattle are mainly dairy types and no beef cattle are available. The heard size of cattle and buffalo depend on the agro-ecological zone, the purpose of raring and the extent of grazing lands. Herd size can vary from 1-5 (wet areas) to >100 heads (in dry areas). The distribution of livestock population in different agro-ecological zones is given in table 3.46.

TABLE 3.46: DISTRIBUTION OF LIVESTOCK POPULATION

Species	Agro- ecological Zones					
	Wet Zone		Intermediate Zone		Dry Zone	
	Amount	%	Amount	%	Amount	%
Cattle	271,100	15.91	310,300	18.22	1,122,100	65.87
Buffalo	120,300	15.20	222,400	28.10	448,700	56.70
Sheep	500	2.48	2,100	10.40	17,600	87.12
Swine	115,300	19.65	107,800	18.36	364,300	61.99
Goat	41,700	44.46	19,000	20.26	33,100	35.28
Poultry	4,113,400	43.39	2,093,900	22.08	3,273,500	34.53

Source: Department of Census and Statistics.

Since ruminant livestock is raised under an extensive, free range system, the accumulation of manure is very rare. Therefore, the only enterprises that stockpile or accumulate dung are the poultry and swine industries. The livestock population in 1994 are given in table 3.47.

TABLE 3.47: LIVESTOCK POPULATION - 1994

Species	1,703,500
Buffalo	791,400
Sheep	20,200
Swine	93,800
Goat	587,800
Poultry	948,200

Source: Department of Census and Statistics.

Ruminant livestock produce large quantities of CH_4 through their enteric fermentation in the fore stomach called rumen. Other non-ruminant herbivores produce CH_4 through their hind gut fermentation. In ruminants, for every 100g of carbohydrate fermented in the rumen, 4.5g of CH_4 is produced. In other words 8% of dietary gross energy or 12% of digestible energy is lost as CH_4.

In addition to enteric fermentation in ruminants and hind gut fermentation in non-ruminant, stockpiled or accumulated animal waste (faeces, litter and bedding) when subjected to anaerobic fermentation, undergoes Methonogenesis and produce and release CH_4 to the atmosphere. Therefore, the amount as well as the method of handling of livestock waste will influence the rate and release of CH_4 to the atmosphere.

METHODOLOGY

Calculations were made according to the revised guideline of IPCC (1996) and using the IPCC data processing package. For the values that are not available locally, default values of the IPCC reference manual were used. In using these default values, the most relevant and appropriate values for Sri Lankan conditions were selected considering animal breeds, type of feed, level of management and body weights.

ASSUMPTIONS

1. The cattle and buffalo herd (population) comprise of animals with different age groups and different body weights. Therefore, to avoid variation, all these animals were brought to a standard unit, which is accepted universally. This is called "livestock unit" (LU; Livestock unit = mature cow = LU)
   Mature cow = 1 LU; Mature bull = 1.25 LU; Buffalo = 1 LU; Calves / Heifers = 0.6 LU
2. All of cattle and buffaloes are considered as dairy animals. In Sri Lanka, there is no beef cattle operation or feed lot system. Therefore, all are considered as dairy animals.
3. Almost all the ruminant livestock are managed under a free grazing/browsing system mainly depending on natural roughages. Concentrate feed is used in very insignificant amounts compared to the total dry matter intake.
4. Since all ruminant livestock are managed under a free grazing system, excreta (both urine and dung) are naturally disposed on the field. No stockpiling or accumulation is therefore present.
5. Poultry comprise ducks and chicken and other minor important domesticated avian species. All the members were taken into account if recorded.
6. Where goats and sheep are not specified individually, they are taken together (similar LU values).
7. All ruminant livestock spices are fed on similar diets (mainly roughages). The methane production is therefore similar.
8. The ruminant livestock population in the country is found within the same temperature range, with the exception of cattle in the Nuwara Eliya district (<27^{o}C). Since the latter population is very insignificant, compared to the total cattle population, they were not considered.

The emission factors for enteric fermentation and manure management systems are scanty. No scientific evaluation has been done locally in estimating the emission factors for enteric fermentation and manure management. The recommended default values suited for Sri Lankan conditions are therefore used, and are given in table 3.48.

TABLE 3.48: METHANE EMISSIONS FROM ENTERIC FERMENTATION AND MANURE MANAGEMENT

Livestock species	Emission factors (kg/head/yr)	
	Enteric Fermentation	Manure Management
Dairy Cattle	56	27
Non dairy cattle	44	2
Buffaloes	55	3
Sheep	5	0.21
Goat	5	0.22
Swine	1	7
Poultry	Not emitted	0.023

Source : IPCC Guideline (1996).

The composition of the manure depends on the livestock species, because different species consume different feeds. The capacity to produce methane is determined by the C:N ratio, anerobicity and method of storage. Faeces of ruminant livestock has a high C:N ratio than non-ruminant faeces. The methane producing capacity, and animal excreta of different livestock species are given in table 3.49.

TABLE 3.49: METHANE PRODUCING CAPACITY (Bo) OF THE MANURE OF LIVESTOCK SPECIES

Livestock species	Capacity (m3/kg, VS)
Dairy Cattle	0.13
Non dairy cattle	0.10
Buffalo	0.10
Swine	0.29

Source : IPCC Guideline (1996); VS - Volatile solid.

Nitrous oxide (N_2O) is another important GHG generated in the livestock industry and released in to the atmosphere. N_2O is produced mainly from animal excreta including dung and urine. The rate of production depends on the N content in the excreta. Once the feed is ingested, the undigested nitrogen as faecal N and metabolized N as urinary nitrogen are excreted out of the body. Therefore, the level of N in the excreta depends on the N states of the feed and rate of digestion.

When these N rich excreta undergoes aerobic microbial decomposition, N is converted N_2O and escape in to the atmosphere. Since diet and level of N in the diets of different species of livestock differ, the N excretion (Nex) also varies. Table 3.50 indicates the N excretion by different livestock species.

TABLE 3.50: NITROGEN EXCRETION (Nex) BY DIFFERENT LIVESTOCK SPECIES

Livestock Species	Nitrogen excretion (Nex) kg/head/yr
Dairy cattle / Buffalo	60
Sheep	12
Goat	12
Poultry	0.6
Swine	16

Source: IPCC Guideline (1996).

In this analysis, all ruminant livestock are considered to be free ranging and that voided excreta are readily dispersed on the grazing fields. Therefore, no stock piling or accumulation is considered possible. However, swine and poultry are raised under intensive systems of management under confined housing. Therefore, only these species are considered under dry lot or solid storage waste management systems. However, since emission factors for methane, and N_2O are not available. Hence, the default emission factors recommended by IPCC were used. These default values are given in table 3.51.

TABLE 3.51: EMISSION FACTORS OF N_2O FROM DIFFERENT ANIMAL WASTES MANAGEMENT SYSTEMS (AWMS)

AMWS	Emission Factors (EFS) (kg N_2O -N / kgN)
Solid storage and dry lot	0.02
Pasture range and paddock	0.02

Source: IPCC Guideline (1996).

TABLE 3.52: EMISSIONS FROM LIVESTOCK SECTOR – 1994

Methane (Gg)		Nitrogen Dioxide (Gg)
Enteric Fermentation	Manure Management	
135.81	46.71	0.14

3.7 AGRICULTURE SECTOR

Rice is the major food crop grown in Sri Lanka, cultivation being confined to two major seasons namely Yala and Maha. During 1994 655,272 ha were cultivated under irrigation and 229,924 ha under rain-fed conditions.

In addition to rice, other short-term food crops such as pulses, oil crops, fibre crops, other cereals, yams, vegetable etc. are also grown annually. These include The extent under these crops are not extensive as rice and mostly location specific. However, they all are grown under aerobic soil conditions. Crop residues are produced in large quantities in this sector but these residues are not fully utilized as manure or animal feed. Usually they are allowed to decompose or burnt on site. The total extent of these crops cultivated during 1994 is given in table 3.53.

TABLE 3.53: HARVESTED EXTENT (ha) OF FIELD CROPS - 1994

Type of crops	Area
Other cereals	44,506
Pulses	50,546
Oil crops	19,293
Yams	49,592
Spices	44,854
Total	**208,791**

Source: Census and Statistics Department.

The other major agricultural crop sector is the plantation sector. This comprises of perennials such as tea, rubber, coconut and other export agriculture crops. These crops with other field crops demand large quantities of commercial fertilisers. The major crop residues, their N:C ratio, carbon fractions are given in table 3.54.

In addition to commercial N fertilisers, animal excreta also contribute to total N_2O pool from field disposals. The N excretion rate and fraction of N per AWMS is given in table 3.55.

TABLE 3.54: DRY MATTER FRACTION, CARBON CONTENT AND N/C RATIO OF SIXTEEN CROP RESIDUES

Residue	Fraction of Dry Matter	Carbon Fraction of Residue	N/C ratio
Rice	0.83	0.4144	0.014
Maize	0.4	0.47.9	0.02
Kurakkan	0.5	0.45	0.016
Sorghum	0.5	0.5	0.02
Pea	0.5	0.5	0.02
Soyabean	0.5	0.4	0.05
Potatoes	0.4	0.4226	0.02
Ground nut	0.7	0.4	0.02
Cowpea	0.5	0.4	0.02
Green gram	0.5	0.4	0.02
Black gram	0.5	0.4	0.02
Gingerly	0.5	0.4	0.02
Manioc	0.5	0.45	0.02
Chillies	0.5	0.45	0.02
Big Onion	0.5	0.4	0.02

TABLE 3.55: NITROGEN EXCRETION, FRACTION OF MANURE NITROGEN PER AWMS

Livestock type	N_2 Excretion Nex (kg/head/yr)	Fraction of Manure N per AWMS (%) (Fraction)
Non-dairy	60	29
Dairy	60	24
Poultry	0.6	0
Sheep	12	83
Swine	m	53

Other than N_2O many other gases such as CH_4, CO, NOx are generated during field burning of crop residues. As a practice many crop residues specially rice straw is burnt on site. This results in generation of GHGs. Emission and conversion ratio of GHGs due to field burning is given in table 3.56.

TABLE 3.56: EMISSIONS RATIO OF CH_4, CO, N_2O, AND NO_x FROM THE RESIDUE BURNING

	Emission Ratio	Conversion Ratio
CH_4	0.005	16/12
CO	0.6	28/12
N_2O	0.007	44/28
NO_x	0.121	46/14

METHODOLOGY

The GHG emissions for the year 1994 were calculated by using secondary data from relevant sources. The collected information was sorted, tabulated and modified to suit IPCC (1996) software package for analysis.

ASSUMPTIONS

1. Rice was the only crop cultivated under submerged conditions.
2. Yala and Maha were taken together in every year. Even though Maha season extends to the following year, it was included in the current year for calculations.
3. Extraction rates of crop residues were taken from international references.
4. Default values for emissions are not available locally; therefore, values from Indian Sub-continent were used.
5. Rice cultivation is done under single aeration method.

TABLE 3.57: EXTENT RICE CULTIVATED AND METHANE EMITTED - 1994

Extent cultivated (ha)	885196
Methane produced (Gg)	41.96

Cultivation of other field crops does not produce CH_4 since they are grown under aerobic condition with plenty of soil aeration. However, they produce large quantities of crop residues, which are often, under utilised, except for a small quantity of rice straw. Therefore, more than two-thirds of these crop residues are burnt on the field. The burning generates many GHG's (table 3.58). Of all the gases released from the field burning of crop residues, the major gas is CO. The production of CH_4 and CO_2 was only 9% of the total gas production, production of N_2O were very negligible.

In addition to emission from field burning, direct emission from the use of commercial N fertilisers (F_{SN}), application of animal wastes as manure (F_{AW}) and through N fixing crops (F_{BN}) also play a vital role in contributing N_2O to the atmosphere. These sources are illustrated in table 3.59.

TABLE 3.58: TOTAL BIOMASS BURNT, C, N AND GHG GASES RELEASED FROM FIELD BURNING OF CROP RESIDUES

Total dry matter biomass burnt (Gg)	199.98
Total Carbon released (Gg)	501.94
Total Nitrogen released (Gg)	7.52
Total gases released from field burning (Gg)	
CH_4	3.35
CO	70.27
N_2O	0.08
NO_x	2.99

TABLE 3.59: DIRECT EMISSION OF N_2O FROM AGRICULTURAL FIELDS

	Direct emission Gg N2O - N / yr - 1994
Synthetic Fertiliser (FSN)	1.27
Animal Waste (FAW)	0.04
N – Fixing Crops (FBN)	0.03
Crop Residues (FCR)	0.50
Total	**1.84**

In addition to these direct emissions, N_2O is also released to atmosphere through histosols, pasture and range paddocks (AWMS). Also indirect emission from atmosphere depositions of NH_3 and NO_x. These emissions are given in table 3.60.

TABLE 3.60: EMISSION N_2O FROM HISTOSOLS, GRAZING ANIMALS, LEACHING

	N_2O Emission (Gg)
Direct from Histosols	21.32
Grazing animals / Paddocks / Range	0.13
Leaching	1.57
Total	**23.02**

Overall generation of CH_4, CO, N_2O and NO_x from agriculture sector is given in table 3.61.

TABLE 3.61: TOTAL EMISSIONS FROM THE AGRICULTURAL SECTOR - 1994

Source	**Emission (Gg)**
CH_4	
Rice Cultivation	20.98
Field burning of crop residues	3.35
Total CH_4	**24.33**
CO	
Field burning of crop residues	70.27
N_2O	
Field burning of crop residues	0.08
Direct emissions	1.84
Indirect emissions	23.02
Total N2O	**24.94**
NO_x	
Field burning of crop residues	2.99

3.8 FORESTRY AND LAND USE SECTOR

The forest cover in Sri Lanka has been gradually depleting and presently stands at 1.58 million hectares or 24% of the total land area. Depletion of the forest cover contributes to the elevation of carbon dioxide concentration in the atmosphere.

METHODOLOGY

The forest cover and deforestation and reforestation data were obtained from the Forest Department records and reports. Data on logging and rate of extractions were obtained from the State Timber Corporation. Data on land use changes are scanty, but some data were obtained from the Land Use Division of the Department of Agriculture, the Upper Mahaweli Watershed Management Division, the Irrigation Department, the Mahaweli Authority and the Ministry of Environment and Forestry.

The changes in forest and woody biomass stocks were highly variable. The rate or the actual extent of change in the forest cover and conversion of land use systems are not properly documented and therefore records are not freely available. Hence, in this study the woody biomass sticks are only approximations. Change in forest and woody biomass stocks are presented in table 3.62.

TABLE 3.62: TOTAL BIOMASS CONSUMPTION FROM STOCKS AND TOTAL CARBON UPTAKE INCREASE IN 1994

Total Carbon uptake increase (kt C)	615.55
Total biomass consumption from stocks (kt DM)	9,289.10

Since, undisturbed forests maintain carbon dioxide equilibrium, any changes in the forest system due to deforestation or logging can severely affect the equilibrium. This will lead to a change in the net carbon uptake or release. Table 3.63 represents the annual carbon release/uptake and emission/removal.

TABLE 3.63: CARBON RELEASE/UPTAKE AND CO_2 EMISSION AND REMOVAL – 1994

Annual Carbon release (kt)	4,644,55
Net Annual Carbon uptake (+)/release (-) (kt)	-4,029.01
CO_2 Emission (-)/removal (+) (Gg CO_2)	-14,773.00

The information on biomass burnt onsite and offsite is not available. These values therefore were not given much consideration. This information however is very crucial for CO_2 release.

Information on above ground re-growth for the past few decades is not available. As a result, the annual uptake of C or CO_2 by the above ground biomass cannot be estimated. During logging and deforestation, a part of the biomass such as twigs, small branches is burnt on site; another part is allowed to decompose. This however takes a long period since the natural decomposition is a slow process and depends on many factors. Natural decomposition duration has been estimated as ten years. Annual C and CO_2 released due to the burning of forest biomass and natural decomposition is given in Table 3.64

TABLE 3.64: ANNUAL CARBON AND CO_2 RELEASED DUE TO BURNING AND DECAYING ABOVE GROUND BIOMASS -1994

Immediate release from burning (kt C)	None
Delayed emission from decay (average over 10 years) (kt C)	1,022.13
Total annual Carbon release (kt C)	***1,022.13***
Total Annual CO_2 (Gg)	**3,747.80**

In addition to the forest system, CO_2 is also emitted from agricultural impacted soils due to natural oxidation of soil organic C. CO_2 is also released from limestone and dolomite used as a liming material. These figures are represented in tables 3.65 and 3.66.

TABLE 3.65: TOTAL CARBON EMISSION FROM AGRICULTURALLY IMPACTED SOILS (Mg/yr) - 1994

Total net change of soil carbon in mineral soils (Mg/yr)	-9.28
Total net carbon loss from organic soils (Mg/yr)	2,087,910
Carbon emission from liming (Mg/yr)	915

TABLE 3.66: TOTAL ANNUAL CO_2 EMISSION FROM AGRICULTURALLY IMPACTED SOILS (Gg) - 1994

Total net change in soil CO_2 in mineral soils (Gg)	1,701.70
Total net CO_2 Loss from organic soils (Gg)	7,655.67
CO_2 from liming (Gg)	3.36
Total (Gg)	**9,360.73**

Total net CO_2 emissions in 1994 from forest and other land use systems are given in table 3.67.

TABLE 3.67: TOTAL CO_2 EMISSIONS IN 1995 FROM FOREST AND OTHER LAND USE SYSTEMS

Source	Emission of CO_2 (Gg)
Change of forest and woody biomass	14773.02
Forest and grassland conversion	3774.8
Forest soils	9360.73
Total	**27881.55**

3.9 WASTE

Waste includes Agricultural wastes (mainly crop residues), Livestock waste (farming manure), Industrial waste and Domestic waste. The quantity and type of agricultural and livestock waste has been discussed under the sections on Livestock and Agriculture. This section will focus on the domestic solid waste and wastes from agro-based industries. Domestic waste also known as municipal waste, includes any waste generated domestically. These wastes are translocated from their point of origin.

The actual solid waste production cannot be determined since no proper records have been maintained. What is available are estimates based on sample surveys. The estimation of municipal solid waste (MSW) expressed as kg MSW/person/day, has been done by the Municipal Council of Colombo using the number of garbage truck loads transported and the population of the collected area.

Based on the estimates made the daily MSW generation was 0.5 kg per person. In this MSW 0.77% of the Carbon is degradable (IPCC, 1996). Of the total MSW produced, 60% is used for land filling.

TABLE 3.68: MUNICIPAL SOLID WASTE GENERATION RATES, LAND FILL AND DEGRADABLE ORGANIC CARBON FRACTION

	IPCC [1]	Urban
MSW Generation (kg/Capita/day)	0.5	0.5 [2]
Land fill Fraction (%)	0.6	-
Degradable Organic Carbon (%)	0.77	0.78 [3]

Source: 1. IPCC Guideline (1996) 2. Municipal Council Colombo 3. Dr. Basnayake.

Certain agro-based industrial wastes require treatment before they are released to the environment. Their Chemical Oxygen Demand (COD) is very high and therefore, pre-treatment can reduce many environmental hazards. Some estimated volumes of waste water and their COD are given in table 3.69.

TABLE 3.69: VOLUME AND COD FOR ANAEROBIC WASTE WATER TREATMENTS

Type of Industry	Waste water out flower (m^3 /ton of product)	Degradable organic component (kg COD / m^3 waste water)[1]
Fertilizer	5**	0.25[1]
Canaries	26*	0.25[1]
Beer	5*	17 *
Meat Packing	18*	0.25[1]
Dairy Products	2.8*	1.5*
Sugar	15**	98*
Soft Drinks	2.5**	0.25[1]
Paper	44**	3*
Petroleum Refining	3**	0.35*
Rubber	22.7	0.25[1]

Source: 1. National GHG Inventory Australia (1988- 1990)
*IPCC Guidelines (1996) ** Prof. N. Fernando.

The total annual MSW disposal and net CH_4 emissions are presented in table 3.70.

TABLE 3.70: TOTAL ANNUAL MSW DISPOSAL AND NET CH_4 EMISSION - 1994

MSW disposed	1,956.22
Gross Methane Generation	469.96
Recovered Methane	0.0
Net Annual Emission	**469.96**

The methane emission from domestic water is given in table 3.71.

TABLE 3.71: ESTIMATION OF METHANE EMISSION FROM DOMESTIC WASTE WATER -1994

Total Organic Product (kg BOD/ yr)	62,232,600
Total Methane Emission (kg)	592,805.63
Net Methane Emission (Gg)	0.59

Table 3.72 represents the CH_4 emission from treatment of industrial (commercial) waste water.

TABLE 3.72: ESTIMATION OF METHANE EMISSIONS FROM COMMERCIAL WASTE WATER TREATMENT

Total Organic Product (kg BOD / yr)	292,058,514
Total CH_4 Emission (kg)	131,426,33
Net CH_4 Emission (Gg)	13.14

The Overall breakdown of GHG emissions in Sri Lanka in 1994 is given in Table 3.73. It can be that the single most important source of CO_2 emissions in the country is the Land Use and Forestry Sector. This is followed by the Energy Sector. In terms of CH_4 emissions, the Energy Sector is the single largest contributor and is followed by the Agricultural Sector. It is therefore important that greater attention should be focused on GHG mitigation measures and adaptation responses within these sectors.

TABLE 3.73: BREAKDOWN OF OVERALL GHG EMISSIONS IN SRI LANKA – 1994

Green House Gas Source and Sink Categories	CO_2 (Gg)	CH_4 (Gg)	N_2O (Gg)
Total (Net) National Emission (Gg per year)	***33630.22***	***1098.375***	***162.8657***
1. All Energy	**5447.668**	**927.785**	**156.0257**
Fuel Combustion			
Energy and Transformation Industries	482.358	0.021	0.0041
Industry - Contribution from Fossil fuel	801.08	1.92	0.07
Transport – National navigation, Rail and road transport and Domestic aviation	2946.31	263	116.12
International Bunkers (Not included in national total)	1540.82	74	21.6
Commercial and Institutional	32.49	21.57	1.29
Residential- Contribution from Fossil fuel	834.18	640.17	38.51
Other – Agriculture, Forestry and Fisheries Sectors	351.25	0.024	0.0106
Biomass burned for energy		0.98	0.021
Fugitive emissions			
Oil refining, Transport and storage		0.1	
Coal Mining		Not Applicable	
2. Industrial Processes	**300.55**		
3. Agriculture		**156.86**	**3.42**
Enteric Fermentation		135.86	
Rice cultivation		21	
Savanna Burning		Not available	
Others – Manure management		47	3.34
Field burning of crops			0.08
4. Land Use Change And Forestry	**27882**		
Changes in forest and other woody biomass	14773		
Forest and grassland conversion	3748		
Abandonment of Managed lands	Not Available		
Forest Soils	9361		
5. Other Sources		**13.73**	
Domestic Waste Water Management		0.59	
Commercial Waste Water Management		13.14	

CHAPTER 4

IMPACTS AND VULNERABILITY

INTRODUCTION

Global warming is expected to lead to a rise in sea level, higher temperatures, more frequent and prolonged droughts, high intensity rainfalls and increased thunder activity. These anticipated changes represent a significant threat to the coastal areas, the different sectors of the national economy and human health. The major impacts that can be expected from these changes are outlined below.

4.1 IMPACTS OF RISE IN SEA LEVEL

As indicated in the IPCC Second Assessment Report (IPCC 1996, WG 1, Section 7.2):

- Global mean sea level has risen 10-25 cm over the last 100 years.
- There has been no detectable acceleration of sea level rise during this century.

Studies of historical rates of relative sea level rise in the South Asia Seas region, reported by Gable and Aubrey (1990), indicate an average annual relative sea level rise of 0.67 mm/year. In addition, during the past half-century or so, relative sea level changes in the region have ranged from a fall (i.e., land emergence) of 1.33 mm/year to a rise (i.e., land submergence) of 2.27 mm/year (IPCC 1998).

4.1.1 The Coastal Zone – Socio Economic and Environmental Perspective

The coastal zone can be defined based on either one or a combination of geo physical, eco-system and human development considerations. There are 67 coastal administrative units in the country and if the coastal zone is defined landward by these administrative units and seawards by the narrow continental shelf, the coastal zone will include:

a) Approximately 24% of the land area and 32% of the population
b) 65% of the urbanized land area
c) Principal road and rail transport infrastructure
d) Principal commercial ports, fishery harbours and anchorages
e) 65% of the industrial output
f) 80% of tourism related infrastructure with the majority being located in the western and south-western coastal regions and most of them within close proximity to the shoreline
g) 80% of fish production
h) A significant extent of agricultural land
i) Substantial reserves of valuable minerals
j) Some of the richest areas of biodiversity including coral reefs, seagrass beds, mangroves, lagoons, estuaries, wetlands and sanctuaries covering an extent over 160,000 hectares
k) Sizeable areas of usable land which remain undeveloped
l) Areas subject to extensive water pollution associated with industrial pollution sources, domestic waste water and sewage disposal and garbage disposal
m) Many areas of cultural, historical and religious significance and scenic beauty

In Sri Lanka, the Coast Conservation Act has defined the coastal zone on geo-physical considerations using linear dimensions (Fig. 4.1). This narrow and geographically defined coastal zone does not recognize the interconnections within coastal eco-systems, its resources and the human interactions. This limitation in the definition of the coastal zone could become a critical constraint when implementing action plans to respond to sea level rise.

4.1.2 Analyzing the Impacts of Sea Level Rise

Global warming generates a chain of impacts of which sea level rise is one. When assessing the impacts of global sea level rise on coastal regions, it is important to identify and understand the connectivity of these inter-related issues, all emerging as a result of global warming. It is also important to recognize the global, regional and local scales of impacts as it would be the resultant impacts that would finally affect a given environment.

Since the comprehensive analysis of impacts of global warming is a complex exercise, attention is usually focussed on predominant parameters. For example, the impacts of sea level rise would be analyzed while giving due consideration to the influence of the impacts of other related parameters.

Sea level rise on its own would,

a) raise the mean sea level, leading to inundation of low lying coastal areas, shoreline retreat, intrusion of salinity and impacts on coastal habitats.
b) increase wave height (1) disturbing equilibrium beaches and making them more prone to erosion; (2) interfering with existing longshore sediment transport rates and distribution.

In addition, the combined effects of an increased mean sea level rise and increased wave heights would result in further impacts such as undermining the stability of coastal structures, and the altering of circulation patterns inside coastal embayments and estuaries. It is also recognized that a change in climate due to global warming would contribute to the reduction in the frequency of occurrence of extreme events thereby adding further complexity to the analysis of overall impacts. There are several impacts due to sea level rise and these impacts were identified, based on a survey conducted among stakeholders. The Ministry of Forestry and Environment had also commissioned a study on the impact on inundation of coastal land arising from sea level rise as part of the US Country Studies Programme (USCSP).

Sri Lanka is one of the few countries which has a fully operative national Coastal Zone Management Plan. The Coast Conservation Department has the full responsibility for the implementation of the plan. It is therefore necessary that the impacts of sea level rise are addressed via the Coastal Zone Management Plan.

4.1.3 Impacts due to Sea Level Rise

INUNDATION

The most direct impact of the rise in sea level is the inundation of areas that have been located just above the water level prior to sea level rise. Low lying coastal settlements and coastal wetlands belong to this category.

(i) *Coastal Settlements*:
Low lying coastal settlements which are highly populated will be directly affected by sea level rise. Impacts on such land should be assessed in the context of a sea level rise of the order of 1 m. In assessing the impacts, due consideration should be given to the combined influence of coastal erosion, flooding and storm drainage.

(ii) *Coastal Wetlands*:
Coastal wetlands are generally found at elevations just above mean sea level and below the highest tide. These wetlands account for a significant proportion of land less than 1m above sea level. With the rise in sea level marshes have generally kept pace by migrating inland and this has helped the prevention of wetland loss. However, if marshes are unable to keep pace with sea level rises, it would lead to a net loss of wetlands. Such losses would be greater if protection of developed areas prevents the inland migration and formation of new wetlands.

COASTAL EROSION

A rise in sea level would increase the present rates of erosion, thereby resulting in the loss of land and increasing the vulnerability of coastal communities. The country has been experiencing an erosion rate of 0.30–0.35 m per year for 45%-55% of its coastline. Any acceleration of erosion due to sea level rise will contribute to an increased loss of land, thereby affecting communities and economic activities.

The lowering or loss of sandbars due to sea level rise would increase the tidal prism of coastal water bodies with larger volumes of water entering during the tidal cycle. This would result in the risk of greater inundation of coastal areas, intrusion of salt water and associated environmental impacts on coastal eco-systems.

Figure 4.1: The Coastal Zone of Sri Lanka as defined by the Coast Conservation Act of 1981.

Estimates of land loss and inundation along the south-west coast of Sri Lanka has been made for the UNCSP (1998). Table 4.1 provides the estimates of land loss on the south-west coasts of Sri Lanka resulting from sea level rise.

TABLE 4.1: LAND LOSS OF THE SW COAST OF SRI LANKA

Sea Level Rise Scenario m	Land Loss km^2
0.30	6.0
1.00	11.5

Table 4.2 provides estimates of inundation around the lowlands adjacent to coastal wetlands of the south-west coast of Sri Lanka.

TABLE 4.2: ESTIMATED AREAS OF INUNDATION AROUND THE LOWLANDS ADJACENT TO MARSHLANDS, LAGOONS AND ESTUARIES OF THE SW COAST OF SRI LANKA

Type of Landforms Adjacent to:			Area Inundated km²	
Marshlands	**Lagoons**	**Estuary**	**Sea Level Rise 0.3 m**	**Sea Level Rise 1.0 m**
	Garanduwa		2.5	4.0
Goyyapana			0	1.0
Galle-Magalle			0.5	2.0
		Gin Ganga*	1.0	3.5
	Ratgama		3.0	5.5
	Hikkaduwa Ganga		2.5	3.25
Akurala			0	4.0
	Madampe		3.5	7.0
	Randombe Lake		1.0	5.0
Ahungalle			0	0.5
	Madu Ganga		1.0	2.5
Induruwa			0	0.5
Bentara Ganga			4.0	6.5
Palliyawatta-Pinwatta			1.5	2.0
Nugape-Bopitiya			4.5	12.0
	Panadura Ganga		6.0	8.0
	Baire Lake		0	1.0
Endigastenna	Elenegoda		3.0	4.5
		Kelani Ganga	2.0	4.5
	Negombo Lagoon		12.0	23.0
Total			41.0	91.25

* Ganga 'means River

FLOODING AND STORM DAMAGE

A rise in sea level could affect flooding and storm damage in coastal areas due to two main reasons. Firstly, higher water levels would provide storm surges with a higher base to build upon. Secondly, higher water levels would decrease natural and artificial drainage; this could also lead to pollution of water bodies. It is also recognized that change in climate due to global warming could contribute to the reduction of the return periods of storms and floods, thus increasing the frequency of extreme events. This will cause disasters in which there will be large losses of lives, property and infrastructure. It must be noted that in contrast to coastal erosion, flooding is a sudden occurrence leaving very little time for preparation for the disaster. The relevance of disaster preparedness should also be given due consideration.

SALT WATER INTRUSION

The increase in inland penetration of salt water is another major impact of sea level rise. A rise in sea level increases the salinity of an estuary by altering the balance between fresh water and salt water hydraulic regimes. The impact would be widely felt during dry weather conditions with greater penetration of salt water.

Sea level rise will therefore cause a number of problems such as the penetration of salt water into cultivated areas, increase of saline water in aquifers, migration of fresh water fish and impacts on other habitats causing a breakage in the food chain of certain species. The entry of saline water to fresh water intakes is also a major problem, which demands engineering interventions. Deepening of estuaries will also increase intrusion and care should be exercised in the planning of development work which includes dredging of estuaries.

(i) *Low Lying Agriculture:*

The impact of salt water intrusion on low lying agriculture should be given due consideration in analyzing the impacts of sea level rise because the implementation of mitigatory measures would require a considerable length of time. The loss and degradation of arable lands will significantly lower the agricultural output. The introduction of salinity tolerant varieties of crops, alternative land use or engineering interventions to maintain the existing regime will require investment funding and also time for planning and implementation. It will be necessary to study the impact on existing irrigation structures widely used in low-lying agricultural schemes.

(ii) *Fresh Water Intakes:*

The prevention of salt water entering fresh water intakes could be achieved by either relocation of the intake or by constructing salt-water barriers. Both options are costly and hence the long-term behaviour of the aquatic system has to be studied prior to planning engineering interventions.

FISHERY INDUSTRY

The fishery industry too would be affected by the impacts of global warming and sea level rise. The level of impact of climate change will vary widely and will also depend on attributes of the species. A temperature rise of about 2°C may have substantial impacts on the distribution, growth and reproduction of fish stocks. Commercially important fish stocks may change their spawning areas and distribution patterns. A given population within a species is adapted to a hydrodynamic environment of specific temporal and spatial characteristics. Therefore, changes in the ocean circulation may lead to the loss of a certain population or the establishment of new ones, particularly at the periphery of the areas of species distribution.

Fishery activities which would be affected include, beach seine fishery, sea ranching in coastal areas, stilt fishery, boat landing sites and fisher folk settlements along the beach. Due attention should also be focused on shrimp fishing under coastal aquaculture.

CORAL REEFS

Rising ocean temperatures will systematically bleach fragile coral reef systems. Ocean temperatures calculated by model projections indicate that thermal tolerances of reef building corals are likely to be exceeded within the next few decades. Increase in ocean temperatures has imposed a severe stress on coral reefs against their tolerance levels. Damage to coral reefs will depend very much on whether coral reef systems can adapt with the rate of change of ocean temperature.

SEA DEFENCE STRUCTURES AND BREAKWATERS

Sea level rise will increase the hydraulic force regime on coast protection and port structures such as revetments, sea walls and breakwaters. These structures will become vulnerable to the impacts of increased erosion as well as the possible increase in the frequency of extreme events such as storms and flooding. To maintain their functions efficiently, such structures will have to be reinforced; this is likely to lead to an increase in the maintenance costs. Reinforcement of the structure may also necessitate an increase in crest levels to withstand the impacts of a higher sea level.

Sea defence and coast protection plans which form key elements of an overall Coastal Zone Management Plan should be based on Policy and Management Options which have taken into consideration the impacts of sea level rise. The IPCC has recognized the adaptive response strategy classified under three categories namely, Retreat, Accommodation and Protection. The selection of the appropriate adaptive strategy for a given area will have to be made after considering the economic, social, environmental, legal and institutional implications of each of the responses. In order to implement the policy options, various management options are considered, provided they are appropriate for the coastal classification. These can be

summarized as, Do nothing, Reinstate, Modify and Create. By defining Policy Options and Management Options for the entire coast, the basis of a strategic approach for achieving long term stability is established.

NEARSHORE INFRASTRUCTURE

(i) Nearshore Land Based Infrastructure

The impacts of sea level rise should be taken into consideration in the planning of maintenance strategies for nearshore land based infrastructure such as highways and rail tracks. Due attention should also be focussed on impacts of sea level rise in the planning of new infrastructure development projects for urban areas located along the coast.

(ii) Nearshore Land Reclamation

In the recent past, several proposals have been made by both the private and the public sectors in development projects, to acquire land via reclamation. The marine highway project from Colombo to southern parts of the city is such an example. While appreciating the need for such projects, the impacts of sea level rise have to be given very high consideration when preparing development proposals.

TOURIST INDUSTRY

Loss of prime land on the shore front has had impacts on the tourist industry, particularly in the case of beach resorts. A rapid rise in the sea level would therefore inevitably increase the cost of coast protection and the generation of beaches at locations where major investments have been made in the tourist industry. In the planning of new resorts, depending on the location, the policy of 'retreat' from the shoreline will have to be given serious considerations as opposed to the spending of excessive amounts on protection.

4.2 IMPACTS OF TEMPERATURE RISE

Analyses of temperature data over a period of more than 100 years have indicated that the air temperature over Sri Lanka has shown an increasing trend since the 1960s. This increase which has been found to be about 0.016 degrees C per year, is likely to increase in the future. A study was done in Sri Lanka in 1997 under the US Country Studies Programme, using the four equilibrium General Circulation Models, viz, CCC, GFDL-R30, UKMO and GISS and one transient model GFDL 01 using monthly mean temperature data over the period 1961-1990 at 19 meteorological stations scattered throughout Sri Lanka. Of these models, only GFDL-R30 and CCC were found to meet two criteria, i.e. how well the model simulates the annual cycle and the approximate magnitude of the model estimate. The study indicated a significant equilibrium increase of between 1.4 and 2.7 deg. C in the mean monthly temperature over Sri Lanka, due to a doubling of Carbon Dioxide.

4.2.1 Power

Rise in atmospheric temperature results in a higher rate of water evaporation from the hydro reservoirs, thus reducing available reserves for power generation. The limited availability of water in the reservoirs will require the addressing of complex water management issues in the areas of power generation and irrigation in multipurpose reservoirs.

The efficiencies of thermal generation plants, other industrial thermal installations and engines used in vehicular transport are directly related to the atmospheric temperature. Therefore, any increase in atmospheric temperature results in lower plant efficiencies thereby affecting overall efficiency of the plants. Also, with increased atmospheric temperature, the efficiencies of cooling equipment drop affecting all forms of industrial, commercial and domestic sector installations involving a cooling component. Further, there will be an increased demand for air-conditioning and ventilation due to high temperature environment. This in turn increases GHG emissions per unit of energy output.

4.2.2 Agriculture

Higher temperatures are expected to cause heat waves leading to increased evapotranspiration, depletion of soil moisture, premature desiccation of crops and extinction of economically important crop types. Increased temperatures will also affect the yields of all crops adversely beyond certain limits.

High daily temperatures even for a few hours duration could cause pollen sterility in crops such as rice. It has been shown that Sri Lanka's rice output will be reduced by 5.91% with a temperature increase of 0.5°C. Increased temperatures are also expected to negatively affect high value crops such as vegetables and potatoes.

With increased temperatures, pests and diseases extend their range, e.g. the flour beetle (Tribolium castaneum, Tribolium confusum) and the brown plant hopper (Nilapavata lugens). Their breeding cycles could become shorter with a consequent increase in the frequency and intensity of outbreaks.

4.2.3 Health

In many work places such as foundries, kilns, textile and tyre industries, thermal stress will impose an additional strain on the thermo-regulatory system of the body, particularly when the work place itself has been poorly designed. For example, excessive sweating results in dehydration and loss of salt from the body. The severity of the impact would depend on the age, state of health/fitness and acclimatization which in turn determines the degree of reduction in work output, efficiency and overall productivity.

When environmental and metabolic heat gain cannot be counteracted by adequate heat loss, there is elevation of heat storage in the body and an increase in the body temperature to a point where circulatory failure can induce heat collapse or heat stroke, which can be fatal. The degree of the impact depends on the person's fitness, clothing worn and the degree of acclimatization. Global warming can only aggravate the above conditions.

Excessive heat can cause disorders such as heat cramps, dehydration, rashes (prickly heat) and heat oedema. Dehydration and electrolyte imbalance over a long term can also predispose to cardio-vascular and renal disorders. The poor, the aged, those involved in outdoor activity, workers in 'hot' working environments and pregnant women in the first trimester will face greater risks.

4.2.4 Transport Infrastructure

The main effects of temperature rise in transport infrastructure are surface flow of asphalt carpet roads, distortion of road markings, bleeding of bitumen in bitumen surfaced roads, making old road surfaces brittle and rail creep due to excessive temperature.

4.3 IMPACTS OF DROUGHTS

If the rainfall received in a given district is less than 75% of the normal rainfall, then that district is said to be affected by a drought. According to a study done in Sri Lanka under a UNDP project, it has been found that droughts are more frequent during the 'yala' (April to August) agricultural season than during the 'maha' (September to March) agricultural season. During the 'yala' season, some of the districts in the Dry Zone of the country experience droughts on an average of once in 3 to 4 years, while the other districts in the Dry Zone and the districts in the Intermediate Zone experience droughts once in 5 to 6 years. During the 'maha' season, many of the districts in the Dry Zone also experience a drought once in 5 to 6 years. Thus areas most vulnerable to droughts are the districts in the Dry and Intermediate Zones. Within these two zones, the districts of Jaffna, Kilinochchi, Batticoloa, Polonnaruwa, Anuradhapura and Kurunegala have the highest probability of experiencing droughts.

Some of the droughts are due to El Nino events, the severe drought during the period January to March 1983 being a case in point. During this period, about 55% of the land area mostly in the Dry and Intermediate zones received less than 10% of the normal rainfall for that period. It is likely that Sri Lanka will experience drought situations even in the future, some of which may be due to El Nino events. The severity of these droughts, however, cannot be predicted.

4.3.1 Ground and Surface Water

Climate change can affect groundwater and its users essentially in two ways. Firstly, it could cause a net depletion of the groundwater recharge volumes. Secondly, groundwater resources located in the coastal plains such as the miocene limestone aquifers in the northern dry zone coastal districts could be subjected to contamination with salinity intrusion.

Since shallow groundwater is slow flowing into surface water bodies, it plays an important role in maintaining the river flows during dry periods and protecting important environmental areas such as wetlands and estuaries. Groundwater release helps to limit saline intrusion in the coastal river mouths, maintain an acceptable surface water quality in the dry zone and contribute to continued existence of coastal aquatic ecosystems. Therefore, droughts arising from climate change will have major impacts on the extent of groundwater release and the resulting increase of salinity.

The expansion of rural and urban population leads to a continuously increasing stress on the quantity and quality of water in shallow groundwater aquifers. The impacts of droughts aggravate the problem by increasing the occurrence of drying up of domestic wells during dry periods and the deterioration of the quality of water in wells.

Agriculture accounts for a little over 20% of GDP and provides nearly 70% of the rural employment. A large proportion of the food grain production is dependent on irrigated agriculture. Irrigation is the major user of fresh water consuming over 90% of the total annual available water. The quantity of water available is strongly linked to the availability of water in the source catchment. The situation could be aggravated as a result of droughts arising from the impacts of long term climate change.

4.3.2 Power

The design of hydropower reservoirs have been carried out using historical data and therefore tend to be heavily under-utilized as a result of possible prolonged droughts resulting from climate change. Moreover, this will reduce the system power generation capacity affecting its ability to ensure a continuous power supply to the country's population. Prolonged droughts will also seriously affect the cooling water supplies to thermal plants forcing a reduction operational capacity and introduction of new designs involving cooling towers making these plants more expensive to install and operate. Further, irrigation capacity of multipurpose reservoirs also drops affecting the agricultural lands.

4.3.3 Forestry

Drought could lead to increased fire hazard in forests. Furthermore, under extreme drought conditions, small plants below 2 years of age could die due to water stress.

4.3.4 Agriculture

A large proportion of the food grains production comes from irrigated agriculture. Paddy is the major food grain grown under irrigation. It is the staple carbohydrate of the Sri Lankans and accounts for 45% and 40% of the per capita calories and proteins respectively in the Sri Lanka diet. Approximately 740,000 hectares are given over to paddy cultivation and of this 44% is irrigated under major irrigation schemes and another 24% under minor irrigation schemes. The bulk of this land is in the Dry and Intermediate Zones. In addition to paddy, a variety of grain legumes and condiments are also grown in the Dry and Intermediate Zones partly under irrigation.

Prolonged and more frequent droughts would reduce the availability of water for irrigation and this in turn could lead to a drop in crop production. It has been predicted that rice cultivation in major irrigation schemes based on trans-basin diversion will be substantially affected in very severe drought years while production in other major and minor irrigation schemes will show significant shortfalls with greater frequency than in the past.

A number of Other Field Crops including coarse grains, grain legumes, oil seeds and condiments are grown on rainfed upland areas in the Dry and Intermediate Zones. It has been predicted that the production of these crops will also be adversely affected with severe fluctuations occurring in annual production.

Prolonged droughts will also affect plantation crops such as tea, rubber and coconut and minor export crops such as cocoa and coffee grown almost exclusively in the Wet and Intermediate Zones. These two zones account for almost 100% of the extent under tea, rubber, cocoa and coffee and 75% of the extent under coconut. Collectively, they account for a little over 700,000 hectares of agricultural land in the two zones. Increase in dryness is expected to cause a reduction in yields of tea, rubber and coconut due to moisture stress. It is also expected to cause a greater annual variation in production of minor export crops.

4.3.5 Health

During drought periods, the scarcity of water would affect human health. The scarcity of water for drinking, washing and cooking will not only affect the hygiene of the population but it will also lead to various diseases. The collection of water in rock pools and river beds will help to breed mosquitoes and this will lead to the spread of vector borne diseases.

The study referred to in section 4.2 on the impact of climate change on the incidence and distribution of malaria, has shown that, with the anticipated climate change, there will be an expansion and shifting of the malaria transmission zone to areas that are hitherto free from malaria. However, the vectorial capacity for malaria in the dry zone has been shown to be small and insignificant. According to the CCC model used in the study, the seasonal pattern of malaria transmission is likely to undergo a change, from the high transmission season which now occurs from November to February being curtailed, and the minor mid-year peak being enhanced with high rates of transmission occurring in September. The study has also shown that spatially, areas bordering the non-endemic wet zone of the country would very likely become highly vulnerable to malaria, with other areas being less vulnerable.

4.3.6 Transport Infrastructure

Droughts could lead to a lack of suitable water for regular road construction and maintenance within reasonable distances, destruction of turf on road embankments and cracking of road pavements with poor sub grade.

4.4 IMPACTS OF HIGH INTENSITY RAINFALL

Cyclones, depressions, mid-tropospheric circulations, monsoonal rains and severe thunderstorms cause high intensity rainfall over Sri Lanka. Although cyclones do not occur frequently (only 13 cyclones have crossed Sri Lanka during the period 1901-1999), the other weather systems are common. High intensity rainfalls can occur at any place in the island during different months. Records indicate that the highest 24-hour rainfalls have occurred mostly during the months of October, November and December (Table 4.3).

TABLE 4.3: HIGHEST 24-HOUR RAINFALLS RECORDED OVER SRI LANKA

Meteorological Station	Zone	Highest 24-hour Rainfall (mm)	Date of occurrence
1. Jaffna	Dry	520.2	17.11.1918
2. Colombo	Wet	493.7	04.06.1992
3. Kankesanthurai	Dry	406.9	17.11.1918
4. Ratnapura	Wet	394.5	15.07.1942
5. Maha Iluppallama	Dry	375.9	15.12.1907
6. Ratmalana	Wet	365.5	04.06.1992
7. Vavuniya	Dry	351.5	24.12.1957
8. Nuwara Eliya	Wet	343.2	23.11.1978
9. Batticaloa	Dry	330.7	05.12.1967
10. Trincomalee	Dry	322.8	17.12.1949
11. Katunayake	Wet	321.3	17.10.1977
12. Galle	Wet	319.8	07.05.1915
13. Anuradhapura	Dry	319.5	31.12.1948
14. Hambantota	Dry	296.9	06.05.1975
15. Puttalam	Dry	294.6	21.10.1891
16. Mannar	Dry	284.7	12.02.1992
17. Katugastota	Wet	266.7	14.08.1947
18. Kurunegala	Intermediate	249.4	25.10.1972
19. Badulla	Intermediate	230.6	04.01.1990
20. Diyatalawa	Intermediate	197.6	14.04.1931

SOURCE: DEPARTMENT OF METEOROLOGY, SRI LANKA

4.4.1 Floods

High intensity rainfall will contribute to short term inundation with serious impacts on life and infrastructure. The inundation will increase due to poor storm water drainage and a decrease in areas available for flood water storage. Ad-hoc reclamation has increased the vulnerability against flooding. Flash floods would be a significant problem in low-lying areas where the topography is essentially flat, thus making natural drainage paths ineffective. In the hill country, high intensity rainfall may initiate landslides and destabilize road/rain embankments leading to heavy social costs and damage to public utilities and infrastructure.

4.4.2 Land Degradation

Soil erosion and land degradation are widespread and occurs in all agro-ecological regions at different intensities. The problem is more acute in the hill country where soil erosion is high under low levels of management.

A major impact of high intensity rainfall would be accelerated soil erosion particularly on steeply sloping lands and lands that have already been degraded. Studies undertaken by the Land Use Policy Planning Division have indicated that there are approximately 250,000 hectares of land in the country with slopes of over 60%. Of this, 50% is intensively used and the balance sparsely used. It has also been stated that another 225,000 hectares of land between 30% and 60% slope in ten districts within the wet zone need upgrading of use.

High intensity rainfall may provoke landslides and erode road/rail embankments leading to heavy social costs and physical damage to infrastructure and public utilities such as water-supply lines, electricity/telecommunication cables and storm water drains. Available evidence suggests that the frequency and magnitude of landslides is already on the increase. Prior to 1980, there were only 34 known landslides in Sri Lanka. Between 1980 and 1991, the number of known landslides had increased to 171. According to the data available with the National Building Research Organization, approximately 12,500 hectares of land in the hill country are vulnerable to landslides.

4.4.3 Agriculture

Increased cloud cover and precipitation could decrease yields of many corps. In the case of C4 plants, e.g. Sugar cane, maize, sorghum, which yield well with high light intensities, there will be a reduction in yield but the reduction will be comparatively low. In the case of C3 plants, e.g. Rice, legumes and vegetables, where the yields are lower than C4 plants, the reduction in yields can be significant.

4.4.4 Health

High intensity rainfall will affect human health indirectly by damaging structures and houses, and by inundating roads and compounds. At the same time, waterways and wells could get polluted leading to an increase in bowel diseases such as diarrhoea, typhoid and dysentery. Dengue mosquitoes will breed in collections of clear water leading to an increase in the incidence of dengue hemorrhagic fever.

4.4.5 Transport Infrastructure

The major effects include severe negative impact on road surface maintenance, inundation of low line road sections due to flooding, inadequate roadside drainage, landslides and rockslides in hilly terrain, erosion of road sides, railway track and gravel and earth roads.

4.4.6 Power

Long term high intensity rainfall is likely to affect the reservoir structures designed for historical rainfall patterns. This will also result in more frequent unexpected heavy downstream water flows due to water regulation in the reservoirs, exposing the population to dangers of flooding.

4.5 IMPACTS OF INCREASED THUNDER ACTIVITY

Analysis of data on the occurrence of thunder activity has shown that there has been an increasing trend in thunder activity in the recent past, particularly during the intermonsoon months of March, April, October and November. This analysis has also revealed a positive correlation between thunder activity and air temperature, implying that there is likely to be an increase in thunder activity in the near future.

4.5.1. Infrastructure

Increased thunder activity results in more frequent damages to infrastructure particularly those involving power, telecommunication and other industrial installations.

4.5.2 Heath

Since lightning strikes cause deaths to human beings and animals and leads to property losses, this increase is likely to result in more deaths and injuries. In fact, a recent study has revealed that damages to property and loss of life by lightning strikes are on the increase. However, the wider health implications, if any, of this climatic effect is yet to be determined.

4.6 IMPACTS OF CLIMATE CHANGE ON HUMAN SETTLEMENTS

Human settlements are distributed throughout the island except in protected areas such as forest reserves and wildlife reserves. The impacts of climate change on these settlements are estimated to be high.

All natural hazards prevalent in the country, i.e. coastal erosion, coastal inundation and salinity intrusion; floods, erosion and landslides; storms, cyclones, droughts, high winds and lightning; and forest fires are likely to be aggravated by expected climatic changes. These in turn will have adverse effects on human settlements.

Human settlements in the island fall into five broad classes according to their level of vulnerability.

a) Settlements located within the 1.m Mean Sea Level contour and settlements encroaching on 50 and 100 year flood plains. These include substantial areas of squatter settlements and low income housing.
b) Settlements on or including landslide prone areas and settlements on steep erodible slopes. They too include substantial squatter settlements and low income housing.
c) Settlements in cyclone prone areas; settlements in drought prone areas, and settlements dependent on subsistence-type rainfed agriculture and on commercial fishing.
d) Settlements in or close to forest fire prone areas and settlements in storm, lightning and strong wind prone areas.
e) Settlements under irrigation schemes.

Further assessment and mapping in suitable detail will have to be undertaken in order to determine the vulnerability of human settlements.

CHAPTER 5

MITIGATION OPTIONS AND ADAPTATION RESPONSES

INTRODUCTION

Sri Lanka's response strategy to anticipated climate change includes the implementation of both mitigation and adaptation measures.

The country's contribution to the emission of green house gases is considered negligible. Even so, every effort has to be made to maximize the country's potential contribution towards controlling the amount of gases being emitted to the atmosphere. The mitigation options available in the major sectors of the national economy are listed in Section 5.1.

Adaptation measures are required to address the potential impacts of climate change. A few measures have already been adopted in some sectors such as agriculture and energy, to promote better environmental management. In the agricultural sector, programmes have been developed to control soil erosion, encourage conservation farming and agro-forestry, promote better water management and diversify agricultural production while in the energy sector, efforts have been made to increase energy efficiency, reduce energy costs and associated environmental pollution and examine available GHG mitigation options. These programmes can be strengthened and extended to include elements that could address some of the impacts of anticipated climatic changes. Further action is required to address other impacts. The action proposed for each of the sectors is given in Section 5.2.

5.1 MITIGATION OPTIONS

5.1.1 Energy Sector

Emissions from the energy sector are not significant at present. However, due to the rapid expansion, this sector's contribution to GHG emissions will be more significant in the future. This is particularly noticeable in the electricity generation sub-sector which has been expanding its fossil fuel based thermal generation capacity in recent times.

Certain studies and projects have been carried out in the past in the energy sector, directly or indirectly addressing impacts of climate change. They are:

- Study on GHG mitigation options in the sub-sectors of electricity generation, biomass and small and medium scale industries funded by the Swedish International Development Agency (SIDA) through Asian Institute of Technology (AIT), Bangkok and Sri Lanka Energy Managers Association.
- Demand Side Management Project of the Ceylon Electricity Board (CEB) funded through Energy Services Delivery Project of the World Bank.
- Transmission Loss Reduction Program of the CEB.
- Sri Lanka Power Technology Assessment Study carried out by International Development and Energy Associates Limited.
- Global Overlay Study on GHG mitigation options in the Sri Lanka power sector carried out by the Environment Department of the World Bank.

Further, there have been many other small-scale projects and studies carried out, particularly in energy conservation, addressing climate change issues.

The options available for Sri Lanka in mitigating GHG emissions in the energy sector are as follows:

- *Fuel switching:* Replace existing (or planned) use of fossil fuel with low GHG emitting fuels in electricity generation and in the industrial, commercial and household sectors.

- *Use of energy efficient technologies:* Use new technologies such as efficient combined cycle plants, combined heat and power systems, efficient lighting and air-conditioning systems with higher overall energy efficiency to replace the existing less efficient systems and in developing new systems.

- *Loss reduction:* The average energy losses in Sri Lanka power system is around 17%. It is also estimated that older generation plants in this region consume 18%-44% more fuel compared to their counterparts in OECD countries. Adoption of loss reduction measures at generation, transmission and distribution levels would reduce GHG emissions per unit of energy consumed.

- *Renewable energy systems:* Promote renewable energy technologies in place of fossil fuel fired plants wherever they are technologically and economically feasible.

- *Energy plantations:* Encourage commercial fuelwood plantations.

- *Pricing:* Incorporate environmental and social impact mitigation costs in pricing of electricity generated with different technologies. Petroleum products should also be priced at their true costs considering environmental and social costs/benefits.

- *Energy conservation:* Encourage energy conservation through consumer education in industrial, commercial and domestic sectors.

- Propagate biogas technologies such as those developed by the National Engineering Research and Development Centre (NERD).

5.1.2 Industrial Sector

In Sri Lanka, the industrial sector is one of the major consumers of energy in different forms such as electricity, petroleum and biomass. Therefore, adoption of any mitigation measures within the industrial sector such as those given below will have a significant effect in GHG reductions in the country.

- *Industrial policy:* Whenever possible, encourage 'soft industries' with a relatively low specific energy consumption. Also locate new industries in industrial estates where feasible.

- *Emissions:* Develop and enforce emission standards related to GHGs in the industrial sector.

- *Energy efficiency:* Adopt energy efficient building codes and the standardization and labelling of energy consuming end use equipment. Encourage the manufacturing sector to replace high energy consuming equipment with modern energy efficient devices.

- *Pollution control:* Promote proper solid waste management with methane recovery.

- Revive the programme to manufacture charcoal from wood left after harvesting timber instead of burning on site.

- Enhance productivity in the industrial sector.

5.1.3 Transport Sector

Much of the petroleum consumed in Sri Lanka is in the transport sector where the use of other forms of energy is insignificant. As a result, it is a major contributor to GHG emissions. Recent trends in fuel switching from gasoline to L.P.G. in motor cars due to financial benefits has already helped to reduce GHG emissions in this sector. The mitigation measures given below can be adopted to reduce the contribution.

- ❖ Enforce and monitor emission standards for motor vehicles.
- ❖ Promote inter-modal transport.
- ❖ Introduce traffic management measures to minimize private and low occupancy vehicles.
- ❖ Encourage the use of railways through financial incentives.
- ❖ Offer financial and other incentives aimed at greater use of public transport systems.

5.1.4 Agricultural Sector

Agriculture is an important source of carbon dioxide, methane and nitrous oxide. Net emissions could be reduced by changing the current land uses on marginal agricultural lands and by adopting better management practices on lands given over to crop production and livestock farming. Some of the options available are listed below:

- ❖ Establish forests or any other vegetation (perennials and grass) on degraded or non-forested lands.
- ❖ Promote mixed cropping and agro-forestry instead of monoculture wherever possible.
- ❖ Cut down methane emissions from livestock with new feed mixtures.
- ❖ Introduce changes in irrigation and fertilizer use to reduce methane emissions from wet rice cultivation.
- ❖ Minimize nitrous oxide emissions from agriculture with new fertilizers and practices.
- ❖ Alter breeding criteria for crop varieties with high carbon dioxide sequestration.

5.1.5 Forestry Sector

- ❖ Establish forests on degraded or non-forested lands so that carbon could be stored in trees and soils.
- ❖ Use fast-growing fuelwood in place of coal or oil to preserve the carbon reservoir contained in fossil fuels.

5.2 ADAPTATION RESPONSES

5.2.1 Proposed Action for the Coastal Zone

Sea level rise which is one of the more certain responses arising from global warming will manifest over long time scales. Comprehensive analyses on the rate of sea level rise have been carried out and the best estimates are that by the year 2100, the rise will range from 0.31 to 1.10 m, with the most likely rise being 0.66 m. Although the magnitude of future sea level rise is uncertain, knowing the order of magnitude of the likely increase and the fact that it will rise in response to global warming will certainly assist in planning response strategies. A primary requirement in conducting impact and adaptation assessment is the availability of reliable data

and most recent information on assets and activities at risk in the coastal zone. It is in this context that the proposed actions for the coastal zone are recommended.

a) Assessment of Vulnerability and Overall Management
   - Prepare contour maps at suitable resolution (at least 0.5m contour interval)
   - Identify human population, natural resources, infrastructure and assets in the coastal zone
   - Assess vulnerability to sea level rise along the coastal area of the country and estimate the economic cost of climate vulnerability
   - Delineate critical areas and prepare special area management plans
   - Monitor meteorological parameters in all coastal districts
   - Formulate coastal database for implementing integrated coastal area management
   - Incorporate greater consideration of climate change impacts in the next revision of the Coastal Zone Management Plan (CZMP)

b) Inundation
   - Incorporate climate change concerns in wetland conservation programmes

c) Salt Water Intrusion
   - Evaluate engineering interventions needed to counter threat

d) Fresh Water Intakes
   - Review the performance of existing intakes taking sea level rise into account
   - Design new water intakes giving due consideration to climate change impacts

e) Fishery Industry
   - Conduct sectoral assessment on climate change impacts on fishery development including fishery harbours, fishery settlements and sustainable use of fishery resource as a basis for long term planning

f) Sea Defence Structure and Nearshore Infrastructure
   - Assess vulnerability and prepare emergency response / contingency plans
   - Accommodate sea level rise in the design of new coastal structures

g) Nearshore Land Reclamation
   - Screen nearshore reclamation against sea level rise impacts

h) Tourism
   - Prepare set back limits to take account of sea level rise
   - Formulate tourism development guidelines to highlight for investors the potential problems arising from climate change
   - Update / revise Master Plan on tourism to incorporate climate change concerns

5.2.2 Proposed Action for the Transport Sector

Transport infrastructure is highly vulnerable to climate change impacts such as sea level rise, droughts and high-intensity rain particularly because Sri Lanka has a considerable length of the major road and railway network along the coast and in low-lying areas. Therefore, transport sector requires an adaptation measure such as:

- Improved road / railway infrastructure design standards to incorporate climate change considerations

5.2.3 Proposed Action for the Agriculture Sector

The climate change that is envisaged will have adverse impacts on agriculture. Since agriculture is the main source of livelihood for the majority of the rural population in the country, strategies are required to make the sector less vulnerable to the environment. Some of the possible resource strategies are given below:

a) Productivity
- Increase agricultural productivity by introducing improved varieties and improved management practices
- Increase productivity in the plantation and minor export crop sectors, and diversify agricultural production and the food habits of the people

b) Cropping Systems
- Change cropping patterns to offset any unpredicted weather changes by developing tree-crop agriculture in the Dry Zone; promote conservation farming techniques in areas vulnerable to soil erosion; develop tree-crop agriculture on degraded agricultural lands and promote agro-forestry on lands over 60% slope
- Develop drought resistant rice varieties with high yields

c) Water Management
- Introduce better water management by strengthening the institutional base to manage water resources economically and increase the efficiency of irrigation by adopting sprinkler irrigation methods and drip irrigation systems
- Introduce and promote water harvesting techniques

d) Land Use
- Change land use patterns in landslide prone areas and other vulnerable areas and discourage settlement in such areas
- Initiate land use planning to ensure the proper utilization of land

e) Awareness
- Make farmers aware of climate change and instruct them in ways of adapting to it. Special attention should be focused on the poorer sections of the farming population because of their greater vulnerability to climate change impacts

5.2.4 Proposed Action for the Forestry Sector

In evaluating the impacts of climate change on forests, it is important that the manner in which forests will respond to such change should be considered in parallel with a range of processes affecting different parts of the total forest eco-systems. This will include responses to flora and fauna at micro level to major changes in the distribution of species over short and long-term time scales. It is by examining the integrated effects of such interrelated aspects that a meaningful assessment could be carried out on the impacts of climate change in forests.

- Identify vulnerable areas and prepare contingency plans
- Promote use of alternative traditional timber species, e.g., rubber
- Assess vulnerability of coastal vegetation/mangroves and other ecologically critical areas and evaluate response strategies
- Promote use of alternative materials like plastic, fibre glass and steel
- Ensure conservation of natural forests and ban the clearing of natural forests for commercial purposes

- ❖ Take steps to minimize deforestation

- ❖ Promote urban forestry to establish vegetation in urban and metropolitan areas

5.2.5 Proposed Action for Water Resources Sector

In developing adaptation strategies for water resources affected by the impacts of climate change, it is recognized that climate change could both decrease and increase the water resources. Hence the need to plan adaptation strategies for both drought and flood scenarios. Within this framework, attention should be focussed on both the impacts of climate change on the resources (supply) and demand (water uses). The vulnerability of the country could only be properly assessed by examining supply and demand for water arising from global warming. Once a clear understanding on vulnerability is achieved, alternative adaptation strategies for climate change impacts can be developed. It is in this context that the proposed action for the water resources sector is recommended.

a) Rainfed Water Supply
   - ➢ Encourage minor storage reservoirs
   - ➢ Make allowance for re-distribution of population with respect to climate change impacts in land use planning
   - ➢ Investigate feasibility of trans-basin diversion schemes to counter climate change impacts
   - ➢ Conserve in-situ seasonal water bodies having valuable biological resources

b) Storage / Diversion Water Supply
   - ➢ Rehabilitate irrigation water tank networks in dry and intermediate zones
   - ➢ Promote participatory micro-watershed management

c) Groundwater
   - ➢ Prepare groundwater extraction regulation policy
   - ➢ Introduce permit / monitoring systems for groundwater extraction and water quality assessment in vulnerable areas

5.2.6 Proposed Action for Health Sector

Impacts of climate change on human health could be categorized as direct and indirect. The direct effects result from changes in climate characteristics or short-term weather extremes that impinge directly on human biology. The indirect effects are those that do not entail a direct causal connection between a climatic factor (such as heat, humidity, or extreme weather event) and human biology.

A number of adaptation measures are possible to reduce the impacts of climate change on human health. Some of these are given below.

One of the important adaptation measures in the health sector is the creation of awareness among the people in all aspects of human health affected by climate change, e.g. health risks due to natural disasters, heat related illnesses, health effects of exposure to UV-B light, precautions to be taken during the occurrence of lightning and thunder, spread of infectious diseases, etc.

a) General
   - ➢ Prepare baseline maps of disaster risk areas for specific extreme weather events
   - ➢ Develop early warning systems (using, for instance, GIS techniques) for monitoring of natural disasters
   - ➢ Develop institutional facilities and provide the necessary financial inputs for the implementation of Natural Disaster Management Plans
   - ➢ Upgrade health facilities in vulnerable areas, especially remote areas with difficult terrain and limited transport

- Formulate and enforce regulations to building design (public/private, households) to withstand/minimize structural damage and injury to people
- Motivate people to accept and heed to safety measures at individual household level by providing (a) free engineering/architectural advice and consultations and (b) soft loans for alterations to dwellings
- Establish database on health facilities at provincial level

b) Heat Stress, Heat Related Illnesses and Disorders
- Establish local standards for 'hot' working environments and enact laws for effective enforcement of such safety standards
- Encourage house/work place designs to suit hot climate; well-ventilated, good air circulation, less glass and if cost permitting, fans and air-conditioners.
- Create zones with shade trees, parks and fountains, etc., in urban areas.

c) Health Effects of UV-B Light
- Monitor indices of ill health, e.g. cataract, pterygium, keratitis, skin malignancies at sentinel and control locations. Identify any shifts in age group pattern especially for incidence of cataract
- Promote the use of antioxidants in diet, e.g. vitamin A and vitamin C
- Promote wearing of wide brimmed hats outdoors and sunglasses conforming to effective light filter standards
- Promote use of sunscreen applications and limit outdoor behaviour to direct exposure to sun in light skinned individuals

d) Spread of Infectious Diseases
- Establish RS/GIS information systems in areas prone to outbreaks/epidemics
- Develop baseline maps with local epidemiological information for specific diseases
- Develop epidemiological forecasting/early warning systems using ranges of criteria relevant to each disease
- Upgrade health manpower resources and facilities in high-risk areas to meet increased needs in curative/preventive actions and control of disease
- Monitor specific disease patterns at Health Care Centres in sentinel stations where climate change predictions are significant
- Upgrade safe drinking water and sanitation facilities in the rural sector

e) Food Shortage and Nutritional Disorders
- Monitor the growth of pre-school children at sentinel stations
- Educate people on low-cost nutritive foods which are being promoted for cultivation
- Promote dietary supplementation of high risk groups such as pregnant mothers, infants, pre-school children and the elderly

5.2.7 Proposed Action for Human Settlement and Public Utilities Sector

Impacts of climate change on human settlements and public utilities may be direct as well as indirect. The direct effects could be due to sea level rise and extreme events in the case of floods, droughts, cyclones and landslides. The indirect effects could be impacts on other sectors such as agriculture, water resources, health, etc. Several adaptive mechanisms are suggested to address these effects.

a) General
- Develop and establish RS/GIS/early warning systems in vulnerable areas
- Integrate suitable adaptation measures into all urban development plans
- Prepare and update national disaster management plan with adequate coverage on climate change
- Integrate climate change concerns/responses in relevant national policies
- Relocate people from vulnerable locations

- Develop storm, wind and cyclone resistant building standards and guidelines for different building categories

b) Floods
   - Conduct flood plain mapping for different return periods and delineate flood plains for conservation
   - Take steps to conserve natural drainage network including depression storage areas in all areas of the country
   - Formulate "climate change coefficient" for estimation of flood and drainage design.

c) Droughts/Cyclones
   - Develop early warning systems and prepare emergency response/contingency plans for vulnerable areas

d) Landslides
   - Undertake hazard area mapping
   - Take steps to conserve natural drainage networks at macro and micro levels
   - Introduce vegetative silt traps to reduce siltation of water courses

The adaptation responses proposed above need to be prioritized because of the limited availability of resources. The prioritization will have to be made on the basis of more detailed assessments of the physical and economic impacts of climate change; the cost of the adaptation measures to alleviate these impacts and the availability of resources to implement them.

CHAPTER 6

POLICIES AND MEASURES

6.0 POLICIES AND MEASURES

Policy recommendations and adaptation measures must be based on sectoral climate change studies and long term research, which would provide a scientific basis for decision making. The policy recommendations will have to focus on two aspects; reduction of emissions and mechanisms to mitigate impacts. However, there may be a certain amount of risk involved in investing in this regard. The measures adopted therefore should be "no regrets" options. This means that they will produce benefits even if climate change problems do not occur. These measures suggested fall into this category. They are activities that have been identified as national priorities and in any event need to be carried out for the development of the country in general and the sustainable management of resources in particular.

6.1 GENERAL RECOMMENDATIONS

Taking into account the possible impacts of climate change on the different sectors discussed earlier, some strategies that would increase resilience to climate change and reduce its overall impact are listed below:

- **Protect arable soil:** The country's food production depends largely on the land productivity. At present the country is faced with a severe problem of soil erosion and associated land degradation. This threatens the ability to produce adequate food and therefore needs immediate attention.

- **Improve water management:** An effective water management system should be in place to reduce floods and also to improve water efficiency during periods of drought.

- **Enhance agro-technology:** New agricultural technologies based on applied research must be adopted in order to provide food for the growing population, especially in the face of adverse climatic events and long term climate changes.

- **Formulate land use policies:** Land use policies should be prepared particularly for coastal areas. In preparing these policies, stakeholder participation is vital.

- **Maintain food reserves:** Food stocks should be built up to be used in times of need.

- **Provide emergency disaster relief:** Emergency aid should be readily available in times of disaster.

- **Enforce policies:** Implementation of policies containing provisions pertaining to climate change impacts should be given high priority. .

6.2 SPECIFIC RECOMMENDATIONS

6.2.1 Agriculture

(i) *Revision of Agriculture Policy*:

There is a need for revising the existing Agriculture Policy taking into account the climate change impacts. These need to be strongly addressed and an action plan prepared for implementing the policy. Particular attention should be placed on breeding for high drought/pest/and disease resistant varieties and the development of measures for soil and water conservation. It is also essential that adequate funds are provided for conducting of research to address the impacts of climate change on agriculture.

(ii) *National Land Resources Management Policy & Plan:*

In view of the proposed action to increase agricultural productivity by changing cropping patterns, improved water management and better land management, it is clear, that the bottom line is the need for a cohesive National Land Resources Management Policy and Plan. The objectives of the land resources policy would be to allocate land rationally amongst competing users, based on physical suitability and social, economic and environmental implications. Under the management plan, land will be allocated based on the suitability of the land for a particular use. For example, in agriculture, this will ensure that crop distribution will be determined by the suitability of land. This will lead to an increased output per hectare.

The land resources management plan will also ensure that the misuse of land will be minimized and that each parcel of land will be put to the highest and best use. The management plan will also bring about a more efficient management of lands given over to crop production and livestock.

6.2.2 Energy, Transport and Industry

ENERGY

The Energy Policy of Sri Lanka covers aspects relating to energy efficiency in terms of fuel switching to improve technologies. The policy should place greater emphasis on the promotion of renewable energy, including biomass thereby decreasing the dependency on fossil fuels.

(i) *Cost-reflective Pricing:*

A cost-reflective pricing policy should be formulated for the entire energy sector to represent the true cost of production, taking into account environmental impacts and mitigation costs. At present most of the energy sources are subsidized, due to social considerations. The subsidies on fuel for example are enjoyed by all. On the other hand, electricity is also subsidized, but has different costing for households, commercial establishments and for industries, with the households getting a better subsidy. In a developing country like Sri Lanka, marginal social-cost-based pricing would be more appropriate. However, the decision as to which is better will have to be made based on further studies.

It is proposed that such economic studies be carried out before the preparation of the second communication.

(ii) *Financial Incentives/Disincentives:*

Provide rational financial incentives for environmentally benign technologies and practices. Incentives should also be provided for replacing existing use of fossil fuel in electricity generation, with low GHG emitting fuels.

TRANSPORT

Although the existing transport policy does not directly address the climate change issues, nevertheless it includes elements that would contribute to a reduction of emissions in a direct and indirect manner. An important policy recommendation is the improvement of mass public transport systems. This recommendation should be implemented so that the inefficient use of personal transport systems can be reduced.

INDUSTRY

(i) *Revision of Current Environment Protection Licences (EPLs):*

The guidelines used in granting EPLs should be reviewed. EPLs should be granted based on applicable emission standards for selected GHGs.

(ii) *Encouragement of Soft Industries:*

The industrial policy should give prominence to encouraging soft industries, which consumes lesser energy wherever it is appropriate.

(iii) *Institutional and Legal Reforms:*
In order to effectively implement policy decisions aimed at reducing emissions, institutional and legal reforms in the energy, transport and industrial sectors will have to take place. Such reforms will improve the operational efficiency and productivity in these sectors. The necessary framework for monitoring the policy changes should also be in place.

6.2.3 Coastal Zone and Marine Resources

Implementation of Coastal Zone Management Plan (CZMP):
The CZMP addresses the current threats to the coastal areas and coastal resources. These threats are bound to become greater due to climate change impacts. The plan should be revised taking into consideration the potential impacts.

6.2.4 Forestry

*Implementation of the National Forestry Policy **(NFP)** and the Forestry Master Plan **(FMP)**:*
The main objectives of the National Forestry Policy of 1995 are:

a) Conserving forests for posterity, with particular emphasis to bio-diversity, soils, water and historical, cultural, religious values;

b) To increase the tree cover and productivity of forests to meet the needs of present and future generations; and

c) To enhance the contribution of forestry to the welfare of the rural people.

An important policy objective is the effective management of state forest resources. This will be done by bringing all state forests under sustainable management both in terms of the continued existence of important ecosystems and the flow of forest products and services; by allocating the natural forests firstly for conservation, and secondly for regulated multiple-use production forestry, by rehabilitating degraded forest for conservation and multiple-use production, where it is economically and technically feasible, mainly for the benefit of local people, by ensuring that the planned conversion of forests into other land uses can take place only in accordance with procedures defined in legislation and with accepted conservation and scientific norms, and by promoting tree growing by local people, rural communities, NGOs and other non-state sector bodies for the purpose of environmentally sensitive areas.

6.2.5 Water Resources

(i) *Preparation of Water Management Plan:*
The draft water policy emphasizes the efficient use of water. However, it is important that the plan takes into account climate change impacts. Since the sources of water have to be protected, the plan should also pay attention to the protection of the upper watersheds in the country. The Water Resources Management Plan would any case have benefits beyond climate change mitigation.

(ii) *Ground Water Extraction Regulation Policy:*
The indiscriminate exploration of ground water in the Dry zone and the Intermediate zone is causing concern. The availability of water has not been assessed. This has to be done. In the meantime, a policy should be in place to regulate and monitor the construction of tube/agriculture wells in the Dry zone and in the Intermediate zone.

6.2.6 Health and Settlements

(i) *Implementation of Disaster Management Action Plans:*
The Presidential Task Force for Preparing a National Programme on Human Disaster Management has submitted their report which is presently under discussion. The programme should be implemented by preparing Action Plans. The action plan dealing with natural and manmade disasters should take into account the possible impacts of climate change. Data from the Department of Meteorology and other relevant institutions should be used in the preparation of the plans.

(ii) *Preparing Land Use Plans:*
Land Use Plans should identify vulnerable areas and allocate those areas for forestry. Areas for flood plain conservation and areas suitable for settlements should also be identified in the plans.

(iii) *Establishing Disaster Management Centres:*
Disaster Management Centres in sensitive areas for dealing with emergencies including landslides, flash floods, etc., should be established.

(iv) *Implementation of Action Plan on Waste Management:*
A Solid Waste Management Strategy has been approved and an action plan for implementing the strategy is being prepared. The action plan should take into account the health issues relating to climate change and recommend action that will deal with management of waste (both industrial and household), including recycling or use of such waste in an economically viable manner to minimize emissions from unscientific land fills and reduce possible health hazards. A co-ordinated effort is required in implementing the programme.

(v) *Re-focus Health Policy and Specialized Health Programmes:*
The Health Ministry has well organized programmes for the prevention of Malaria, respiratory diseases, etc. The malaria control programme being implemented under the National Malaria Control Policy is aimed at the reduction, elimination and prevention of malaria. The programmes implemented will have to take into account possible outbreaks of epidemics due to climate changes and adopt measures that would prevent or control such epidemics.

(vi) *Air Quality Management:*
Maintenance of good air quality is the objective of the National Policy on Air Quality Management. The national policy on air pollution abatement focuses mainly on Vehicle Inspection and Maintenance, Fuel Reformulation, Pricing and Fleet Mix, Emission Inventory, Monitoring and Reduction, Standard Setting, Institutional Framework and Regulatory Compliance, Economic Instruments, Transport Planning and Traffic Management and Public Awareness.

The Clean Air 2000 Action Plan for Air Quality Management in the Colombo Metropolitan Area was prepared in late 1992 recognizing the growing problem of air pollution in the Colombo Metropolitan area. This Action Plan was prepared in consultation with Ministries and Agencies whose activities influence air quality and has been considered by the National Environmental Steering Committee. The Plan combines policy and strategic measures that were to be introduced to the overall policy making framework. This is the first real attempt to reduce automotive air pollution in Colombo Metropolitan area. It is expected to stimulate future multi-lateral investment initiatives in the areas of energy conservation.

6.3 FURTHER ISSUES TO BE CONSIDERED

It is evident that there are several policies that are capable of dealing with some of the climate change issues. The implementation of these policies could help to reduce the impacts of climate change. However, they should not be implemented in isolation to each other because they are closely connected.

The strengthening of the existing policies will not be adequate to handle all of the impacts of climate change. They have to be supported by formulating policies in areas where there are policy gaps. Some issues that will have to be considered when strengthening existing policies and preparing new policies are given below:

- **The need for building up a database:** The available data has not been sufficiently collated and analyzed. This has to be done as a matter of priority. At the same time the data gaps have to be identified early and steps taken to fill the gaps.

- **The need to provide incentives / disincentives:** Based on the experiences of other countries, it is clear that some of the most innovative experiences in climate change mitigation have come in the form of new incentive and disincentive mechanisms to encourage reliance on renewable energy and co-generation. Hence appropriate financial incentives and disincentives need to be worked out. Innovative policies can spur rapid adoption of new technologies, leading to sharp declines in the combustion of fossil fuels. It is evident that among the policies adopted so far, the removal of energy subsidies has had the greatest short-term impact leading to a stringent adaptation of Demand Side Management Measures.

- **The need to consider the cost-effectiveness of policies:** The policies need to be reviewed in terms of cost-effectiveness taking into account the socio-economic impacts as well. In the case of health, for example, there are two levels of prevention, which can be adopted, i.e. primary and secondary. Primary prevention consists of those measures that reduce or prevent the risk of developing the disease. Secondary prevention involves the detection and treatment of a disease at a stage early enough to prevent serious clinical illness. Primary prevention measures are often more cost effective than higher level interventions, and clearly reduce the burden of human disease and suffering.

- **The need to adopt an integrated approach:** Integration of climate change aspects with other development priorities is a two way process. Integrating climate change into a country's general planning process makes it possible to ensure that other macro-economic and sectoral policies can be adjusted to take climate change into consideration. At the same time it will ensure that whatever climate change initiatives implemented are in line with sustainable national development thereby reducing economic burdens on the country.

- **The need to promote stakeholder collaboration:** Adaptation measures recommended, e.g. in agriculture should be acceptable to all stakeholders. The need and extent of adoption will depend on the commitment of national policy makers and the support provided through research, training and communication.

- **The need to increase the awareness of climate change:** Awareness of climate change is inadequate in Sri Lanka. Therefore, it is of utmost importance to enlighten the relevant parties and policymakers on the imminent effects and ensuing problems. In this context, the advisory and extension services of various institutions and organizations could play a key role.

CHAPTER 7

EDUCATION, TRAINING AND AWARENESS

INTRODUCTION

In order to meet the challenges posed by climate change in the coming decades, great importance has to be attached to education, training and promotion of awareness among different groups. With this in view, Sri Lanka has already launched a number of programmes to educate, train and promote awareness.

7.1 EDUCATION

Considering the fact that the present student population, from the school system to the university system, would be the decision makers of the future, Sri Lanka has taken steps to include some basic concepts of meteorology, climatology, environment, bio-diversity and climate change into the respective curricula.

In the primary school, environment is taught as part of the syllabus. In the junior school, the syllabus content of General Science contains the above areas whereas in the senior school, students are taught these concepts through science subjects as well as Geography. At the university under-graduate level, climate change has been included as one of the subjects in the field of climatology taught in different universities in Sri Lanka, whereas special subjects in post-graduate courses include environment, oceanography and climatology.

In the context of changes that are taking place in the area of climate change and related issues, the contents of these courses will have to be expanded to include the latest climate change related information.

For non-science students in the General Certificate of Education (Advanced Level) classes, a new subject called "Science and Society" which includes climate change concepts, will be introduced in May 2001.

The Open University of Sri Lanka also hopes to introduce a new course on Climate and Climate Change at the under-graduate level.

7.2 TRAINING

A number of training workshops and seminars have been conducted by the Ministry of Forestry and Environment and the Department of Meteorology, with the assistance and cooperation of the National Institute of Education to train master teachers in several aspects of climate change and related issues. Topics covered at these workshops and seminars included climate variability in Sri Lanka, climate change impacts and vulnerability, the United Nations Framework Convention on Climate Change and Sri Lanka's obligations under the UNFCCC, etc.

These programmes will be expanded to train Master Teachers for the expanded syllabuses with climate change contents. It is also hoped to conduct short courses and training workshops for the university staff on advanced aspects related to climate change. Training workshops will also be held for the benefit of those conducting awareness programmes and also for the print and electronic media personnel.

Sri Lanka also hopes to undertake capacity building programmes to train scientists (a) to undertake relevant research, and (b) to formulate and implement projects and research programmes on a priority basis.

The above programmes will be organized by the recently established Centre for Climate Change Studies (see 7.4) with the assistance and cooperation of the Ministry of Forestry and Environment, the Ministry of Education and Higher Education, the Education Commission and the National Institute of Education.

7.3 AWARENESS

Sri Lanka has been conducting awareness programmes on climate change and related issues for several years since the early 1990s. The target groups have been school children from grades 9 to 12 and school teachers. Originally, the funding for carrying out these programmes was provided by the US Country Studies Programme, but now the funding is provided by the Ministry of Forestry and Environment. These seminars are organized by the Department of Meteorology and the resource persons are from the Department of Meteorology and the Ministry of Forestry and Environment. This is an ongoing programme.

Several workshops on climate change and related issues have also been conducted by the Ministry of Forestry and Environment for the benefit of senior government officials, policy makers and NGOs.

The Centre for Climate Change Studies will also be conducting awareness programmes (see 7.4).

7.4 CENTRE FOR CLIMATE CHANGE STUDIES

Although Sri Lanka's contribution to the problems of climate change is negligible compared to those from developed countries and some larger developing countries, the country remains vulnerable to the economic, ecological and social impacts of climate change. Realizing this, the Hon. Minister of Science and Technology obtained the approval of the Government of Sri Lanka to set up a Centre for Climate Change Studies. This Centre which was opened on 05 April, 2000, is located at the Headquarters of the Department of Meteorology in Colombo and is headed by one of its Deputy Directors.

The objectives of the Centre are:

i. to encourage scientists to carry out research on climate change and related issues;
ii. to conduct awareness programmes on climate change and related issues;
iii. to serve as a depository of information nationally on research on climate change and climate change related activities generated in Sri Lanka and in other countries.

The functions and activities of the Centre would be:

i. to carry out research on climate change and related issues;
ii. to execute climate models;
iii. documentation, bibliography and library services;
iv. information gathering and dissemination;
v. to conduct awareness programmes on climate change and related issues for the benefit of
   - policy makers, planners and politicians
   - scientists
   - general public
   - teachers and students
vi. establish links with the relevant international agencies

The activities of the Centre are guided by a Technical Advisory Committee which consists of senior scientists from various disciplines.

This Centre will work in close collaboration with related national agencies and the outcome of studies done will be made available to policy making bodies in the government and other concerned institutions.

CHAPTER 8

RECOMMENDED RESEARCH STUDIES AND PORTFOLIO OF PROJECTS

INTRODUCTION

Research and scientific assessments play a vital role in improving the understanding of the potential impacts of climate change in Sri Lanka, with specific reference to their scale and timing. Such investigations will enable the development and assessment of appropriate adaptation strategies. There is a clear need for a coherent, national approach to provide the tools and organization to understand the impacts of climate change as opposed to continued reliance on individual agency initiatives. Such an approach would also promote integrated impacts studies which would improve the information and data available to decision-makers in all sectors for developing plans and future policies on climate change. The research studies and projects recommended in this chapter have arisen from the sectoral analyses carried out for the preparation of the National Action Plan for Climate Change.

8.1 RESEARCH STUDIES

8.1.1 Coastal Zone

a) Prepare a coastal data base both referral and relational at a suitable resolution and link the same with an appropriate environmental monitoring system for updating, analyzing and predicting coastal responses. It is recommended that a hydrodynamic modelling system be incorporated as an integral part of the monitoring system.

b) Undertake studies on the impact of rise in temperature and sea level on coral reefs and marine species.

8.1.2 Energy Sector

a) Coal will be the preferred option for power generation at present based on a variety of factors such as the relative cost advantage, lack of infrastructure to transport and handle Natural Gas, lack of sufficient capacity of power generating facilities to utilize Natural Gas, etc. In such a scenario, immediate power requirements will be based on oil and coal until the year 2008 or so. Beyond this, it would be pertinent to consider Natural Gas as an option for the future plants as well as the conversion of existing plants especially the large number of combustion turbines that will be in the system. A study in this respect should commence.

b) Undertake a study of the economic and environmental impact of identified hydro-power potential.

c) Undertake an in-depth Integrated Resource Planning study on Energy Conservation and other Demand Side Management (DMS) measures.

8.1.3 Industry Sector

a) Develop and enforce emission standards related to GHGs in the industrial sector.

8.1.4 Transport Sector

a) Carry out research studies on the selection of suitable material for road construction. Work already carried out can be extended to accommodate climate change concerns.

b) Develop representative emission factors for different fuel and vehicle types.

c) Improve methodologies for estimation of emissions in the transport sector, in absolute terms as well as in output related terms.

d) Develop an appropriate road pricing system.

e) Identify roads and railway vulnerable to sea level rise and develop strategies to protect these infrastructure.

8.1.5 Agricultural Sector

a) Breed drought/salinity tolerance varieties and study the use of traditional varieties.

b) Estimate the change in production rates with carbon dioxide fertilization and increase in temperature on different crops – rice, field crops, vegetables, plantation crops.

c) Study the role of agrosilvicultural systems in Sri Lanka – carbon dioxide sinks or sources of GHG emissions?

d) Undertake studies of economic models that determine the ability to mitigate climate change through emission reduction vs. ability to adapt to such changes through adjusting production functions.

e) Study aspects of soil organic matter and nutrient cycling (rates of accumulation, decomposition, etc.) in relation to climate change and agricultural sustainability.

f) Study the effect of different cultural practices such as green manuring, continuous cropping with fertilizer, multiple cropping, modified alley-farming, etc., on mitigating climate change impacts.

g) Study the effect of climate change indicators on weed, pest and disease occurrence of cultivated crops and develop forecasting systems.

h) Study the effect of carbon dioxide fertilization on radiation use efficiency.

i) Identify agroecological zones particularly sensitive to climate change impacts and potential desertification areas.

j) Examine factors affecting methane production in rice paddies of different agro-ecological zones and farming practices.

k) Study the impact of climatic change on agriculture – water availability and crop water requirements.

8.1.6 Forestry Sector

a) Conduct research and development of appropriate protocols for community forest management or agroforestry type projects. The selection of projects for GHG mitigation should consider:
   - The potential social impacts, in particular the potential for poverty reduction through improved management of communal forest areas or development of agroforestry systems on individual farm holdings.
   - The potential for Carbon sequestration.
   - Other potential benefits such as biodiversity conservation or watershed protection.

b) Prepare protocols and guidelines for transferring resources for sustainable forestry and agro-forestry to farmers on the basis of Carbon sequestration.

c) Develop effective systems (standards and procedures) for monitoring and regulating Carbon sequestration by forestry and other land use projects.

d) Evaluate socio economic benefits from Carbon offset projects. Regulatory systems should include mechanisms for selecting and promoting projects that contribute to the development of sustainable rural livelihood.

e) Develop a database of biomass for different types of vegetation in Sri Lanka. Data can be derived from direct measurements of biomass representing the main vegetation types in the country.

f) Develop genetic guidelines and methods for managing terrestrial Carbon. This should include (a) Guidelines for the establishment of regional baselines (b) Socio-economic design criteria for off set projects (c) Methods for assessment of offset capacity of individual sequestration projects (d) Guidelines for project selection and project development, project monitoring and administration, etc.

8.1.7 Water Resources Sector

a) Study by hydraulic monitoring the extent of intrusion of salinity wedge along waterways for different scenarios of sea level rise.

b) Identify new flood levels via hydrological and hydraulic modelling, access daily the impacts of sea level rise.

c) Study the impact of climate variability and climate change on river flow regimes and on the ground water table in Sri Lanka.

8.1.8 Health Sector

a) Undertake research on low cost thermal environment management and control strategies in work places.

b) Conduct studies on epidemiological forecasting and early warning systems using RS/GIS technology applicable in high-risk areas for malaria, dengue, Japanese Encephalitis, diarrhoeal disease and nutritional disorders.

c) Undertake prospective and retrospective studies on identified disease patterns such as eye and skin disorders relevant to climatic change in sentinel stations.

d) Undertake nutritional research on low cost alternatives to staple diets and supplementary foods based on varieties recommended for climatic change.

e) Undertake surveys to identify thermal environment at various work sectors in Sri Lanka.

f) Conduct studies on vector mosquito dynamics and changes in disease patterns on all vector borne diseases.

8.1.9 Human Settlements

a) Study existing tall structures (telecom towers, etc.) in cyclone prone areas.

b) Study impact of climate change on existing sewerage and drainage systems.

c) Study impact of climate change on existing urban water supply schemes, including reservoirs.

d) Develop storm, wind, cyclone and minor flood resistant building standards and guidelines for different building categories (NBRO, CHPB, ICTAD, BD, NERD, SLT, CEB).

e) Undertake studies to determine the probability of drought in different agricultural seasons and in different areas.

8.1.10 Others

a) Develop rainfall and temperature scenarios for Sri Lanka.

b) Examine possible changes in local and foreign recreational activity.

8.2 PROJECTS

8.2.1 Coastal Zone

a) Using the mathematical modelling developed, study the influence of increased salt water intrusion in a selected river estuaries with emphasis on the impacts of fresh water intakes and low lying agriculture.

b) Undertake a vulnerability assessment in a selected region along the coast which is more prone to the impacts of sea level rise. The impacts on coastal erosion and coastal land slides to be included in the study.

c) Undertake the investigation on the impacts of sea level rise and temperature rise on coral reef systems around the coastal belt.

8.2.2 Energy Sector

a) Harness the total maximum identified potential of hydropower, based on a study of the economic and environmental impacts of identified potential hydropower.

b) Improve transmission and distribution system to bring down the current energy losses.

c) Introduce DSM measures such as peak lopping through appropriate pricing, popularization of more efficient end use devices such as luminairs, refrigerators, air-conditioners and motors, etc.

d) Expand and strengthen the capacity of the Energy Conservation Fund to improve its capability to assist different stakeholders in the energy sector in the areas of energy conservation and management.

e) Commission a study on energy recovery from waste.

8.2.3 Industry Sector

a) Adopt energy efficient building codes and standardization and labelling of energy consuming end use equipment.

b) Promote proper solid waste management with methane recovery.

c) Develop an inventory on emissions from different industries.

d) Develop mechanisms to reduce GHG emissions from such industries.

8.2.4 Transport Sector

a) Improve traffic management systems through the use of information technology.

b) Introduce a suitable vehicle inspection and monitoring programme.

c) Integrate bus-rail operation through proper network planning.

d) Adopt an appropriate road pricing system.

8.2.5 Agricultural Sector

a) Apply simulation models for climatic change and crop response prediction.

b) Promote rainfed farming and the efficient utilization/conservation of water.

c) Develop integrated farming systems in relation to climatic change.

8.2.6 Forestry Sector

Prepare a database to:

a) Achieve a greater understanding of the linkages between climate change and forest eco-systems.

b) Quantify the role of forests, forest soils as reservoirs, sinks and sources of Carbon.

c) Determine the dynamic equilibrium of host/parasite relationship in new climate environment.

d) Define ways to alter forest management systems to optimize adaptation to climate change, sequestration and storage of Carbon.

8.2.7 Water Resources Sector

a) Prepare a groundwater extraction regulation policy.

b) Introduce permit/monitoring systems for groundwater extraction and water quality assessment in vulnerable areas.

c) Assess the extent of land that will be affected by sea level rise under the following categories:
   i. Directly inundated (at high tide)
   ii. Falling below 0.3 m of the new sea level
   iii. Falling between 0.3 to 1.0 m of the new sea level.

8.2.8 Health Sector

a) Establish work environment and occupational safety standards for local conditions.

8.2.9 Human Settlements

a) Map flood plain and flood hazard, especially for Kelani Ganga, Kalu Ganga, Gin Ganga, Nilwala Ganga, Attanagalu Oya, Mahaweli Oya, Heda Oya and Lunu Oya

b) Measure sea level rise on a continuous basis.

c) Identify and prioritize vulnerable areas for human settlement.

CHAPTER 9

CONSTRAINTS AND TECHNOLOGICAL NEEDS

The Enabling Activity Project on Climate Change commenced in 1998, with the main objective of preparing the Initial National Communication of Sri Lanka in response to its commitment to the UNFCCC. The project is also expected to enhance general awareness and knowledge on climate change related issues in Sri Lanka. The constraints faced in preparing the communication and the major technological measures needed to face the potential impacts of climatic change are outlined below.

9.1 CONSTRAINTS

During the implementation phase, the project had to face several constraints. The more important of these were:

i) The inability to recruit experts on a full time basis. The needed expertise was available only with the academic and technical institutions. Being full time staff members of these institutions, they were able to contribute only during their spare time.

ii) The limited availability of specific studies and relevant research. In the preparation of the GHG Inventory for example, reliable data were not available for all aspects. There were also gaps in activity data. In addition, there were no country specific emission factors to be used and default values were taken from IPCC guidelines. These however may not represent the real values for the country. Likewise, very few studies had been undertaken on Vulnerability and Adaptation Assessments.

iii) The inadequate time available for undertaking specific studies and research on impacts of climate change. These could not be done because the experts had previous commitments. Furthermore, there was no mechanism by which their services could be obtained on a full time basis to undertake the necessary research. However, every effort has been made to collect available information both published and unpublished.

9.2 TECHNOLOGICAL NEEDS

9.2.1 Coastal Zone

Preparation of a coastal data base and examining the influence of increased salt water intrusion and vulnerability of coastal areas through case studies.

9.2.2 Energy Sector

Exploring natural gas as an energy option, harnessing the total identified hydro power potential and introduction of DSM measures.

9.2.3 Industry and Transport

Development of emission factors for vehicles; enforcement of GHG related emission standards in the industrial sector; adoption of energy efficient building codes and proper solid waste management techniques; improvement of traffic management systems and integration of bus-rail operations through network planning.

9.2.4 Agricultural Sector

Identification of agro-ecological zones sensitive to climate change impacts; promotion of rainfed farming and; development of integrated farming systems in relation to climate change.

9.2.5 Forestry Sector

Preparation of a data base to understand linkages between climate change and forestry eco-systems and examining the potential for carbon sequestration.

9.2.6 Water Resource Sector

Assessment of the (a) extent of land that will be affected by Sea Level rise and (b) the impact of climate change on river flow regimes.

9.2.7 Health Sector

Establishment of work environment standards for local conditions and the undertaking of studies on diseases relevant to climate change.

9.2.8 Human Settlements

Mapping of flood plains and flood hazards for selected major rivers; development of strong wind and cyclone resistant building standards and guidelines and identification and prioritization of vulnerable areas for human settlements.

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3. Report on Agriculture.
4. Report on Emissions from Energy and Industrial Sectors.
5. Report on Large Hydro and Fossil Fuels.
6. Report on Health.
7. Report on Human Settlements & Public Utilities (HS & PU).
8. Report on Transportation.
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