CITIES AND CLIMATE CHANGE INITIATIVE

FORMULATION OF A CITY DEVELOPMENT STRATEGY
FOR SRI LANKAN CITIES TO RESPONSE CLIMATE CHANGE
NEGOMBO & BATTICALOA MUNICIPAL COUNCIL AREAS

INVENTORY ON GREEN HOUSE GAS EMISSIONS

Negombo Municipal Council & surroundings

Prepared by
Project Consultancy Unit,
Faculty of Architecture,
University of Moartuwa,
Sri Lanka

Supported by
UN-HABITAT
FOR A BETTER URBAN FUTURE

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Project Team

Authors

Prof P.K.S. Mahanama
Director PCU/ Dean, Faculty of Architecture,
University of Moratuwa

Mr. Amila B. Jayasinghe
Infrastructure Planner

Mrs. C. Chethika Abenayake
Environmental Planner

Project Associates

Mr. Chathura de Silva
Ms. V.W. De Edirisinghe

Field Survey Team & Workshop Facilitators

Mr. V.G.M.P.N. Kumara
Mr. P.M.C.J. Paliskara
Ms. T.J.K. Jayalath
Mr. M. P. N. T. Dias
Mr. S. A.D. D. P. Disanayake
Mr. P.H.C.S Rathnasiri
Mr. R. Senanayke
Mr. H.R.L. Bandara

Technical Assistant

Mr. R.A.J. Kithsiri

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- Citizens of NMC and other concerned DS Divisions

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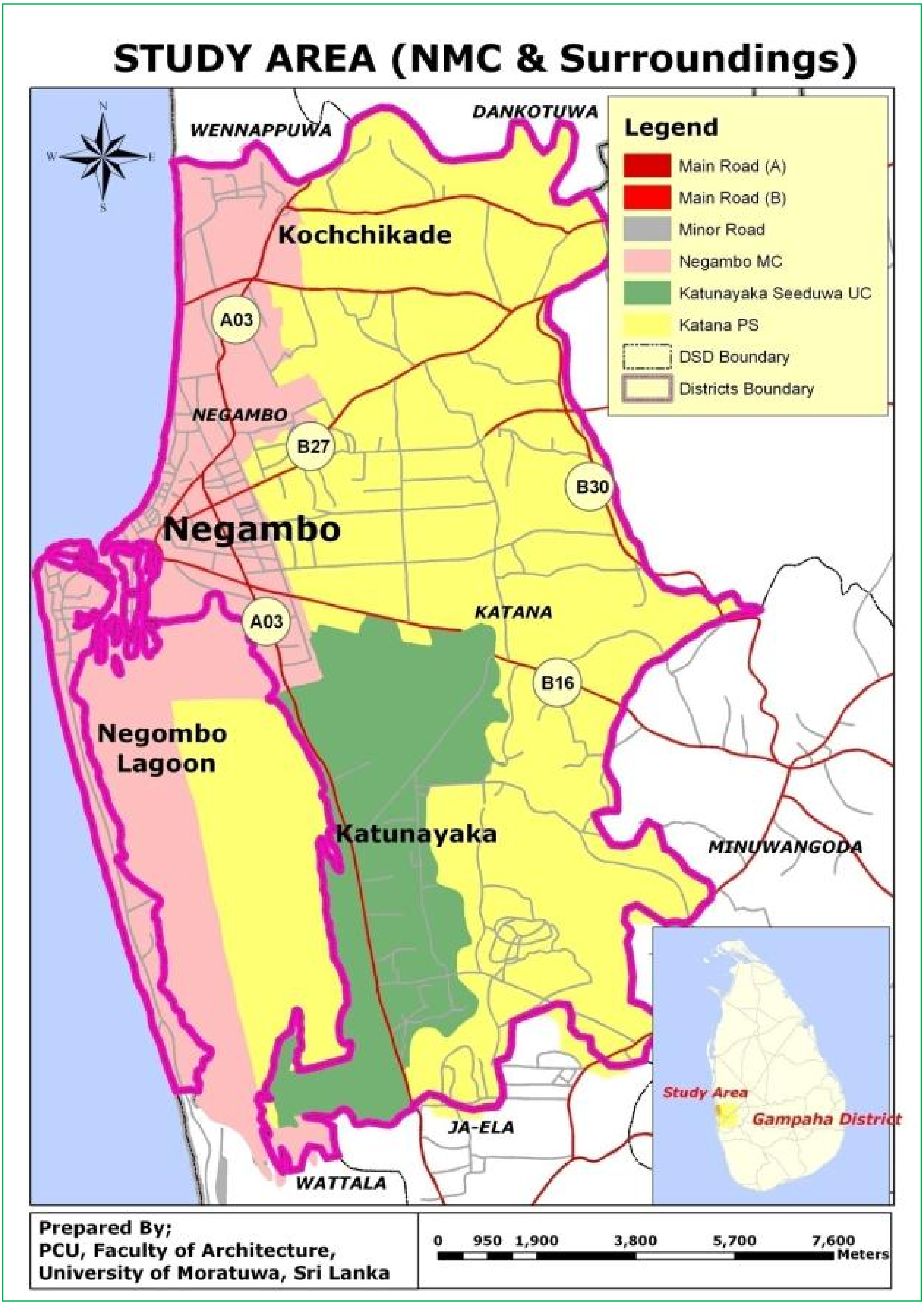
Abbreviation

AFOLU	: Agriculture, Forestry and other Land Uses
BOD	: Biological Oxygen Demand
BOI	: Board of Investment
CC	: Climate Change
CCCI	: Cities and Climate Change Initiatives
EPZ	: Export Processing Zone
DSD	: Divisional Secretariat Division
GHG	: Green House Gas
GWh	: Gigawatt Hour
Ha	: Hectare
IPCC	: Intergovernmental Panel on Climate Change
kt	: Kilotons
KWh	: Kilowatt Hour
N/A	: Not Available
NMC	: Negombo Municipal Council
PS	: Pradesheeya Sabha
TJ	: Tonne Joule
UC	: Urban Council

Summary Table 1 - Community Information

Name of city or local region	Negombo Municipal Council Area and Surroundings 1. Negombo Municipal Council (NMC) i.e. Negombo DSD 2. Katana DSD 2.1. Katunayake-Seeduwa UC 2.2. Katana PS
Country	Sri Lanka
Inventory year	2010
Reporting date	2011 May
Population (year round residents)	325,640
Land area (sq. kilometers)	148.96
Urbanized area (sq. kilometers)	38.4
Heating degree days (18°C base)*	Avg : 31.4°C per day (std. dev 1.56) More than 18°C : 365 More than 25°C : 365 More than 30°C : 251 More than 35°C : 1
Building gross floor areas (m^2)* Residential Commercial / Institutional Industrial	N/A
Name, status and address of reporter	Project Consultancy Unit, University of Moratuwa, Sri Lanka
Name, status and address of third party verifier (if applicable)	UN Habitat – Regional office for Asia and Pacific, Fukuoka
Other information, e.g., websites of fuller inventory report or emissions reduction program	


STUDY AREA (NMC & Surroundings)
Legend
Main Road (A)
Main Road (B)
Minor Road
Negambo MC
Katunayaka Seeduwa UC
Katana PS
DSD Boundary
Districts Boundary
WENNAPPUWA
DANKOTUWA
Kochchikade
A03
NEGAMBO
B27
B30
Negambo
KATANA
A03
B16
Negombo
Lagoon
Katunayaka
MINUWANGODA
Study Area
Gampaha District
JA-ELA
WATTALA
Prepared By;
PCU, Faculty of Architecture,
University of Moratuwa, Sri Lanka
0 950 1,900 3,800 5,700 7,600
Meters

Summary Table 2 - Greenhouse Gas Emissions by Sector

	SCOPE	CO_2	CH_4	N_2O	Other	**TOTAL**
GWP (20 years)		(1)	(56)	(280)		
Units		kt CO_2 e.	kt CO_2 e.	kt CO_2 e.	kt CO_2 e.	kt CO_2 e.
ENERGY						
a) Stationary Combustion						
Electricity (incl. T&D losses)	1,2,3	7.263133	0.001748	0.000749		7.57
District energy, CHP, and energy from waste	1,2,3	-	-	-		0
Commercial & Institutional	1	0.100577	0.000585	0.000004		0.13
Residential	1	12.098399	0.772166	0.001156		55.66
Manufacturing Industries & Construction	1	0.026417	0.002651	0.000004		0.18
Fishery	1	38.165843	0.095901	0.003836		44.61
Agriculture	1	0.083214	0.000165	0.000002		0.09
b) Mobile Combustion						
Road transportation: LDVs	1	-	-	-		0
Road transportation: trucks	1	4.451023	0.001322	0.000661		4.71
Road transportation: other	1	18.337310	0.047966	0.001967		21.57
Railways	1	0.716278	0.000048	0.000006		0.72
Domestic aviation	3	-	-	-		0
International aviation	3	-	-	-		0
Domestic marine	3	-	-	-		0
International marine	3	-	-	-		0
Other	1	-	-	-		0
c) Fugitive Sources						
INDUSTRIAL PROCESSES	1	-	-	-		0
AFOLU	1	5.240761	0.066620	0.00		9.17
WASTE						
Solid waste disposal on land	1,3	2.014906	4.189751	0.001060		236.94
Wastewater handling	1,3	-	0.058808	-		3.29
Waste incineration	1,3	-	-	-		-
TOTAL		**88.50**	**5.24**	**0.01**		**384.65**

(Note: -- Indicate source not available or insignificant in the study area)

Summary Table 3 - Greenhouse Gas Emissions by Fuel or Activity Type

	Activity Data			Emissions Factor			Total GHGs
	Value	**Units**	**Tier**	**Value**	**Units**	**Tier**	**t CO_2 e**
ENERGY							
Electricity (on-site renewable)		GWh	N/A	-	t CO_2 e / GWh	N/A	0
Electricity (grid)	89.59	GWh	2	84.51	t CO_2 e / GWh	2	7,570.75
Natural gas	-	TJ	-	-	t CO_2 e / TJ	-	0
Fuel oil	-	TJ	-	-	t CO_2 e / TJ	-	0
Coal	-	TJ	-	-	t CO_2 e / TJ	-	0
Gasoline	32.70	TJ	2	243.60	t CO_2 e / TJ	-	7,965.03
Diesel	5,087.83	TJ	2	11.19	t CO_2 e / TJ	2	56,932.78
Jet Fuel	-	TJ	-	-	t CO_2 e / TJ	-	0
Marine Fuel	-	TJ	-	-	t CO_2 e / TJ	-	0
Kerosene	1,053.80	TJ	2	22.85	t CO_2 e / TJ	2	24,083.61
LPG	172.11	TJ	-	22.78	t CO_2 e / TJ	2	3,921.11
Fuel wood	251.54	TJ	-	198.91	t CO_2 e / TJ	2	50,034.60
INDUSTRIAL PROCESSES							
Industrial Products	0	kt	-		t CO_2 e / kt	-	0
WASTE							
Solid waste disposal on land	100,510,000.00	kt	1	2.21	t CO_2 e / kt	2	221,682.44
Wastewater handling	6,213,716.68	kt BOD	2	0.53	t CO_2 e / kt BOD	2	3,293.27
Waste incineration	0	kt	-	-	t CO_2 e / kt	-	0
AFOLU							
Livestock activities	25,689.00	kg	1	0.15	t CO_2 e / kt	2	3,769.88
Agriculture activities	835.00	Ha	2	191.35	t CO_2 e / Ha	2	159.78
Land use change	1,527.59	t C	3	3.43	t CO_2 e / kt	3	5,240.76
TOTAL							384,654.01

(Note: -- Indicate source not available or insignificant in the study area)

1. INTRODUCTION

There are well-researched scientific evidences and global awareness that greenhouse gases released into the atmosphere have a significant effect on the climatic ecosystem services. Kyoto protocol is a global agreement in mitigating greenhouse gases releases in order to save the earth from negative consequences of climate change. GHG inventory is a mandatory requirement of annex I parties ratified under Kyoto protocol but has became a high priority among policy makers in annex II countries as well.

Cities and Climate Change Initiatives (CCCI) which implemented by UNHABITAT introduced a national project to formulate City Development Strategies to respond climate change in Sri Lankan cities. Negombo Municipal Council (NMC) and Batticaloa Municipal Council (BMC) are the two selected demonstrative projects in the country at first phase of this programme. University of Moratuwa with the support of UNHABITAT prepared the first two city level GHG emission inventories in Sri Lanka respectively for NMC and BMC keeping a remarkable step in localizing national climate change action plan and building local government consensus on emerging climate change issues. This report presents the GHG inventory prepared for NMC and its surroundings.

This report is an informative database which expected to update serially, for Negombo Municipal Council (NMC) and the concerned two local governments at the vicinity. The series of reports may effectively asses the City GHG emission levels and performance of mitigations whiles this act as the benchmark study.

This GHG Inventory has documented as per the *2006 IPCC Guidelines for National Greenhouse Gas Inventories* produced by Inter Governmental Panel on Climate Change (IPCC) as per the recommendations of United Nation Framework Convention on Climate Change and the '*International Standard for Determining Greenhouse Gas Emissions for Cities, 2010' (Draft, June 2010)*[1] developed jointly by UNEP, UN-HABITAT, World Bank and supported by Cities Alliance.

GHG inventory report includes a set of standard reporting tables as specified in the 'International Standard for Determining Greenhouse Gas Emissions for Cities, 2010 (Draft, June 2010) covering three GHG gases with a written report that documents the methodologies, assumptions and data used to compute the estimates. The findings were discussed with local stakeholders and developed participatory GHG mitigation plan for way forward.

[1] VERSION 2.1, 28 JUNE. 2010. Information from: Soraya Smaoun (UNEP) soraya.smaoun@unep.org, Raf Tuts (UN-HABITAT) Raf.Tuts@unhabitat.org, Daniel Hoorweg (World Bank) dhoornweg@worldbank.org

2. INTRODUCTION TO CLIMATE CHANGE SCIENCE

1.1. What is climate change?

Climate is the long-term[2] average of weather patterns observed for a particular region. It includes the variation of temperature, precipitation, humidity, wind and other climatic variables. Climate change can be either natural or anthropogenic forced.

The natural factors as continental drift, volcanoes, ocean currents, the earth's tilt, and comets and meteorites have been causing a gradual climate change, more like a natural process of change. Anthropogenic factors which are the human activities change the environment have accelerated this change and thus making it a global concern. According to the IPCC reports, modern climate change is dominated by human influences, which are now large enough to exceed the bounds of natural variability. The biggest and probably the root anthropogenic cause of climate change is exponential increase in emissions of Greenhouse Gases, thereby leading to global warming.

Intergovernmental Panel on Climate Change (IPCC) defines "climate change" as "a change in the state of the climate that can be identified by changes in the mean and / or the variability of its properties, and that persists for an extended period, typically decades or longer".

IPCC Fourth Assessment Report, Working Group I, Glossary of Terms: http://ipcc wg1.ucar.edu/wg1/Report/AR4WG1_Print_Annexes.pdf.

The United Nations Framework Convention on Climate Change (UNFCCC) defines climate change as the change that can be attributed "directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

UNFCCC Article 1, Definitions: http://unfccc.int/essential_background/convention/background/items/1349.php

Various hypotheses for anthropogenic climate change have been argued for last decades. Currently the scientific consensus on climate change is that human activity is very likely the cause for the rapid increase in global average temperatures over the past several decades. These perturbations primarily result from emissions associated with energy use, but on local and regional scales, urbanization and land use changes are also important. Cities being subjective to intensive energy consumption account for large quantities of GHG emissions. Transportation, waste management and conversion of green fields to brown fields are very important among all.

[2] According to the World Meteorological Organization, 30 years or more

1.2. Climatic changes during the 20th century due to global warming

Some recent trends and observed climatic variability confirms that the global climate is changing. The following are some of the impacts observed due to global warming during the 20th century.

- A rise of global sea level by an average annual rate of 1-2 mm during the 20th century
- Decrease of snow cover by 10%.
- Intensification of the hydrological cycle and the increase of precipitation by 0.5 – 1.0% per decade over most mid and high latitudes in the Northern Hemisphere.
- Decrease of rain fall by 0.3 % per decade on the average, over much of the subtropical land areas. Over tropical lands, rainfall is likely to increase by 0.3% per decade.
- Increase in the frequency and severity of drought in recent decades in parts of Asia and Africa.
- Increase in the frequency and intensity of El Nino events during the last 2-3 decades
- Lengthening of the growing season by about 1-4 days per decade, during the last 4 decades in the Northern Hemisphere.
- Earlier plant flowering, bird arrival, emergence of insects and earlier dates of the breeding season.
- Increased frequency of coral reef bleaching, especially during El Nino events.
- It is projected that that the global average temperature will increase by from 1.4°C to 5.8°C between 1990 and 2100. The projected increase from 1990- 2025 and 1990-2050 is 0.4-1.1°C and 0.8°C to 2.6°C respectively

Source: Ratified UNFCCC in 1994

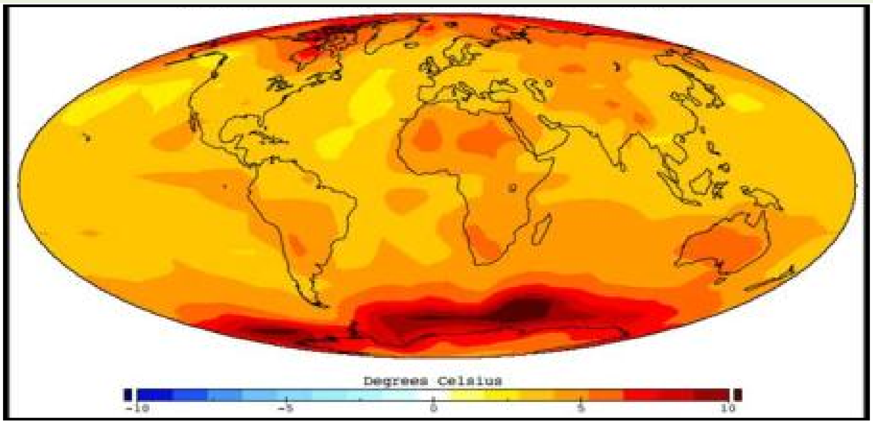
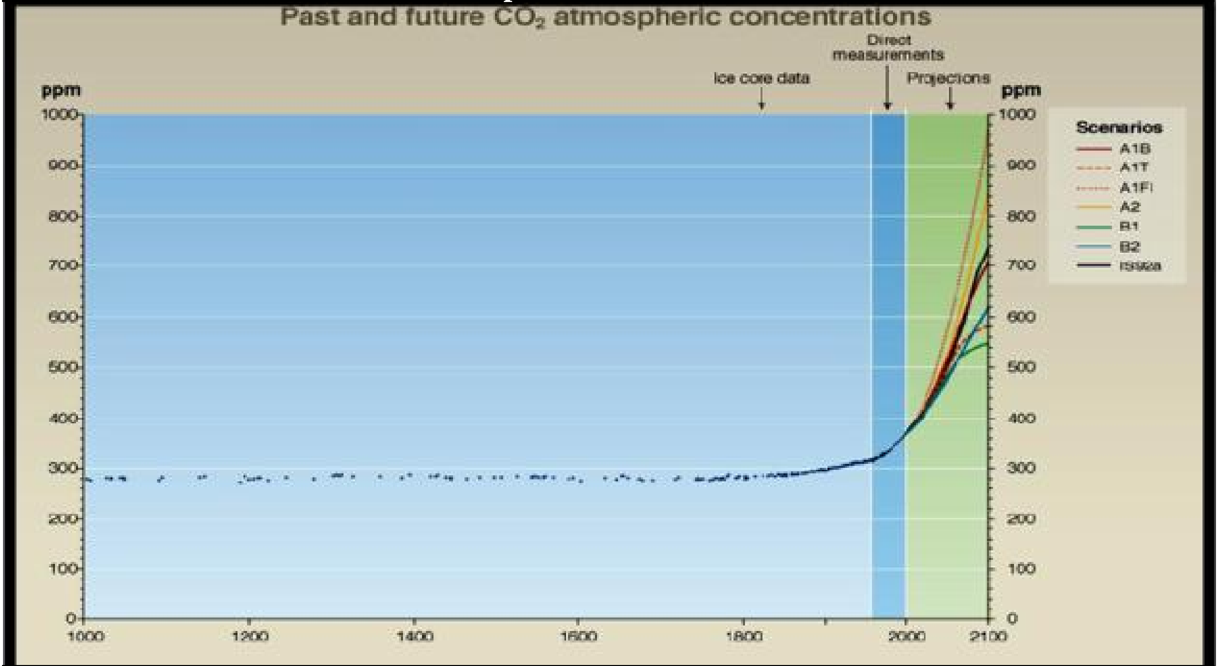


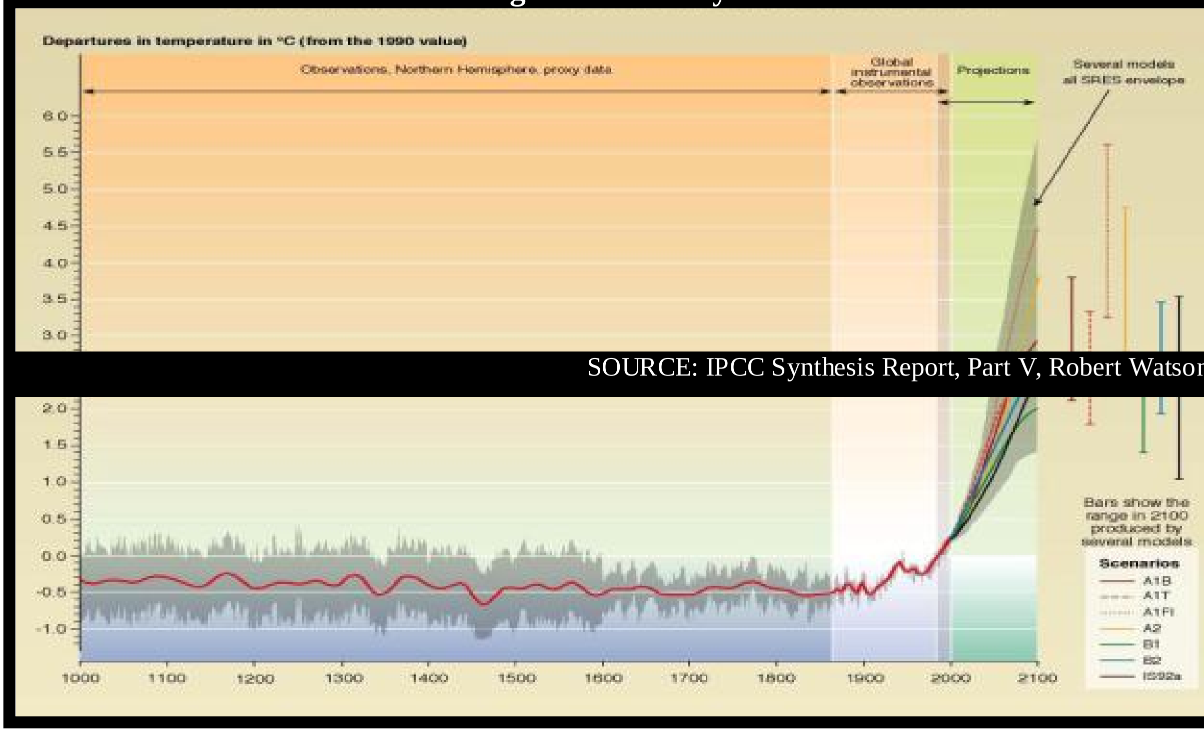
Figure 2.2: Surface air temperature increase 1960-2060, Source: IPPC, Working Paper Series

Projected concentrations of CO_2 during the 21st century are two to four times the pre-industrial level



SOURCE: IPCC Synthesis Report, Part V, Robert Watson

Projected temperatures during the 21st century are significantly higher than at any time during the last 1000 years



SOURCE: IPCC Synthesis Report, Part V, Robert Watson

1.3. Climate change – Negombo Area

There is a significant variation of annual rainfall records taken from Katunayake meteorological station for the period of 1970 to 2009. Rainfall recorded at January during last decade has increased almost two times than the previous decade. Standard Deviation of annual rainfall variability in each decade reveals an increasing trend. This high degree of variability may distort the long term cyclic patterns and regular predictable return periods of extreme climatic events.

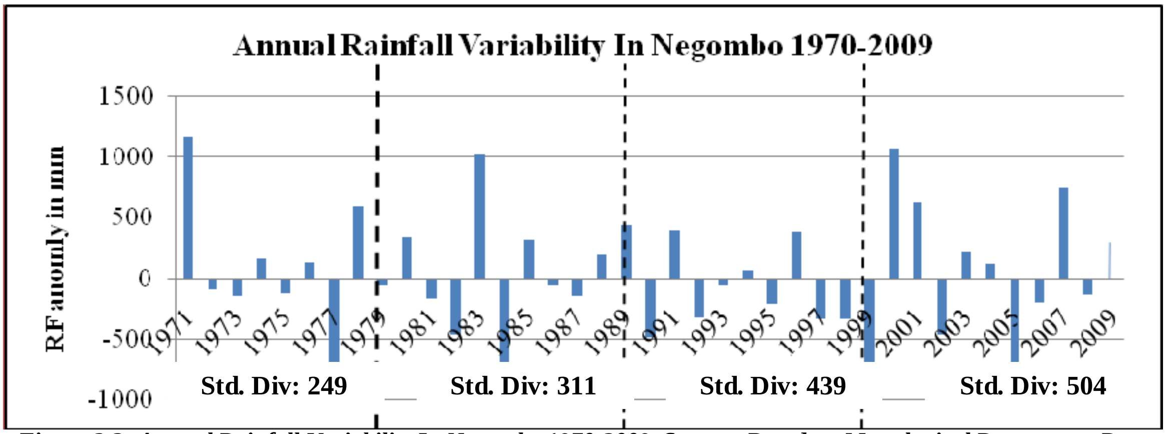


Figure 2.3: Annual Rainfall Variability In Negombo 1970-2009, Source: Based on Metrological Department Data

Peak incident of five consecutive months (December, January, February, March, April) during monsoon records an increasing monthly rainfall. However, the rainfall recorded at July which is well known as the peak of South-West monsoon has reduced by about half during the last decade compare to two previous decades.

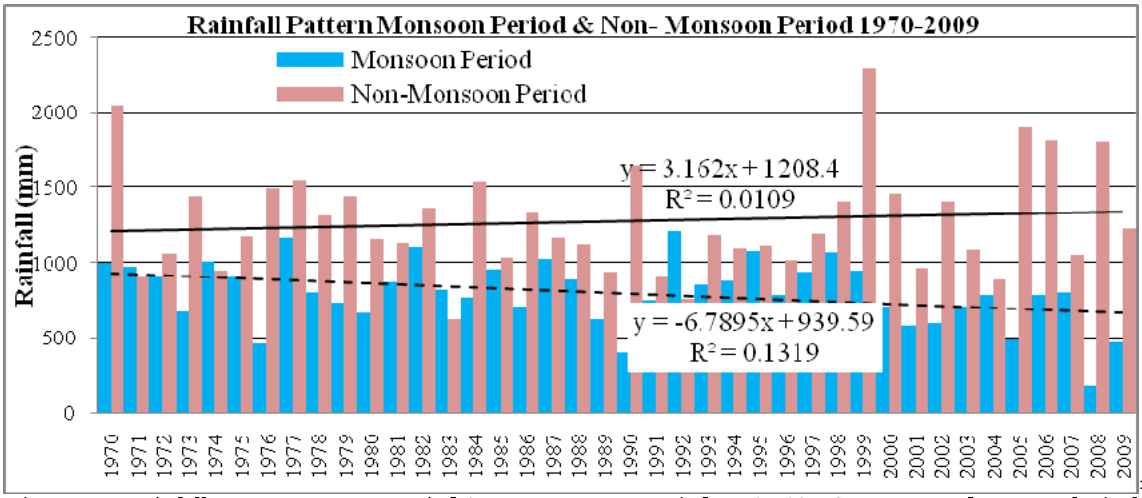


Figure 2.4: Rainfall Pattern Monsoon Period & Non- Monsoon Period 1970-2009, Source: Based on Metrological Department Data

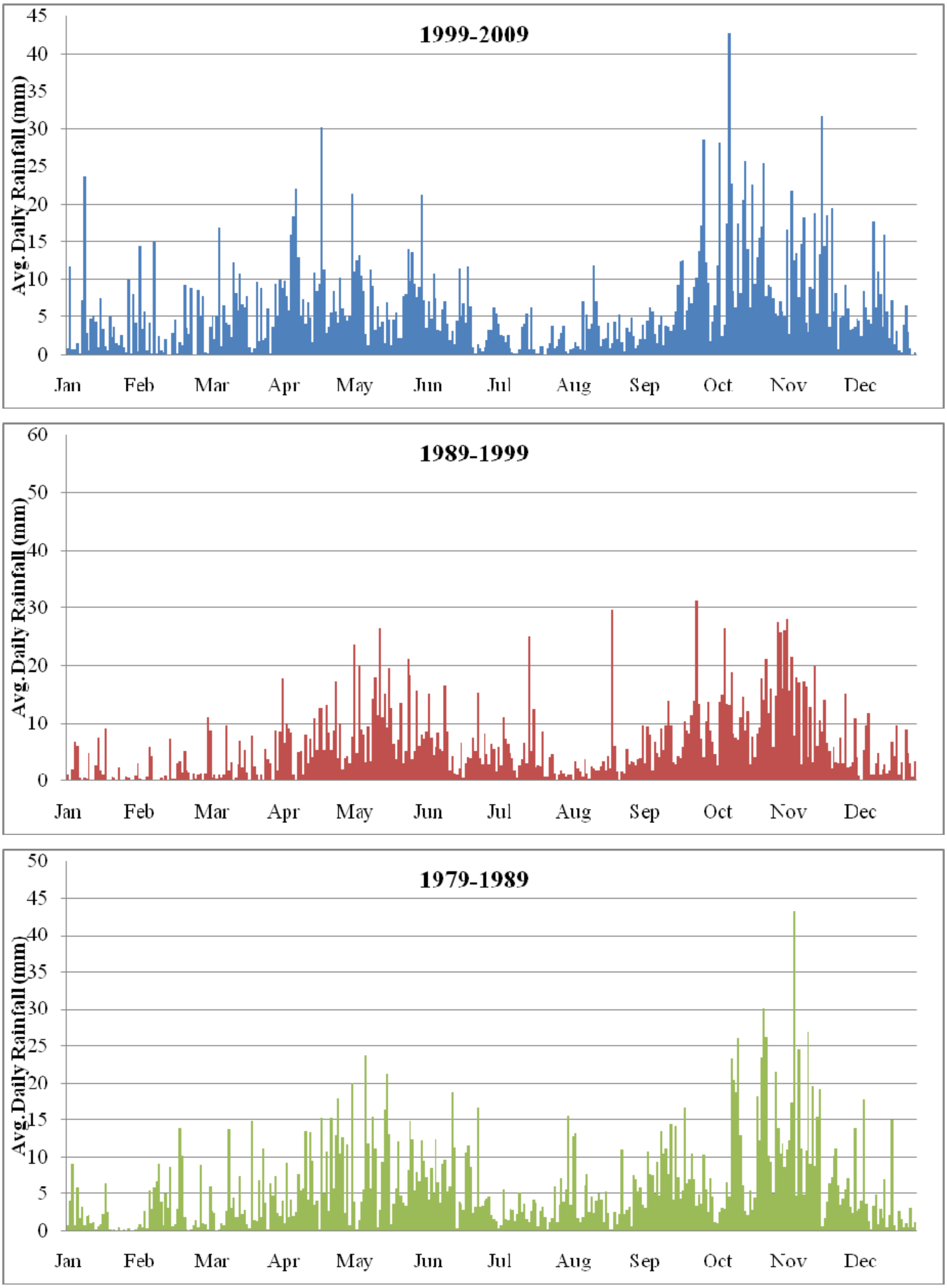


Figure 2.5: Seasonal Changes in Rainfall Pattern, Source: Based on Metrological Department Data

There is a significant increase in number of days having rainfall more than 90mm per day.

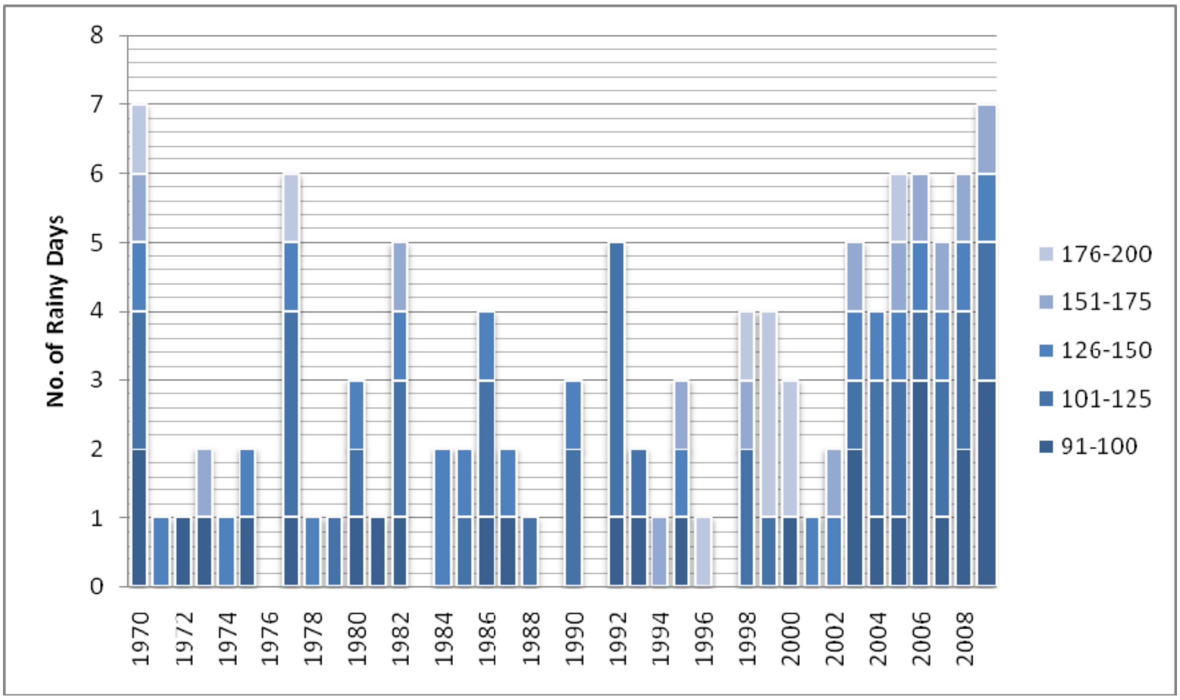


Figure 2.5: No. of Rainy Days, Source: Based on Metrological Department Data

Average monthly temperature of Katunayake observation station is varying from 30 ^{0}C to 32^{0}C. During last forty years the maximum temperature of 38.4^{0}C mm recorded in 1980 January and the minimum temperature of 27.9^{0}C mm recorded in 1978 January.

Annual mean air temperature has showed a decreasing trend during recent few decades in Negombo area. The rate of decrease of mean temperature for the period of 1980-2009 is 0.01^{0}C per year.

Average annual temperature which was 31.75 ^{0}C during 1980 to 1990 has decreased up to 31.28 ^{0}C during 2000 to 2009 by 0.47 ^{0}C. Average decadal temperature has recorded a sharp decrease during the decades from 1990 to 2009 compared to 1980 -1990. However, there is an increase in number of days having temperature 30-32^{0}C in last few decades compared to previous decades

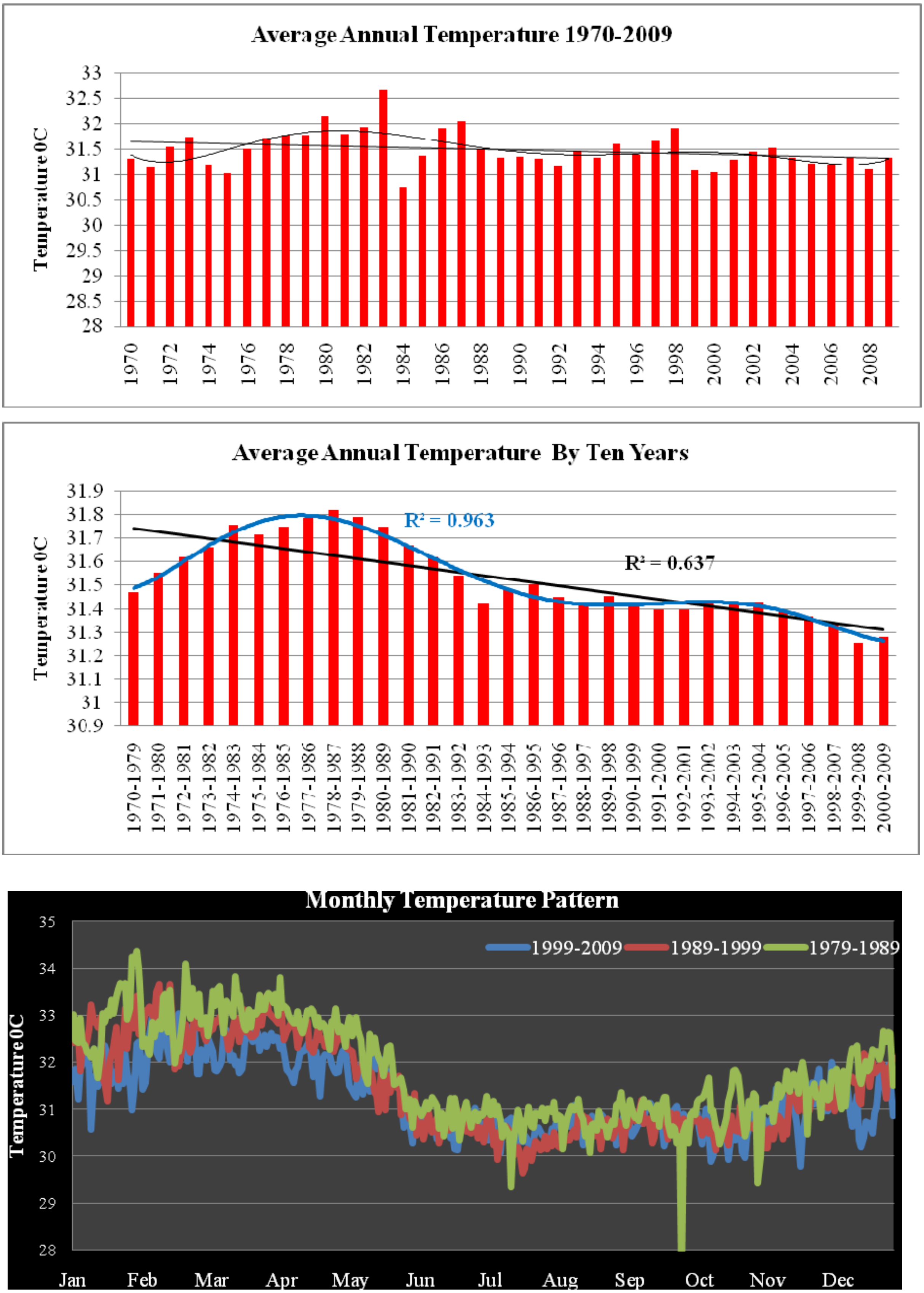


Figure 2.6: Changer in Temperature pattern in Negombo Area, Source: Based on Metrological Department Data

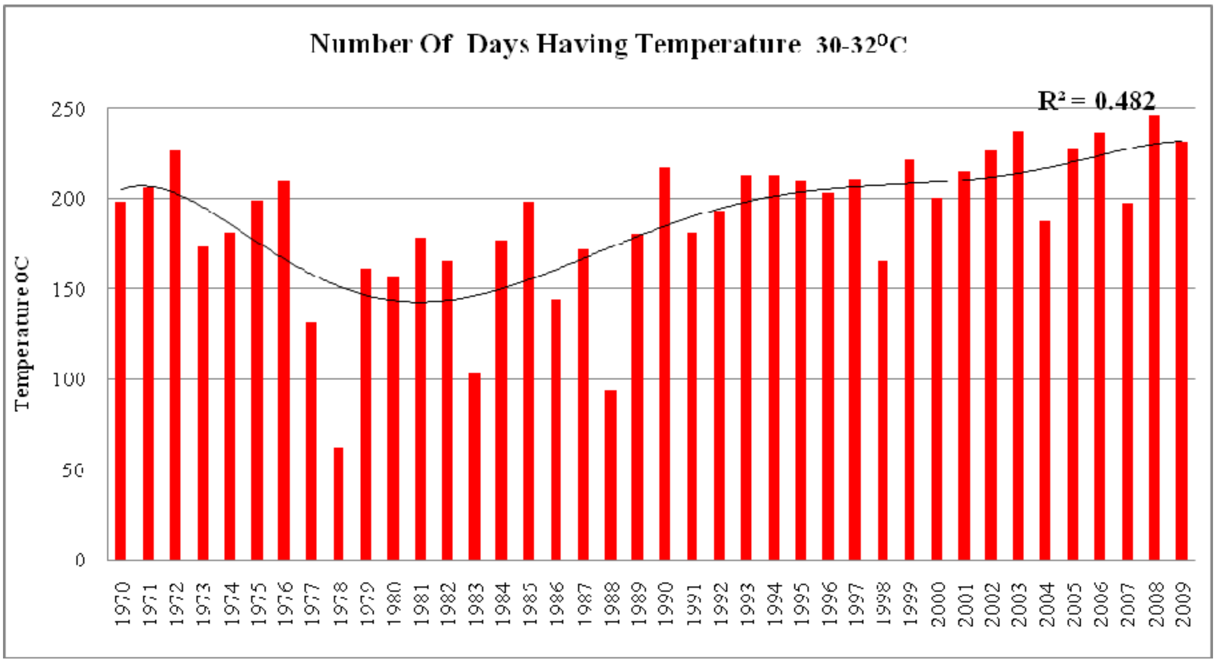


Figure 2.7: Number of Days Having Temperature 30-32^{O}C, Source: Based on Metrological Department Data

Average monthly temperature reduction in Last decade is significant in five consecutive months is December, January, February, March and April. These five months have observed to be increasing monthly rainfall at last decade compared to previous two decades.

2.1.: Percentage increase in Rainfall and Temperature from 1980-1999 to 2000- 2009

	Percentage increase from 1980-1999 to 2000- 2009	
	Temperature (%)	**Rainfall (%)**
January	**-2.88**	**+136**
February	**-1.65**	**+64**
March	**-2.04**	**+49**
April	**-2.23**	**+27**
May	**-0.8**	**-24**
June	**-0.56**	**-21**
July	**-0.23**	**-40**
August	**0.7**	**-20**
September	**0.1**	**-24**
October	**-1.03**	**34**
November	**-0.32**	**-14**
December	**-0.18**	**+30**

Source: Based on Metrological Department Data

There is a significant relationship between decreasing monthly average temperature and increasing monthly average rainfall. There is a strong positive correlation between these two 0. 8169 sets of values. This relationship needs to be further established through a detailed analysis on Humidity changes annual changes.

1.4. Green House Gases (GHG)

Greenhouse gases (GHG) are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of infrared radiation emitted by the Earth's surface, the atmosphere and clouds. This property causes the greenhouse effect.

The global negotiations to reduce greenhouse gases focus on a number of gases that are caused by human activity. The United Nations Framework Convention on Climate Change (UNFCCC) has specified following six green house gases in Kyoto protocol.

GHG's listed in Kyoto Protocol

- Carbon Dioxide - (CO_2)
- Methane - (CH_4)
- Nitrous Oxide - (N_2O)
- Hydrofluorocarbons - (HFCs)
- Perfluorocarbons - (PFCs)
- Sulphur Hexafluoride - (SF6).

CO_2 is the most prominent anthropogenic greenhouse gas and CH_4 and N_2O are also commonly found in urban areas. HFCs, PFCs and SF6 are very powerful but may play a less prominent role in the discussions at the local government level in developing countries.

Greenhouse gases are not equal in terms of their ability to capture and remit heat. The global warming potential (GWP) of each GHG takes into account both the ability to trap heat and the lifetime of the gas. The global warming potential (GWP) depends on both the efficiency of the molecule as a greenhouse gas and its atmospheric lifetime. GWP is measured relative to the same mass of CO2 and evaluated for a specific timescale.

Species	Chemical formula	Lifetime (years)	Global Warming Potential (Time Horizon)		
			20 years	100 years	500 years
CO_2	CO_2	variable **	1	1	1
Methane *	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170

Source: Climate Change 1995, The Science of Climate Change: Technical Summary of the Working Group I Report, page 22
*The GWP for methane includes indirect effects of tropospheric ozone production and stratospheric water vapour production
** Derived from the Bern carbon cycle model.

Carbon dioxide has a variable atmospheric lifetime, and cannot be specified precisely. Recent work indicates that recovery from a large input of atmospheric CO_2 from burning fossil fuels will result in an effective lifetime of tens of thousands of years. Carbon dioxide is defined to have a GWP of 1 over all time periods. Methane (CH_4) and nitrous oxide (N_2O) are 21 and 310 times more potent than carbon dioxide (CO_2) respectively.

3. EMISSION INVENTORY

1.5. Compilation of GHG inventory

Compiling a greenhouse gas inventory is a sequential process. Following steps have adopted in preparation of GHG Inventory for NMC and vicinity area.

Step 1:
Identify available GHG sources in Study areas (NMC & visinity).

Step 2:
Selection of key sectors; caegories and list out GHG sources by categories

Step 3:
List out required data to find out GHG emissions according to Tier one, Tier two andTier three methods

Step 4:
Inquire availability of secondary data and ability to collect primary data according to three tiers

Step 5:
Select suitable tier/method to estimate GHG emissions by sectors.

Step 6:
Collect required secondary & primary data

Step 7:
Compute GHG emissions (Estimations and removals)

Step 8:
Documentation of GHG Inventory

Original steps specified in IPCC guidelines have customized according to the specific requirements of local context and scope of the project.

1.6. Methods of estimation

One of the most challenging tasks at project design is to select best methodologies for computation of GHG emissions/removals avoiding double counting and omissions.

Selection of appropriate methodology is based on several factors as;

- Methodology adopted by Draft National GHG Inventory
- Sectors selected in draft national GHG inventory
- Degree of local stakeholder awareness on climate change
- Availability of data
- Time and resource availability for primary data collection

This inventory rely on Tier one and Tier two; basic and intermediate methods of GHG computation due to the constraints of data collection in this project, and limitations in draft national GHG inventory of the country. Data requirement of each selected category under all three Tiers have listed and then compared with available data sources. With respect to key categories, the possibility to collect secondary data have considered on the basis of time and resource availabilities. Thereafter, the most possible Tier has selected by each category following the steps specified in IPCC decision trees. This process is depicted in Annexure 1 in this document for detailed references.

In spite of limited data and information, this inventory is a truly attempt to ensure good practices of reporting. As per 2006 Guidelines, *good practices are* those which *contain neither over- nor under-estimates as far as can be judged, and in which uncertainties are reduced as far as practicable*.

As with the IPPC guidelines, this inventory follows one of the simplest methodological approaches combining Activity Data (AD) into Emission Factors (EF).

Hence the basic equation is,

GHG Emissions = AD • EF

Where,
AD = Information on the extent of anthropogenic activities take place
EF = Coefficients which quantify the emissions or removals per unit activity

Methodology explained in IPCC guidelines have designed with appropriate methodologies adopted at national level. These approved methodologies have a certain degree of flexibility yet some aspects need to be reconsidered at the application of city level. However, method use to collect Activity Data have mentioned at each entry to ensure transparency of reporting.

1.7. Concepts adopted in preparation of GHG inventory

Concepts adopted are very important to understand the scope and definitions used in the inventory. It makes the inventory comparable to other city level inventories and capable to update consecutively.

Time bound

This GHG inventory of the city is a first study volume of a series which will be the benchmark for future updates.

The benchmark study have documented for a period of one calendar year starting from 1st January 2010 to 31st December 2010 in this inventory. Therefore, all possible data sources have used as per the records obtained through the above period. However, circumstances where suitable data to follow this principle are missing, emissions/removals have estimated using data from other years applying appropriate methods such as averaging, interpolation and extrapolation.

Territorial limits

Clearly defined boundaries are very important to avoid overlapping and exclusions of spatial units. Initially, local authority boundary of the city has taken as the concerned geographic area of the city. The key reasons for the selection are;

- Local authority boundaries are legally defined administrative boundaries. (There are two such local level boundaries are, D.S. Division boundary and Local authority boundary.)

- Local Authority boundaries (Municipal council boundaries)often consider as city limits for revenue purposes
- Local authorities have decision making powers and political authority which could make strong decisions on Green House Gas emissions/removals within the boundary.

'International Standard for Determining Greenhouse Gas Emissions for Cities, 2010' (Draft, June 2010) gave light in this revised report leading to prepare boundary-extended inventory which provide more realistic picture in complex urban form.

"This standard also recognizes that the vitality of cities gives rise to the production of GHG emissions outside of urban boundaries. This standard follows the World Resources Institute / World Business Council for Sustainable Development (WRI/ WBCSD) protocol by including out-of-boundary emissions that are driven by activities in cities. While it is impractical to quantify all of the emissions associated with the myriad of goods and materials consumed in cities, urban GHG inventories must include:

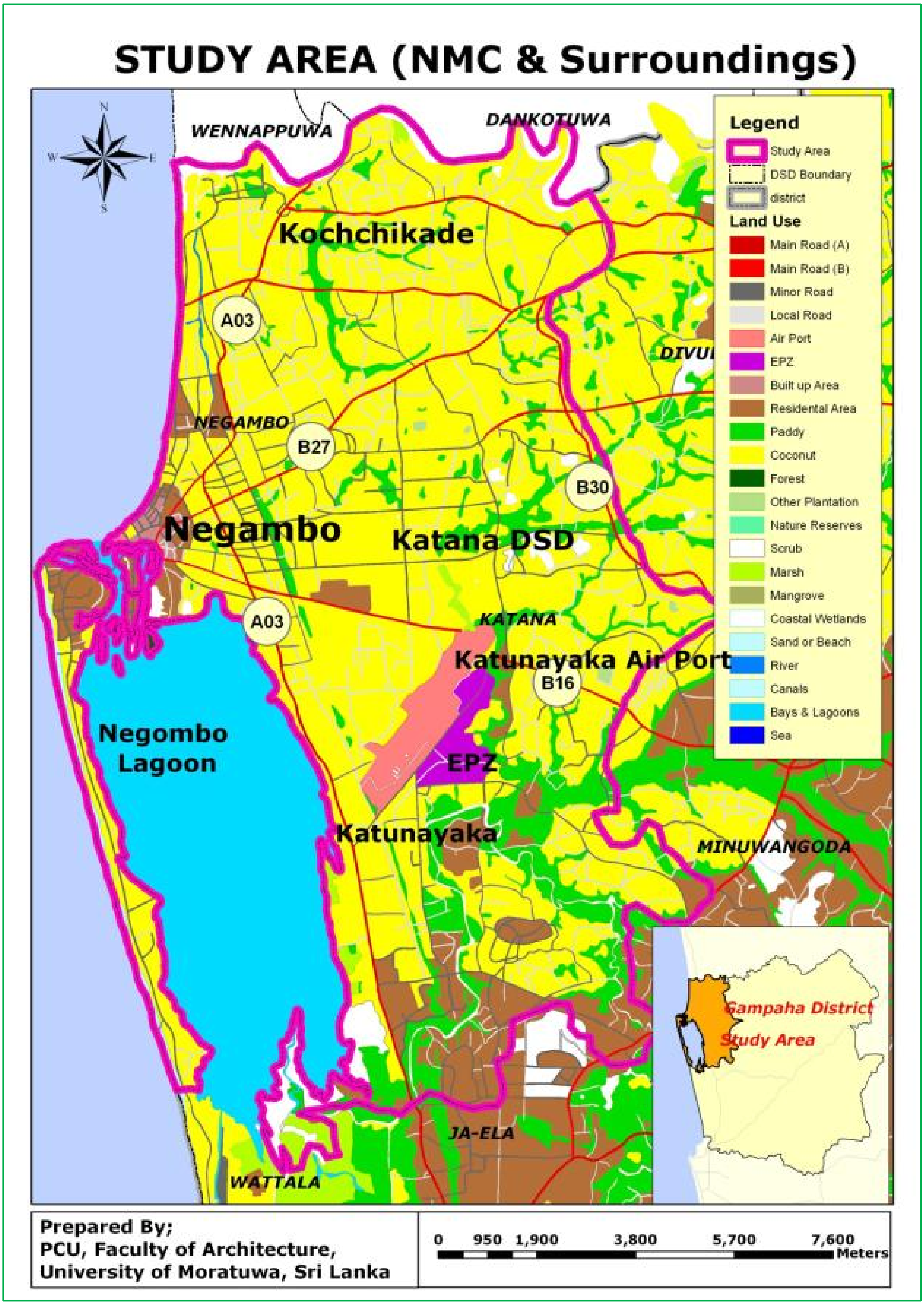
- Out-of-boundary emissions from the generation of electricity and district heating which are consumed in cities (including transmission and distribution losses);
- Emissions from aviation and marine vessels carrying passengers or freight away from cities;
- Out-of-boundary emissions from waste that is generated in cities.

The GHG emissions embodied in the food, water, fuels and building materials consumed in cities should also be reported as additional information items. This is to avoid policies or actions that lower emissions inside of cities, but at the expense of greater emissions outside of cities.

The determination of urban GHG emissions by this standard does not imply that local governments are responsible for these emissions. Rather the inventory reflects the carbon dependence of the urban economy and highlights the extensive experience that local governments already have in monitoring GHG emissions. The standard formatting by local governments would be consistent with national inventories and subject to regional and national compilations as overseen by national directives."

Source: International Standard for Determining Greenhouse Gas Emissions for Cities, 2010' (Draft, June 2010)

Negombo urban area acts as a service centre for a large catchment connecting to A3, national highways and B27, B16 regional arteries. NMC has a strong link to Katunayake Economic Processing zone as well. Urban Development Authority, Sri Lanka has identified the catchment of Negombo including two associated small towns are Kochchikade and Katunayake. Accordingly the declared region under the Negombo growth centre has taken as the study area.


STUDY AREA (NMC & Surroundings)
WENNAPPUWA
DANKOTUWA
Legend
Study Area
DSD Boundary
district
Land Use
Main Road (A)
Main Road (B)
Minor Road
Local Road
Air Port
EPZ
Built up Area
Residental Area
Paddy
Coconut
Forest
Other Plantation
Nature Reserves
Scrub
Marsh
Mangrove
Coastal Wetlands
Sand or Beach
River
Canals
Bays & Lagoons
Sea
Kochchikade
A03
NEGAMBO
B27
B30
Negambo
Katana DSD
KATANA
A03
Katunayaka Air Port
B16
Negombo Lagoon
EPZ
Katunayaka
MINUWANGODA
Gampaha District
Study Area
JA-ELA
WATTALA
Prepared By;
PCU, Faculty of Architecture,
University of Moratuwa, Sri Lanka
0 950 1,900 3,800 5,700 7,600
Meters

Sources of emissions

This inventory comprised with the anthropogenic emissions/removals of Green House Gases. It does not contain the records of natural sources of emissions and sinks which beyond the human interventions. This is because; the aim of this inventory is to formulate local level strategies to mitigate GHG emissions and to serially asses the performance of set mitigation targets.

IPCC guidelines outlines three emissions sources (referred to as '*scopes*') that provide framework for operational boundaries. The three scopes are:

- **Scope 1: "Direct Emissions,"** represent emissions from the combustible fuels and other sources that occur directly within city limits and mobile emission sources.
- **Scope 2 : "Indirect Emissions,"** represent emissions that occur outside the city limits to produce electricity or steam purchased for use at corporate locations.
- **Scope 3: "Other Indirect Emissions,"** represents emissions from activities taken place at outside the city such as automobile traffic, fishery boat riding.

First two scopes consider as mandatory requirement under the GHG Protocol, while the third scope considered as optional to track and report.

In adopting the WRI/WBCSD Greenhouse Gas Protocol for corporations, GHG emissions attributed to cities and local regions can be classified as follows:

- **Scope 1:** GHG emissions that occur within the territorial boundary of the city or local region
- **Scope 2:** Indirect emissions that occur outside of the city boundary as a result of activities that occur within the city, limited to only: electricity consumption and district heating, steam, cooling
- **Scope 3:** Other indirect emissions and embodied emissions that occur outside of the city boundary, as a result of activities of the city, including (but not limited to): Electrical transmission and distribution losses, solid waste disposal, waste incineration, wastewater handling, aviation, marine, embodied emissions upstream of power plants, embodied emissions in fuels, embodied emissions in imported construction materials, embodied emissions in imported water and embodied emissions in imported food

Accordingly, this inventory included GHG emissions that

- **Scope 1:** GHG emissions that occur within the territorial boundary of the city including stationary and mobile emission sources
- **Scope 2:** represent emissions that occur outside the city limiting to electricity[3] consumption[4]
- **Scope 3:** emissions from activities taken place at outside the city are: solid waste disposal, waste incineration, wastewater handling, automobile traffic and fishery boat riding

Operational boundary conditions provide depth to the inventory by identifying which emissions sources are accounted for within the defined territorial limits.

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[3] Electrical transmission and distribution losses are incorporated
[4] there were no any district heating, steam, cooling recorded in the study area.

Types of gases

This inventory is strict to the recommended gases mentioned in IPCC guidelines. Accordingly, This Inventory contends the emissions of following three greenhouse gases.

- Carbon Dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)

Sectors and categories

There are four key sectors need to address in GHG Inventory as per IPPC 2006 guidelines. Namely; Energy, Industrial Processes and Product Use (IPPU), Agriculture, Forestry and Other Land Use (AFOLU) and Waste. Similarly, Draft National Inventory of Sri Lanka, 2000 also uses the above four categories.

IPCC use the concept of *key category* is to identify the categories that have a significant influence on a country's total inventory of greenhouse gases in terms of the absolute level of emissions and removals, the trend in emissions and removals, or uncertainty in emissions and removals. Identification of key Categories is important to prioritize investments on GHG inventories while ensuring optimum resource allocation for data collection and reporting. Selection of key categories of each sector performed through core-team discussion based on local knowledge and initial Field observations at cities which has described at inception report of this project.

Accordingly, GHG inventory of study area has identified three sectors as key sectors.

I. Energy
II. Agriculture, Forestry and Other Land Use (AFOLU)
III. Waste

Industrial Processes and Product Use (IPPU) have omitted from the inventory because though there is a sound Industrial base there are very limited industries which contributed to GHG emissions. The industrial profile of the area predominantly consists of light industries which have not listed in IPCC guidelines. There are very few listed industries but is small scale. Number of industries by type in each city is given below.

Table 3.1.: Types of industries in Study Area (excluding EPZ Katunayaka)

Type of Industry	Small Scale Industries	Medium Scale Industries
Bakery	8	7
Boat Manufacturing Centers	6	5
Roof tile mills	34	0
Fibre works	6	1
Coconut Charcoal	4	0
Engineering Works	14	6
Garments	3	6
Ice Production	3	7
Printing	18	3
Soap Production	6	2
Timber Mills	12	2
Tire house	3	1
Coconut oil	1	1
Rice Mills	1	0
Bricks	1	2

(Source: Resource Profile, DSD Negombo, Katana DSD & Registry of Industry CEA Gampaha)

Table 3.2.: Types of industries in EPZ Katunayaka

Type of Industry	Large Scale Industries	Medium Scale Industries	Small Scale Industries
Garment factories	12	24	3
Footwear's and Bags	3	2	1
Floral production	1	1	
Jewellery production		2	1
Electrical equipments	1	1	2
Fishery products		3	
Container operations		1	
Injector equipments		1	
Gem cutting and polishing	1	1	
Steel production			1
Thread production			1
Trading centre			1
Sponge and Gloves production		1	
Paper bags production			1
Sports equipments		1	
Magnet equipments			1
Rubber equipments		1	
Toys and gifts			1
Nails and fastens		1	
Doors and windows equipments			1
Housing equipments		1	
Stationeries			1
Parachute production		1	
Printing		1	
Computer equipments		1	
Tobacco	1		
Painting brushes		1	

(Source: BOI, Sri Lanka 2010)

Following criteria used to identify the level of significance of the each industry to city GHG emissions.

1. Number of industries
2. Production process and GHG emissions
3. Scale of production

Selected industries from first two criteria are visited (30-50% sample) and discussed with manufactures. As revealed in the discussions and observations those industries have insignificant contributions at production process, therefore not included into the inventory. However, energy consumption of these industries have considered in the Energy sector of this inventory.

There are number of categories under each sector defined in IPCC and selected at National Inventory. Selected sectors and categories of inventory items are attached in Annexure 2.1 & 2.2 detail reference.

4. GREEN HOUSE GAS INVENTORY FOR NEGOMBO MC & SURROUNDINGS

4.1. Sector one: Energy

Energy sector mainly refers to Fuel Combustion activities. Fuel combustion, has categorized into four types for emission assessment in Draft National Green House Gaseous Inventory, i.e. energy industries; manufacturing industries and construction, transport and other sectors having emissions from energy consumption. In this inventory, following sectors have identified as key sources.

Stationery Sources:

I. Manufacturing Industries & Construction
II. Commercial/Institutional
III. Residential
IV. Agriculture
V. fishery

Mobile Sources:

VI. Road Transportation
VII. Railway Transportation

The following formula was applied to compute GHG emissions from specific activities as per the process specified in Tier 02.

$$\textbf{Emission}_{GHG,,Fuel} = \textbf{Fuel Consumption}_{fuel} * \textbf{Country Specific Emission Factor}_{GHG,,Fuel}$$

Country specific emission factors which used for calculation, were obtained from the draft national Inventory, 2000. Other specific references have presented at the end of each section.

4.1.1. Energy sector - Manufacturing industries & construction

Types of industries available in study area as per 2010 registry are listed below. There are very limited number of industries which pre-dominantly small in scale.

Table 4.1.: Types of industries in Study Area (excluding EPZ Katunayaka)

Type of Industry	Small Scale Industries	Medium Scale Industries
Bakery	8	7
Boat Manufacturing Centers	6	5
Roof tile mills	34	0
Fibre works	6	1
Coconut Charcoal	4	0
Engineering Works	14	6
Garments	3	6
Ice Production	3	7
Printing	18	3
Soap Production	6	2
Timber Mills	12	2
Tire house	3	1
Coconut oil	1	1
Rice Mills	1	0
Bricks	1	2

(Source: Resource Profile Negombo DSD Office, Katana DSD, Annual Budget Negombo MC, Inventory on Industries CEA Office Gampaha)

Energy generated through electricity is directly obtained from resource profile (annually compiled by D. S. Division) and verified from Electricity Board, LECO records. Average amount of fuel consumption from other sources have computed through a sample survey (primary data collection).

Stratified random sampling method was employed with stratification based on types of industries. 30-50% sample size was desirable according the scope of study yet each type need to be represented. Number of samples obtained and sample sizes have mentioned in following table.

Table 4.2.: Number of samples obtained from Industries

Type of Industry	Number of Industries		Desired Samples (Sample Size 10%)		Number of samples Obtained		Obtained sample size (%)	
	SSI	MSI	SSI	MSI	SSI	MSI	SSI	MSI
Bakery	8	7	0.8	0.7	4	4	50.00	57.14
Boat Manufacturing Centers	6	5	0.6	0.5	3	3	50.00	60.00
Roof tile mills	34	0	3.4	0.0	5	0	14.71	-
Fibre works	6	1	0.6	0.1	3	1	50.00	100.00
Coconut Charcoal	4	0	0.4	0.0	2	0	50.00	-
Engineering Works	14	6	1.4	0.6	5	3	35.71	50.00
Garments	3	6	0.3	0.6	2	3	66.67	50.00
Ice Production	3	7	0.3	0.7	2	4	66.67	57.14
Printing	18	3	1.8	0.3	5	2	27.78	66.67
Soap Production	6	2	0.6	0.2	3	1	50.00	50.00
Timber Mills	12	2	1.2	0.2	5	1	41.67	50.00
Tire house	3	1	0.3	0.1	2	1	66.67	100.00
Coconut oil	1	1	0.1	0.1	1	1	100.00	100.00
Rice Mills	1	0	0.1	0.0	1	0	100.00	-
Bricks	1	2	0.1	0.2	1	1	100.00	50.00
Total	**120**	**43**	**12.0**	**4.3**	**44**	**25**	**36.67**	**58.14**

SSI = Small scale Industries, **MSI**= Medium Scale Industries

Electricity is the most significant energy source of all above industries. Electricity obtains from National Power Grid and there is no any at-source electricity production presents within the city limits. Bakeries use firewood as a main source but none of the other industries have significant level of consumption other than electricity. Electricity is the main energy source of industries locates in EPZ-Katunayaka.

Table 4.3.: Annual energy consumption by Industries in Study Area

Energy Source	Annual Energy Consumption	Unit	
Electricity (KWH)	1,059,884	KWH	Source : LECO Negombo, Resource Profile of Negombo DSD & Katana DSD Katunayake Export Processing Zone – Statistics, BOI, Sri Lanka for EPZ data
Fuel wood	57,000	Kg	Annual Energy Consumption = No. of Bakery*Avg. Monthly Fuel wood Consumption by Bakery (200kg) * 12

Table 4.4.: Calorific value & emission factors for energy sources

Energy Source	Conversion Factor - Calorific value of the fuel(TJ/kg)	CO_2 Emission Factor (kg/TJ)	CH_4 Emission Factor (kg/TJ)	N_2O Emission Factor (kg/TJ)
Fuel wood	0.0000155	29,900	300	4

(Source: Based on National GHG Inventory, Sri Lanka-2000 & IPCC 2000)

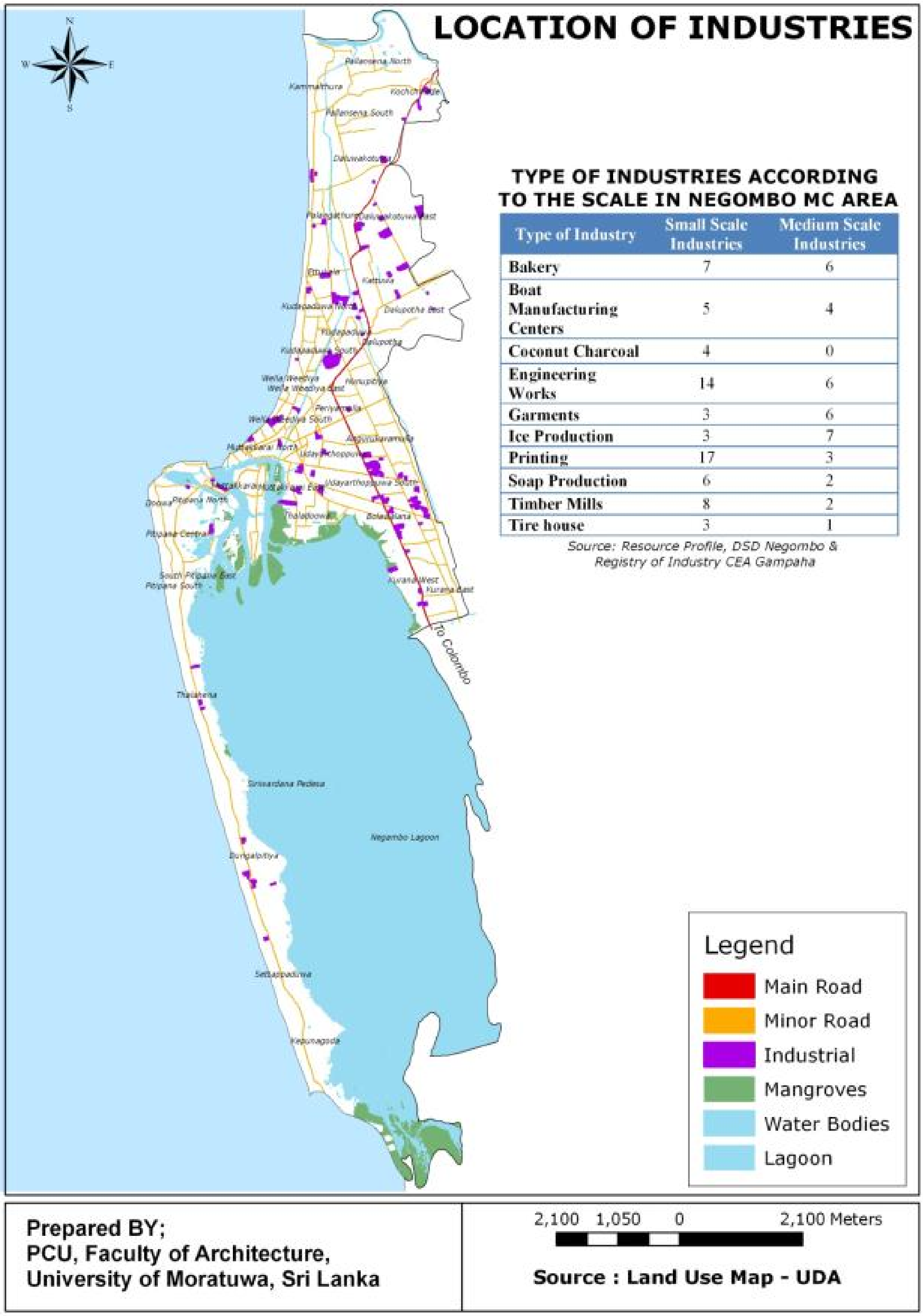
Table 4.5.: Average GHG emission for electricity production in Sri Lanka

GHG Source	Emissions for production of 100KWH(kg)
CO_2 (Biomass)	80.50
CO_2 (Fossil)	223.27
CH_4	0.02
N_2O	0.01

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.6.: Emissions from use of energy for industrial sources in Study Area

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Electricity	321,956.09	20.68	8.88
Fuel wood	26,416.65	2,650.50	3.53
Total	**348,372.74**	**2,671.18**	**12.41**



TYPE OF INDUSTRIES ACCORDING TO THE SCALE IN NEGOMBO MC AREA

Type of Industry	Small Scale Industries	Medium Scale Industries
Bakery	7	6
Boat Manufacturing Centers	5	4
Coconut Charcoal	4	0
Engineering Works	14	6
Garments	3	6
Ice Production	3	7
Printing	17	3
Soap Production	6	2
Timber Mills	8	2
Tire house	3	1

Source: Resource Profile, DSD Negombo & Registry of Industry CEA Gampaha

Note: Map indicate only NMC area

4.1.2. Energy sector - Commercial/Institutional units categories

Commercial and institutional units have taken as a combined category because Electricity consumption of these two sectors has recorded as one category in some resource profile (in respective D.S. Divisions). This data is highly accurate since it is count from the electricity billing records of Electricity Board & LECO.

Electricity is the prime source of energy use in commercial and institutional activities yet some commercial users assumed as consuming other energy. Those sources were listed through community discussions based on local knowledge. As revealed in the discussion, tea shops and hotels were selected as key categories which consume alternative energy sources. Tea shops and hotels use LPG for cooking and boiling water. Average consumption of LPG has counted based on a sample survey (primary data collection). Stratified random sampling method was employed with stratification based on types of industries. 10% sampl**e** size was desirable according the scope of study and number of samples obtained is representing in the following table.

Table 4.7.: Number of samples obtained from Commercial Activities

Type of activity	Number of activities	Desired Samples (Sample Size 10%)	Number of samples Obtained
Tea shops Hotels	179	17.9	20
Tourist Hotels	27	2.7	10
Total	**185**		**31**

(Source: Business and commercial registry NMC, 2010 and Statistical Hand Book in Gampha District)

Data and information were obtained inquiring the capacity of LPG cylinder/s and frequency of refilling. Accordingly, average LPG consumption per unit was calculated.

Table 4.8.: Annual energy consumption by commercial and institutional units according to type of energy source in Study Area

Source	Annual Energy Consumption	Unit	
Electricity	14,089,950	KWH	Source : LECO Negombo and Resource Profile of Negombo DSD & Katana DSD
LPG	123,600	Kg	Annual Energy Consumption =No. of Hotel*Avg. Monthly Fuel wood Consumption per Hotel (50kg) * 12 Annual Energy Consumption =No. of Tourist Hotel*Avg. Monthly Fuel wood Consumption per Tourist Hotel (100kg) * 12

Table 4.9.: Calorific value & emission factors for energy sources

Energy Source	Conversion Factor - Calorific value of the fuel(TJ/kg)	CO_2 Emission Factor (kg/TJ)	CH_4 Emission Factor (kg/TJ)	N_2O Emission Factor (kg/TJ)
LPG	0.0000473	17,200	10	0.6

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.10.: Average GHG emission for electricity production in Sri Lanka

GHG Source	Emissions for production of 100KWH(kg)
CO_2 (Biomass)	80.50
CO_2 (Fossil)	223.27
CH_4	0.02
N_2O	0.01

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.11.: Emissions from use of energy for commercial sources in Study Area

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Electricity	4,280,038.29	274.88	117.82
LPG	100,577.28	584.76	3.50
Total	**4,380,615.57**	**859.65**	**121.32**

LOCATION OF COMMERCIAL & INSTITUTIONAL UNITS

COMMERCIAL UNITS		INSTITUTIONAL UNITS	
Bakery	13	Financial & Insurance Institutions	294
Bar	3	Government Hospital	1
Boat Repairing Centers	6	Private Nursing Homes	5
Coolspots	22	Government Dispensary	4
Fish Selling Centres	13	Private Dispensary	76
Flowers Shop	7	Maternity Homes	4
Fruit Selling Shop	6	Government Clinics	14
Furniture	11	Pharmacy	17
Gas Selling Centers	23	Laboratory (X-Ray)	21
Glass Selling Centers	7	Laboratory (Other)	3
Hardware	46	Aurvedic Centres	9
Hotel L	21	Dental Clinics	8
Hotel M	25	Eye Clinics	4
Hotel S	31	Government Schools	34
Iron Works	10	Semi Government Schools	3
Jeweler Shop	72	Private Schools	5
Londrey /Cleaning Centers	7	International Schools	5
Medical Centers	7	Special Schools	2
Milk Bar	4	Pirivena	1
Panting Production Industry	10	Vocational Training Centres	5
Pester Shop	26	Computer Centres	28
Petrol Shade	6	Tuition Centres	62
Pharmacy	31	Pre Schools	75
Retail Shops	296	Sunday Schools	48
Saloon	66	Roman Catholic Churches	42
Shoe Selling Centres	14	Temples	8
Studio	8	Hindus Kovil	4
Tea shops & Hotels	164	Methodist Churches	2
Tailor Shop	46	Mosques	12
Tourist Hotels	21	Magistrate court	1
TV Repairing Centers	12	District court	1
Vegetabel Selling Shops	8	Police station	2
Vehicle Selling Centers	17	Library	11
Wood stores Centers	9	Main Post office	2

Source: Annual Budget NMC 2009, Resource Profile NDSD 2009

Legend

- Tourist Hotels
- Commercial
- Institutional
- Educational
- Main Road
- Minor Road
- Mangroves
- Water Bodies
- Lagoon

Prepared BY;
PCU, Faculty of Architecture,
University of Moratuwa, Sri Lanka

2,100 1,050 0 2,100 Meters

Source : Land Use Map - UDA

Note: Map indicate only NMC area

4.1.3. Energy sector - Residential category

Data records on source of energy use for cooking and lighting purpose are available in Statistical hand book of respective D.S. Division and district hand book Gampaha. Other energy uses are mainly consist of electric appliances as heaters for boiling water, Fans for air circulation, Irons for pressing clothes, refrigerators for cooling, and television and radios for entertainment. Electricity consumption of residential sector has recorded in the Resource Profile, as per the records of from electricity bills. GHG emissions as per domestic electricity consumption was computed from this secondary data sources, yet other sources of energy use for cooking and lighting was needed to estimate. Average energy consumption for cooking and lighting were obtained from a sample survey (primary data collection). Stratified random sampling method was employed with stratification based on types of industries. 100 samples were selected randomly and number of samples obtained is represent in following table.

Table 4.12.: Type of energy source using by family for lighting & cooking other than electricity in Study Area

Type of fuel	No. of Families*		Number of samples Obtained		Obtained sample Size	
	Lighting	Cooking	Lighting	Cooking	Lighting	Cooking
Kerosene	12,149	11,134	100	100	1.0	1.0
Fuel wood	-	44,921	-	100	-	0.2
LPG	-	23,434	-	100	-	0.4
Electricity	57,179	197	Consumption recodes directly taken by using LECO and CEB records			
Solar power	30		-			

(Source: Statistic Hand Book, respective D.S. Division and district hand book Gampaha - 2010)

Table 4.13.: Annual energy consumption by residential units, according to type of energy source in Study Area

Energy Source	Annual Energy Consumption	Unit	
Electricity	74,436,516	KWH	Source : Resource Profile, Katana DSD, LECO, CEB
Fuel wood	16,171,560	Kg	Monthly Avg. Fuel wood Consumption for Cooking per Family(kg) = 30kg
Kerosene	2,323,148	L	Monthly Avg. Kerosene Consumption for Cooking by Family(L) = 5.625 L Monthly Avg. Kerosene for Lighting per Family(L) = 11.25L
LPG	3,515,100	Kg	Monthly Avg LPG Consumption for Cooking per Family(kg) = 18.75kg

Table 4.14.: Calorific value & emission factors for energy sources

Energy Source	Conversion Factor - Calorific value of the fuel(TJ/kg)	CO_2 Emission Factor (kg/TJ)	CH_4 Emission Factor (kg/TJ)	N_2O Emission Factor (kg/TJ)
LPG	0.0000473	17,200	10	0.6
Kerosene	0.0000448	19,600	4	0.6
Fuel wood	0.0000155	29,900	300	4

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.15.: Average GHG emission for electricity production in Sri Lanka

GHG Source	Emissions for production of 100KWH(kg)
CO_2 (Biomass)	80.50
CO_2 (Fossil)	223.27
CH_4	0.02
N_2O	0.01

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.16.: Emissions from use of energy for residential units in Study Area

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Electricity	2,611,232.76	1,452.23	622.38
LPG	2,860,346.17	16,629.97	99.73
Kerosene	1,743,343.18	3,557.92	53.49
Fuel wood	7,494,709.46	751,977.73	1,002.53
Total	**14,709,631.58**	**773,617.85**	**1,778.14**

4.1.4. Energy sector - Agriculture

The main agricultural crops available within the study area are paddy, coconut, fruit and vegetables. Coconut, fruit and vegetables cultivation does not consume noteworthy amount of energy but paddy cultivation consumes energy for tractors. As per the last year records, area cultivated for paddy was 835ha for Yala season Maha Season. The following assumptions which used in calculation have developed through Key Informant Interview (KII) with agrarian officers. Information have verified through discussions with of farmers (local knowledge). Average diesel consumption for cultivation (tractors and harvesting machines) is 300 litres per hectare.

Table 4.17.: Cultivated area according to the seasons in Study Area

	Maha 2009/2010 (Ha)				Yala 2010 (Ha)			
	Major	**Minor**	**Rainfed**	**Total**	**Major**	**Minor**	**Rainfed**	**Total**
Paddy	0	136	699	835	0	136	699	835

(Source: Resource Profile Negombo DSD and Govijana Kendraya,Katana)

Table 4.18.: Annual energy consumption by paddy cultivation, according to type of energy source in Study Area

Energy Source	Appliance	Avg. Annual Fuel Consumption (L)	
Diesel	Tractors & Machinery	125,250	Avg. consumption 150L per Ha per season (Source: Govijana Kendraya,Katana)

Table 4.19.: Calorific value & emission factors for energy sources

Energy Source	Conversion Factor - Calorific value of the fuel(TJ/kg)	CO_2 Emission Factor (kg/TJ)	CH_4 Emission Factor (kg/TJ)	N_2O Emission Factor (kg/TJ)
Diesel	0.0000403	20,200	4	0.6

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.20.: Emissions from use of energy for agriculture in Study Area

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Diesel	83,214.21	164.78	2.47
Total	**83,214.21**	**164.78**	**2.47**

4.1.5. Energy sector – Fishery

Fishery has identified as a key sector in Negombo area (about 15% of National production). Main energy consumptions of fishery sector undertakes due to extensive use of fuel for fishing motor boats. Energy use for lighting lamps in the boats at night is another appliance which uses kerosene, batteries and petrol. Following assumptions were used to calculate energy consumption of boats. The average fuel consumption of a multi-days boat has assumed as 6000 Litres per month and one day boat is 5000 Litres per month and boat with out-boat 1250 is Litres. This assumption has developed through a Focal Group Discussion (FGD) with local fishermen.

One day Boat **Multi day Boat**

Figure 4.2.: Fishery Boats in NMC area

Table 4.21.: Type of fishery boats according to the source of energy use in Study Area

Energy Source	No of Boat			
	Multi-days boat	One day Boat	Boats with Outboard	Total
Kerosene	-	65	1418	1483
Diesel	403	-	-	403

(Source: Fishery Department Negombo 2010)

Table 4.22.: Annual energy consumption by fishery boats, according to type of energy source in Study Area

Energy Source	Annual Fuel Consummation (L)			Total (L)	Total (kg)
	Multi-days boat	One day Boat	Boats with Outboard		
Kerosene		3,900,000	21,270,000	25,170,000	21,534,698
Diesel	29,016,000			29,016,000	23,710,424

(Annual Fuel Consumption = No of Boat * Avg. Monthly Fuel Consumption *12)

Table 4.23.: Calorific value & emissions factors for energy sources

Energy Source	Conversion Factor - Calorific value of the fuel(TJ/kg)	CO_2 Emission Factor (kg/TJ)	CH_4 Emission Factor (kg/TJ)	N_2O Emission Factor (kg/TJ)
Kerosene	0.0000448	19,600	5	2
Diesel	0.0000403	20,200	5	2

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 5.24.: Emissions from use of energy for fishery sector in Study Area

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Kerosene	18,888,082.60	48,183.83	1,927.38
Diesel	19,277,760.56	47,717.23	1,908.69
Total	**38,165,843.16**	**95,901.06**	**3,836.07**

Note: Map indicate only NMC area

4.1.6. Energy sector - Road transportation

GHG Emissions can estimate from either the fuel consumed (represented by fuel sold) or the distance travelled by the vehicles. In general, the first approach (fuel sold) is appropriate for CO_2 and the second (distance travelled by vehicle type and road type) is appropriate for CH_4 and N_2O. Therefore, this inventory adopted both methods but made sure not to double count.

Data about fuel sold was obtained from all fuel stations within the study area. This data was taken for a period of one year because there may be seasonal variations in travel pattern at different periods of the year due to school vacations, festivals and tourist arrivals. FGD's were conducted with fuel station workers and officers to figure-out the proportion of local users to outsiders who purchase fuel. There are two uncertain circumstances can occur such as;

1. Consumers who purchase fuel from inside stations travel outside the study area limits.
2. Consumers who purchase fuel from outside stations travel within the study area limits.

The first circumstances should exclude from the inventory and the second should include into the inventory. However, that need detailed data collection and therefore, both facts have unaccounted assuming both are equal in quantity.

Traffic along Main Road

Conversely, the second method, which calculates based on distance travelled by vehicle type, can overcome this limitation. That needs detailed traffic counts by type of vehicle on all roads and average trip length all users. Once again that demands a detailed Origin-Destination survey. Since, this study has certain time and resources constraints, the possible secondary data were obtained for traffic counts at major roads from Road Development Authority (RDA, Sri Lanka). Further, average trip lengths and average fuel consumption were obtained through interviews conducted from vehicle users/ drivers at selected fuel stations. Screen line traffic count and vehicle interview surveys (week day - 16hr) were carried out at four entry points to the study area (at A3 road: Kochchikade and Ja-Ela, B27 and B16) to obtained data related to vehicles which passing through study area.

Table 4.25.: Annual energy consumption in Study Area by vehicle and type of energy sources

	Type of Fuel	Vehicle Type	No. of Vehicle	Avg Vehicle km per day	Fuel Consumption per km (L)	Avg Annual Fuel Consumption (L)
Registered Vehicle within Study Area (Source : Number of Vehicles, Vehicles, Motor Traffic Branch, Gampaha, 2010)	*Petrol*	Car	2990	8	0.08	688,965
		Mini Bus	-	-	-	-
		Motor Cycle	35578	12	0.02	3,073,956
		Motor Tricycle	7109	60	0.06	9,213,894
	Diesel Oil	Car	3036	10	0.08	874,283
		Pickup	-	-	-	-
		Medium Bus	236	75	0.1	636,174
		Dual Purpose	3027	10	0.17	1,852,646
		Jeep	-	-	-	-
		Heavy Bus	688	75	0.17	3,156,543
		Truck	2981	10	0.2	2,146,336
Vehicles passing through Study Area (Source : Number of Vehicles, RDA, 2010)	*Petrol*	Car	7781	12.5	0.08	2,801,174
		Mini Bus	-	-	-	-
		Motor Cycle	12692	12.5	0.02	1,142,320
		Motor Tricycle	3808	9	0.06	740,338
	Diesel Oil	Car	6229	12.5	0.08	2,242,288
		Pickup	-	-	-	-
		Medium Bus	699	14	0.17	599,251
		Dual Purpose	890	12.5	0.17	680,791
		Jeep	-	-	-	-
		Heavy Bus	1004	14	0.17	860,339
		Truck	4530	12.5	0.2	4,076,925

Table 4.26.: Calorific value & emissions factors of energy sources

Type of Fuel	Vehicle Type	Density Factor	Calorific value of the fuel (TJ/kg)	Emission Factor (t/TJ)		
				CO_2	CH_4	N_2O
Petrol	Car	0.73722	0.0000448	18.9	0.02	0.001
	Mini Bus	0.73722	0.0000448	18.9	0.02	0.001
	Motor Cycle	0.73722	0.0000448	18.9	0.1	0.001
	Motor Tricycle	0.73722	0.0000448	18.9	0.1	0.001
Diesel Oil	Car	0.81715	0.0000433	20.2	0.002	0.004
	Pickup	0.81715	0.0000433	20.2	0.002	0.004
	Medium Bus	0.81715	0.0000433	20.2	0.001	0.004
	Dual Purpose	0.81715	0.0000433	20.2	0.001	0.004
	Jeep	0.81715	0.0000433	20.2	0.001	0.004
	Heavy Bus	0.81715	0.0000433	20.2	0.006	0.003
	Truck	0.81715	0.0000433	20.2	0.006	0.003
Petrol		0.73722	0.0000448	18.9	0.062	0.0002
Diesel Oil		0.81715	0.0000433	20.2	0.0039	0.0039

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.27.: Vehicular GHG Emissions of the Study Area (According to the vehicle kilometre)

Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Registered Vehicle within study Area	13,846,178	40,068	1,440
Vehicles passing through study Area	8,942,156	9,219	1,188
Total	**22,788,333.68**	**49,287.64**	**2,627.96**

Table 4.28.: Average amount of monthly fuel sold within in Study Area

Type of Fuel	Avg. Monthly Amount of Fuel Sold (L)
Petrol	990,000
Diesel	1,400,000

(Source: Fuel sold record by Fuel Stations, 2010 July)

Table 4.29.: Vehicular GHG Emissions of the Study Area

(According to the fuel sold)

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Petrol	7,415,720.75	7,847.32	392.37
Diesel	12,015,756.68	594.84	2,379.36
Total	**19,431,477.43**	**8,442.16**	**2,771.72**

4.1.7. Energy sector - Railway transportation

Railway transportation consists of different types of engines which consumes alternative energy sources. Railway Department occupy different types of engines at different trip and these types are not uniform because engines rotate time to time. Therefore, the national average fuel consumption of train per kilometre has taken as the emission factor which normalizes the differences of engines. The average trip length has taken by multiplying railway fleet within study area by frequency had counted from time table records of railway station. (Annual Operation Train Trip Length via NMC = 65,700km)

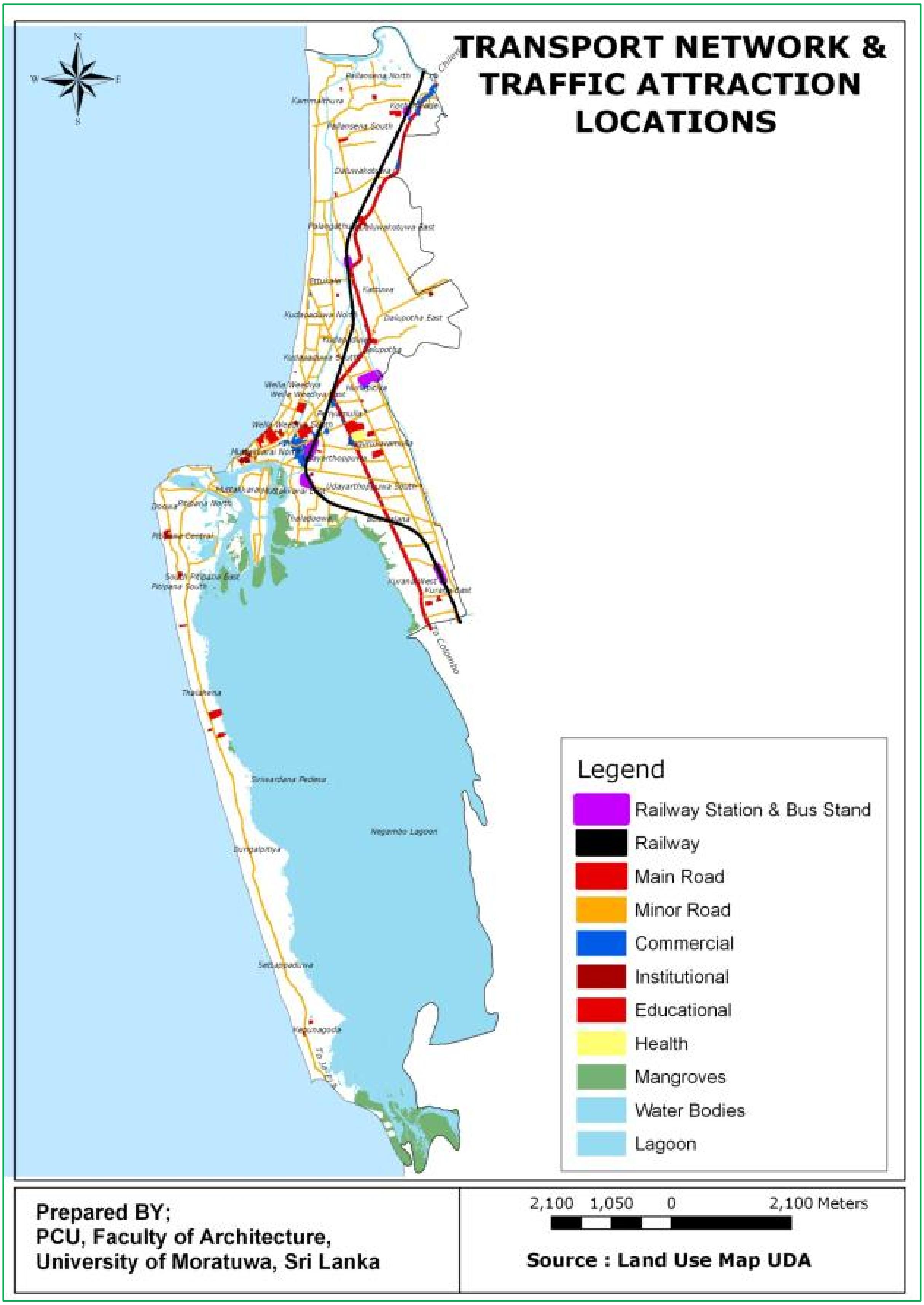
Table 4.30.: Emissions factors for energy sources

Emissions (kg) per train operate km		
CO_2	CH_4	N_20
10.9023	0.0007	0.0001

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.31.: Emissions from use of energy for train transportation in Study Area

Energy Source	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Total	**716,278.20**	**47.75**	**5.76**



Note: Map indicate only NMC area

2.1. Sector two: Agriculture, Forestry & Other land use

4.2.1. Livestock

The key sub categories of livestock have identified as;

a) Enteric Fermentation

Enteric fermentation in the digestive systems of ruminants leads to production and emission of CH_4. Ruminant livestock of the areas is mainly comprised of cattle, buffalo, goat and sheep.

b) Manure Management

Management decisions about manure disposal and storage affect

- Emissions of CH_4 and $N2_O$, which are formed in decomposing manures as a by-product of methanogenesis and nitrification/de-nitrification, respectively.
- Volatilization losses of NH_3 and NO_x from manure management systems and soils leads to indirect greenhouse gas emissions.

This includes ruminant as well as non-ruminant livestock (Poultry and swine).

Livestock population of the area by type is obtained from secondary sources.

Table 4.32.: Livestock population in Study Area

Livestock species	No. of Species	
	Ruminant	Non-ruminant
Dairy Cattle	388	
Non Dairy Cattle	98	
Buffaloes	7	
Goat	3136	
Swine		3173
Poultry		18887

(Source: Vet. Office, Negombo, 2010 & Statistical Hand Book, Katana DSD)

Rest of the calculations were based on the average figures mentioned in the Draft National Inventory. This sector in Draft National GHG Inventory is heavily based on assumptions. Those assumptions are mentioned below for the reference of this section.

Assumptions from Draft National GHG Inventory

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 (<27oC). Since the latter population is very insignificant, compared to the total cattle population, they were not considered.

Table 4.33.: Emission factors for livestock

Livestock species	Emission Factors CH_4 (kg/head/yr)		N_2O Emission Factor from Different Animal Waste Management System(kg/head/yr)
	Enteric Fermentation	Manure Management	
Dairy Cattle	56	27	0.02
Non Dairy Cattle	44	2	0.02
Buffaloes	55	3	0.02
Sheep	5	0.21	0.02
Goat	5	0.22	0.02
Swine	1	7	0.02
Poultry	0	0.023	0.02

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.34.: Emissions from livestock in Study Area

Source	Annual Emissions (kg)	
	CH_4	N_2O
Total	**64,750.40**	**513.78**

4.2.2. Agriculture

Rice cultivation majorly confined into North-West monsoon rain-fed. In addition to rice, fruit (84Ha) and vegetables (34Ha) grow at small scale. The following table represent the extent of paddy cultivation area of last year.

Table 4.35.: Paddy Cultivated area in Study Area by season

	Maha 2009/2010 (Ha)				Yala 2010 (Ha)			
	Major	Minor	Rainfed	Total	Major	Minor	Rainfed	Total
Paddy	0	136	699	835	0	136	699	835

(Source: Resource Profile Negombo DSD and Govijana Kendraya,Katana)

The following assumptions which applied in Draft National Inventory have considered in GHG inventory of Negombo too.

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 Subcontinent were used.
5. Rice cultivation is done under single aeration method.

Rice cultivation contributes to produce CH_4 as a result of sub merged, anaerobic conditions. Burning of crop residues emit carbon and few other GHG substances. Data on amount of crop residues produce and proportion of burning were obtained from FGDs with local farmers

Table 4.36.: Emission factors

	Emission Factors (kg per Ha/Yr)	
	CH_4	N_2O
Rice Cultivation	23.70	-
Field Burning of crop residues	3.06	0.07
Direct emissions	-	1.68
Indirect emissions	-	21.04

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Table 4.37.: Emissions from agriculture sector in Study Area

Source	Annual Emissions (kg)	
	CH_4	N_2O
Rice Cultivation	1,649.21	-
Field Burning of crop residues	220.40	196.71
Direct emissions	-	-
Indirect emissions	-	-
Total	**1,869.61**	**196.71**

4.2.3. Forestry and other land use change

Land Use changes cause to alternate GHG emissions or sinks of the locality. As a common phenomenon in urban areas, green fields convert into brown fields and there by contribute to GHG emissions at higher rate.

This land use analysis is a relative assessment based on a decided base year to current inventory. Land use data is available for previous years. This inventory has compared the changes through last ten years (1999 – 2009) and calculated average change in land use per year by sector. There is no any previous inventory available for study area; therefore this will be the benchmark study for future.

As revealed from calculation, croplands have subjected to a considerable annual change but changes in other land use categories are insignificant. Therefore, this section provides information on greenhouse gas emissions only from croplands. Cropland refers to rice fields, coconut lands and other agro-forestry systems including all annual and perennial crops as well as seasonally cultivated land. Land-use conversions to Cropland from forest land, grassland and wetlands usually result in a net loss of carbon from biomass and soils as well as N_2O to the atmosphere.

The amount of carbon stored-in and emitted or removed from permanent cropland depends on crop type, management practices, soil and climate variables. Carbon stocks in soils can be significant and changes in stocks can occur in conjunction with soil properties and management practices, including crop type and rotation, tillage, drainage, residue management and organic amendments. Changes to biomes, dead organic matters and Soil Carbons need to be assessed in this section.

However, this inventory only considered the changes occurred in biomes. This section has not included in Draft National GHG Inventory. Hence, country specific emission factors are not available. In this situation, the changes have computed by using, default values mentioned in IPCC guidelines. As mentioned in IPCC, the error factor of using default values can be higher as 75% at some instances.

Table 4.38.: Net annual land use change (1999-2010) in Study Area

To / From	Settlements	Cropland	Forest Land	Wetlands	Other Land
Settlements	-	*0*	*0*	*0*	*0*
Cropland	*193.8 Ha*	-	*0*	*0*	*235Ha*
Forest Land	*3.2 Ha*	*0*	-	*0*	*0*
Wetlands	*31.74 Ha*	*0*	*0*	-	*0*
Other Land	*0*	*0*	*0*	*0*	-

(Source : Based on Google Image 2009, Land Use Map 2005 UDA, Negombo& Land Use Data 2000-2009, Resource Profile)

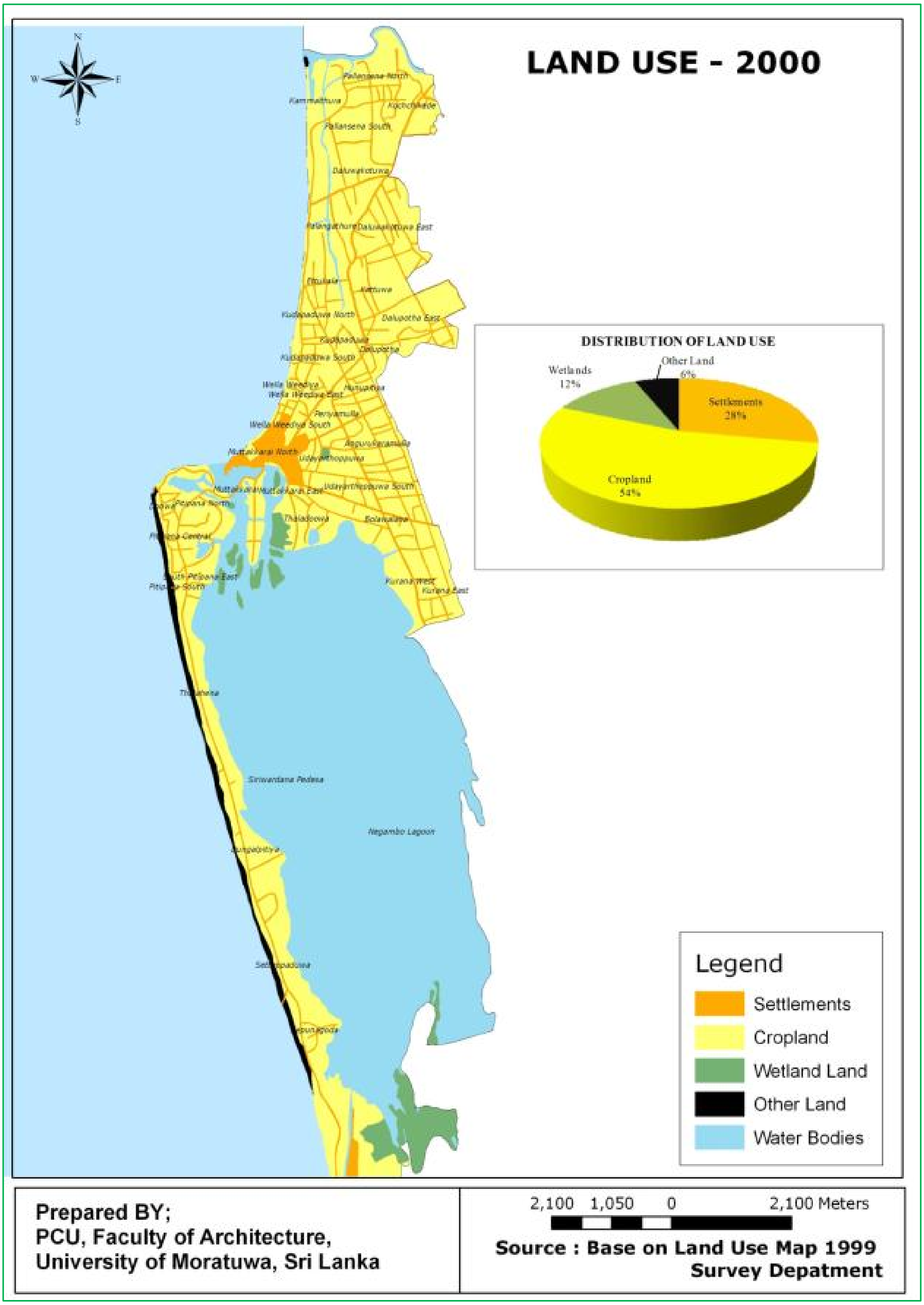
Table 4.39.: Default factors 141,817

	Biomass stocks before the conversion (tonnes dm ha^{-1})	**Carbon fraction of dry matter [tonnes C (tonne dm)$^{-1}$]**	**Annual biomass carbon growth (tonnes C/Ha/yr^{-})**	**Annual loss of biomass carbon (tonnes C/Ha/yr-)**
Cropland Land Converted to Settlements	10	0.5	1.8	0.9
Cropland Land Converted to Other land	6	0.5	1.8	0.9
Forest Land Converted to Settlements	90	0.5	1.8	0.9
Forest Land Converted to Other land	90	0.5	1.8	0.9

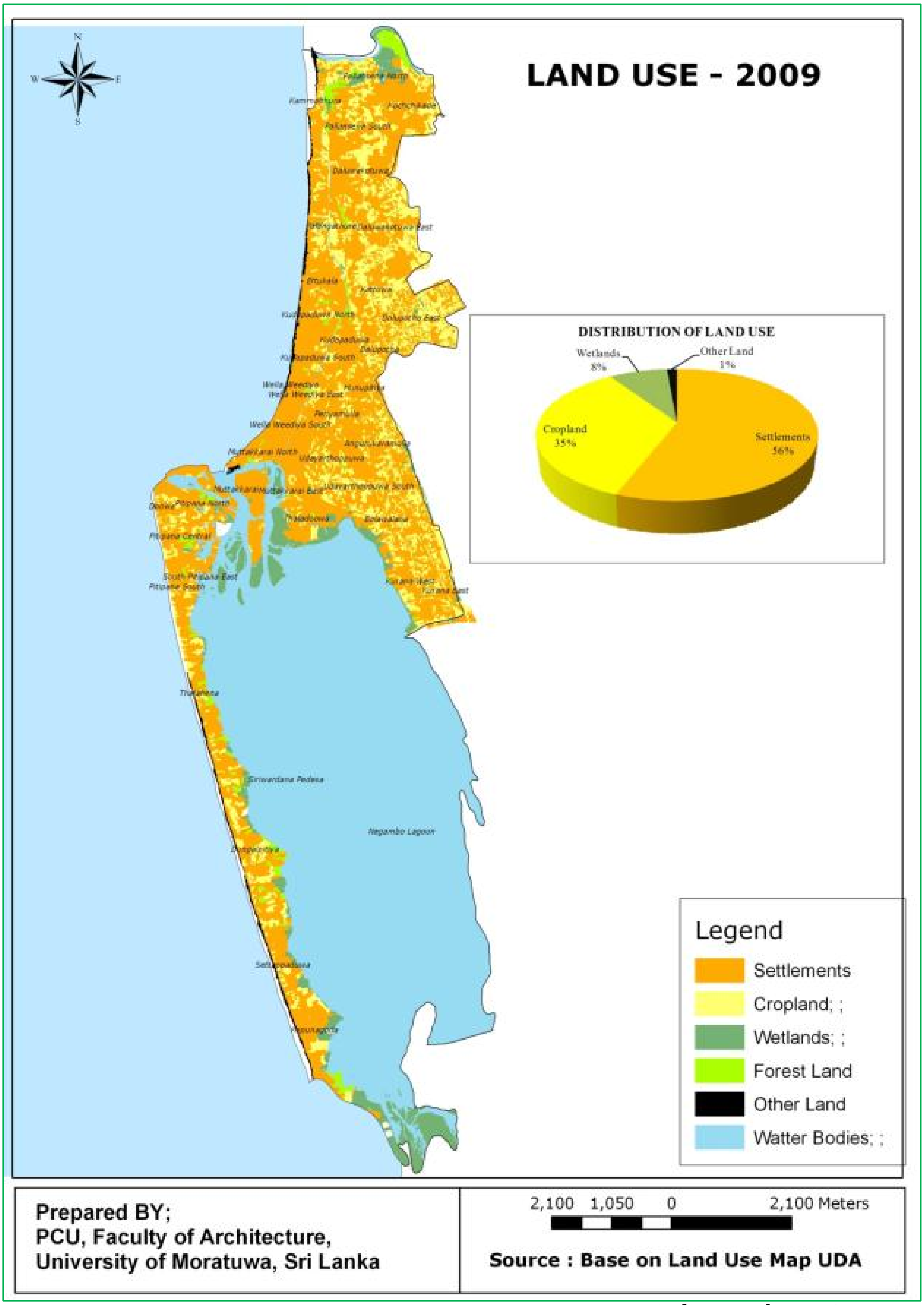
(Source: IPCC 2000)

Table 4.40.: Emissions from land use change in Study Area

Source	**Annual change in carbon stocks in biomass (tonnes C yr^{-1})**	**Annual Emissions CO_2 (kg)**
Cropland Land Converted to Settlements	-794.58	2,913,460
Cropland Land Converted to Other land	-493.50	1,809,500
Forest Land Converted to Settlements	-141.12	517,440
Wetland Land Converted to Settlements	-98.39	360.75
Total	-1,527.59	5,240,760.75



Note: Map indicate only NMC area



Note: Map indicate only NMC area

2.2. Sector three: Waste

Solid waste generation is increasing at alarming rate as a result of urbanization and population growth.

Waste disposal systems are key source of GHG emission in cities. This section estimates carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) emissions from Solid and liquid waste disposal in NMC area. Accordingly, this report consist of three emission categories are,

I. Solid Waste Disposal Sites
II. Incineration & Open Burning of Waste
III. Wastewater Treatment & Discharge

Solid Waste

105,800 MT per annum amount of solid waste generate within the study are. Solid waste disposal practices of city depict in following table. NMC has a well maintained registry on solid waste management and it is nationallyawrded for best municip-le waste demonstration project of the country. However, the demonstration project covers only 1825MTPA.

There is a composting bed under construction, which could reduce Carbon emissions from open dumping in future.

Solid Waste Composting site at Kurana

Solid Waste Dumping site at Kochikade

Table 4.41.: Composition of Solid Waste in Study Area

Area	NMC	Surrounding Area
Annual Generation	43,800 MT	62, 000 MT
Collection & Open Dumping at Municipal Solid Waste Dumping Site	60%	0%
Collection & Open Bunning at Municipal Solid Waste Dumping Site	10%	0%
Composting of Solid Waste at Household Level	5%	5%
Open Burning at Household Level	5%	35%
Open Dumping at Household Level	20%	60%

(Source: PHI & Environment Section, NMC, 2010 July, Katana UC, Katana PS)

There is a composting bed under construction, which could reduce Carbon emissions from open dumping in future.

Table 4.42.: Country specific composting of solid waste

Waste category	Composition %
Kitchen	45.6
Grass & wood	24.7
Paper	8.9
Textile	3.5
Soft plastic	4.0
Hard plastic	0.8
Leather & Rubber	0.9
Metal	0.5
Glass	0.8
Ceramic & stone	8.4
Other	2.0
Total	100

Table 4.43.: Default factors for open dumping

Methane Correction Factor (MCF)	Fraction of DOC in MCW	Fraction of DOC which Actually Degrades*	Fraction of Carbon Released as Methane	Conversion Ratio
0.4	0.1955	0.78	0.5	1.333333333

*(Source: IPCC 2000, *Dr. Basnayake)*

Table 4.44.: Default factors for open burning

Waste Category	Fraction of Carbon in Dry Matter	Fraction of Fossil Carbon in Total Carbon	Oxidation Factor
Paper	0.46	0.01	0.58
Textiles	0.5	0.2	0.58
Food waste	0.38		0.58
Wood	0.5		0.58
Garden & Park Waste	0.49		0.58
Nappies	0.6	0.1	0.58
Rubber & Leather	0.47	0.2	0.58
Plastics		1	0.58
Metl			0.58
Glass			0.58

(Source :IPCC 2000)

Emission Factors (g N2O/t waste treated) = 150*(Source: IPCC 2000)*

Equation for Net Annual Methane Emissions (Gg CH_4) from open Dumping/composting	
A	Total Annual of Open Dumping(Gg)
B	Methane Correction Factor (MCF)
C	Fraction of DOC in MCW
D	Fraction of DOC which Actually Degrades
E	Fraction of Carbon Released as Methane
F	Conversion Ratio
G=CDEF	Potential Methane Generation Rate per Unit of Waste (Gg CH_4/ Gg MSW)
H=BG	Realized (Country specific Methane Generation Rate per Unit of Waste (Gg CH4/ Gg MSW)
J=HA	Gross Annual Methane Generation (Gg CH_4)
K	Recovered Methane per Year (Gg CH_4)
L=J-K	Net Annual Methane Generation (Gg CH_4)
M	One Minus Methane Oxidation Correction Factor
N=LM	Net Annual Methane Emissions (Gg CH_4)

Equation for Net Annual Fossil CO_2 Emissions from Open Burning	
F	Total Amount of MSW Open-burned according to the Waste Category(kg/yr)
G	Dry Matter Content
H	Fraction of Carbon in Dry Matter
I	Fraction of Fossil Carbon in Total Carbon
J	Oxidation Factor
K	Conversion Factor (44/12)
L=FGHIJ K	Fossil CO_2 Emissions (kg CO_2)

Equation for Annual Net Annual Nitrous Oxide Emissions from Open Burning	
A	Total Annual amount Open-burned (t)
B	Emission Factor (g N_2O/t waste treated)
H=A*B	Net Annual Nitrous Oxide Emissions (Gg N_2O)

Table 4.45.: Emissions from solid waste in Study Area

Source	**Annual Emissions (kg)**		
	CO_2	**CH_4**	**N_2O**
Open Dumping at Household Level	-	1,372,813.29	-
Open Burning at Household Level	180,658.33		895.875
Open Dumping at Municipal Dumping Site	-	1,524,178.43	-
Open Burning at Municipal Dumping Site	44,162.61		-
Total	**224,820.94**	**2,896,991.72**	**895.88**

Waste – Wastewater

There is no any centralized waste water treatment facility available within study area. Sewerage manages at domestic level by individual septic tanks. There is no any recorded CH_4 collection practice from septic tanks. Residential waste water (grey water; kitchen waste, bath room and other washing) is discharged to water bodies and low lying areas.

Municipal wastewater discharge at Kurana

Table 4.46.: Country specific factors for Wastewater generation & emission

Organic Product Per Person (kg BOD/yr)	Emission Factor (kg CH_4/kg BOD)
5.81	0.0095

(Source: Based on National GHG Inventory, Sri Lanka-2000)

Total Organic Product (kg BOD/yr)

= Organic Product per Person (kg BOD/yr) * Total Population in study area

Net Methane Emissions (kg CH_4)

= [Total Organic Product (kg BOD/yr) * Emission Factor (kg CH_4/kg BOD) – [Recovered Methane per Year (Gg CH_4)]

Table 4.47.: Emissions from waste water in Study Area

Source	Annual Emissions CH_4 (kg)
Domestic Wastewater	**58,808.39**

2.3. Analysis & Conclusion

Negombo is an emerging city which grows at faster rate as a part of Colombo Metropolitan growth corridors. As mentioned above; energy, land uses and waste are the three identified key sectors of the city GHG inventory. The following table reveals the estimated annual GHG gases emissions by sector.

Table 4.48.: Overall GHG emission by sector in Study Area

SECTOR	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Energy	77,885,338	881,704	8,528
Agriculture, Forestry and other Land Use	5,240,761	66,620	20,190
Waste	224,821	2,955,800	896
Total	**83,350,920**	**3,904,125**	**29,614**

Energy sector contribute to the largest proportion of CO_2 emissions and considerable proportion of CH_4 and NO_2 emissions. Waste sector contribute to a significant amount of CH_4. Following table present the emissions in detailed by sectors.

Table 4.49.: Overall GHG emission in Energy sector in Study Area

Sector	Source	Annual Emissions (kg)		
		CO_2	CH_4	N_2O
Energy	Industrial	348,373	2,671	12
	Commercial & Institutional	4,380,616	860	121
	Residential	14,759,537	773,618	1,778
	Agriculture	83,214	165	2
	Fishery	38,165,843	95,901	3,836
	Road Transportation	19,431,477	8,442	2,772
	Rail Transportation	716,278	48	6
	Total	77,885,338	881,704	8,528

Accordingly, fisheries sector stand the highest responsibility on CO_2 emissions. Road transportation obtained the second highest to city GHG emissions directly through CO_2. Residential sector also highly contributes to city GHG emissions directly through CO_2 mainly because of the extensive electricity appliances at households.

Table 4.50.: Overall GHG emission in Agriculture, Forestry and Other Land Use in Study Area

Sector	Source	Annual Emissions (kg)		
		CO_2	CH_4	N_2O
Agriculture, Forestry and Other Land Use	Livestock	-	64,750	514
	Agriculture	-	1,870	19,676
	Land Use Change	5,240,761	-	-
	Total	**5,240,761**	**66,620**	**20,190**

Land use changer contribute very large amount of CO_2 emissions in study area. This is mainly due to the conversion of coconut land, paddy land and wetland land in to residential land (with the end of civil conflict situation).

Table 4.51.: Overall GHG emission in Waste sector in Study Area

Sector	Source	Annual Emissions (kg)		
		CO_2	CH_4	N_2O
Waste	Solid Waste	224,821	2,896,992	896
	Wastewater	-	58,808	-
	Total	**224,821**	**2,955,800**	**896**

Solid waste sector is the main contributor which emits CO_2 from open burning and CH_4 from un-mange waste dumping sites. This needs to be properly addressed by the city council as a sustainable practice than a mandatory duty.

The below mentioned values represent the GHG emissions of NMC as a percentage of country levels by sector. It is noteworthy to mention that Negombo is a medium town area of country which consists of 1.82 % of country's population and 0.23% of country's land area.

Table 5.50.: GHG Emissions in Study Area as A Percentage of Country Levels (1994 inventory) by Sector

	Annual Emissions (kg)		
	CO_2	CH_4	N_2O
Energy	2.80%	0.70%	0.09%
Agriculture, Forestry and Other Land Use	0.02%	0.04%	0.59%
Waste	-	0.43%	-
Total	1.81%	0.56%	0.03%

The results reveal that study area has relatively very low contribution to country's GHG emissions. However, CO_2 emission from energy sector and CH_4 from waste sector has high compare to national emission level of that sector. This need to be consider especially in Mitigation Plan at local level.

CO_2 is the major contributor of city GHG emissions. Energy mainly contributes to that.

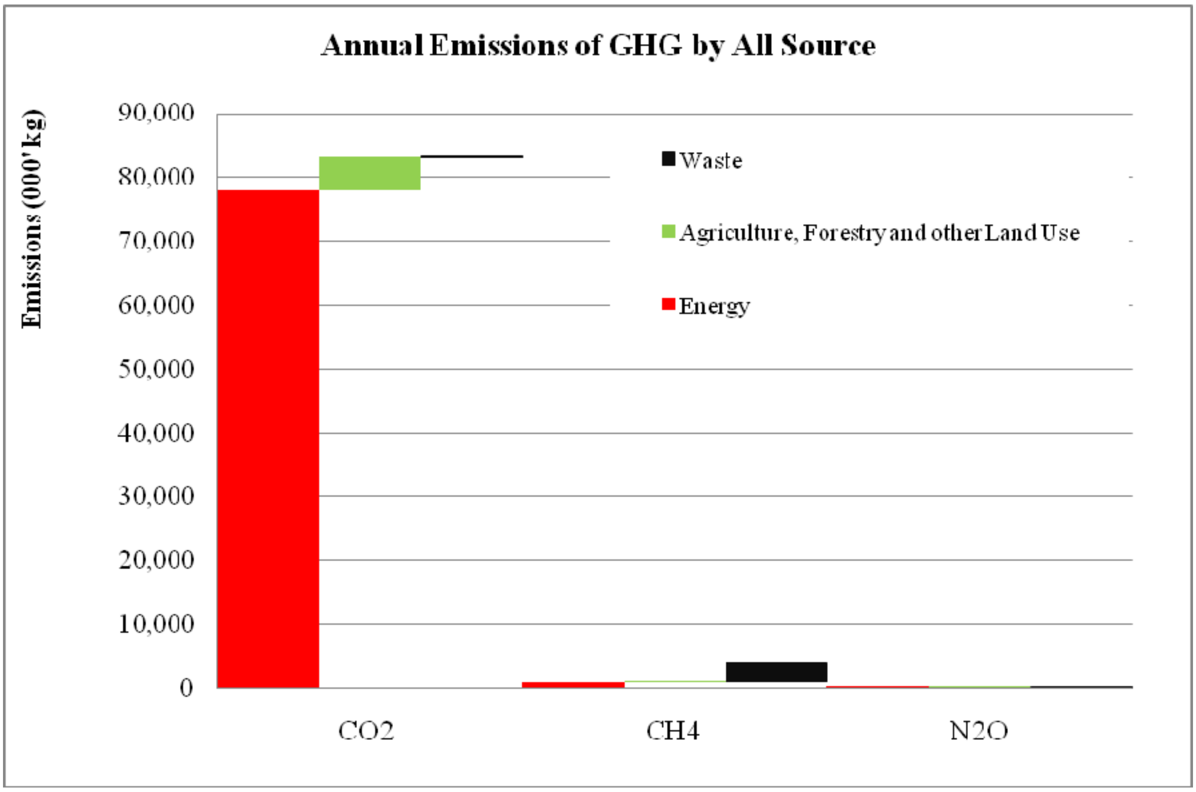


Figure 4.6: Annual Emissions of GHG by All Sources

Detailed findings are illustrated in following graphs.

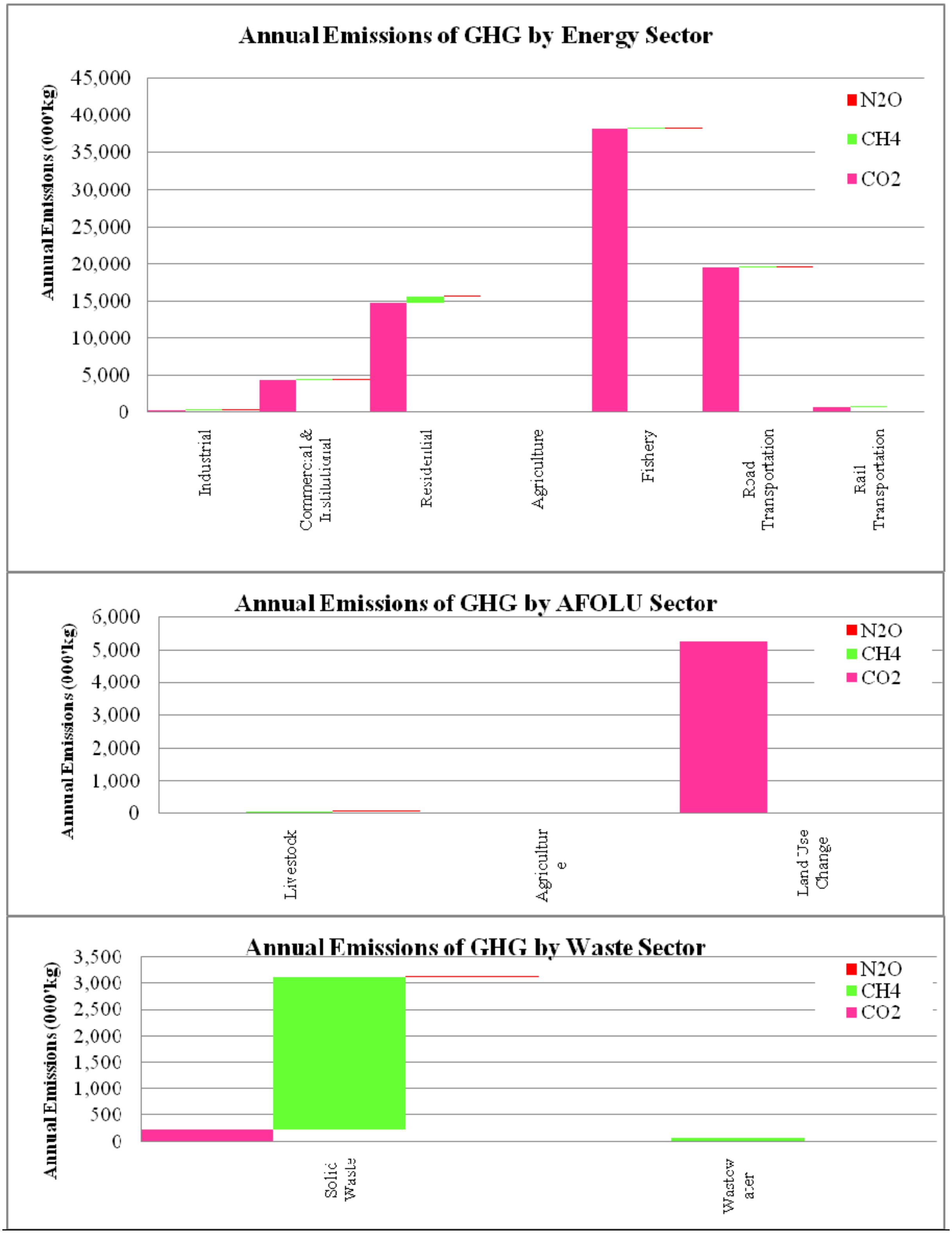


Figure 4.7: Annual Emissions of GHG by Sector

Accordingly, fishery, road transportation and residential sectors are the main contributors of CO_2 while solid waste sector holds the lion's share of CH_4 emissions

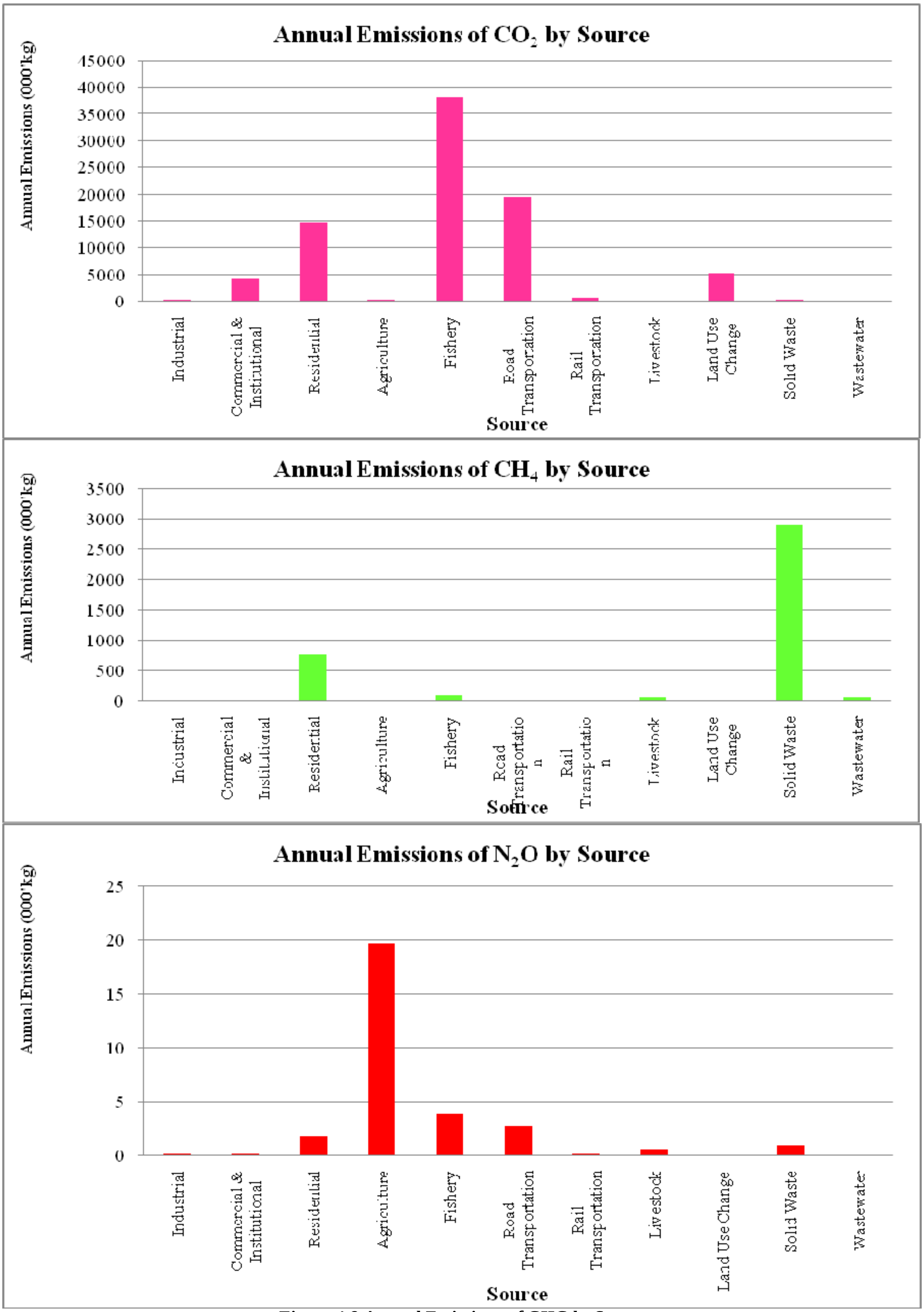


Figure 4.8 Annual Emissions of GHG by Source

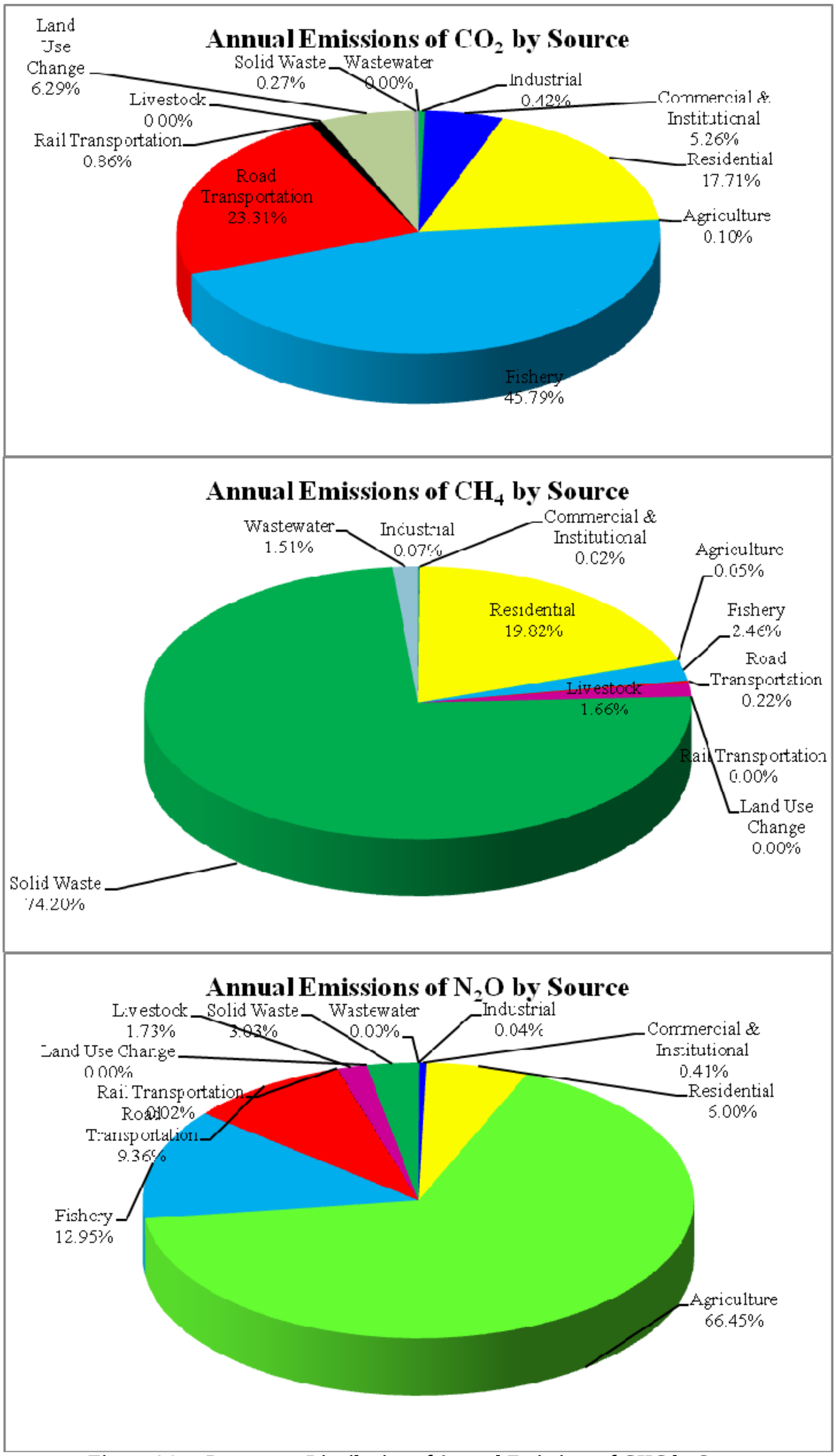
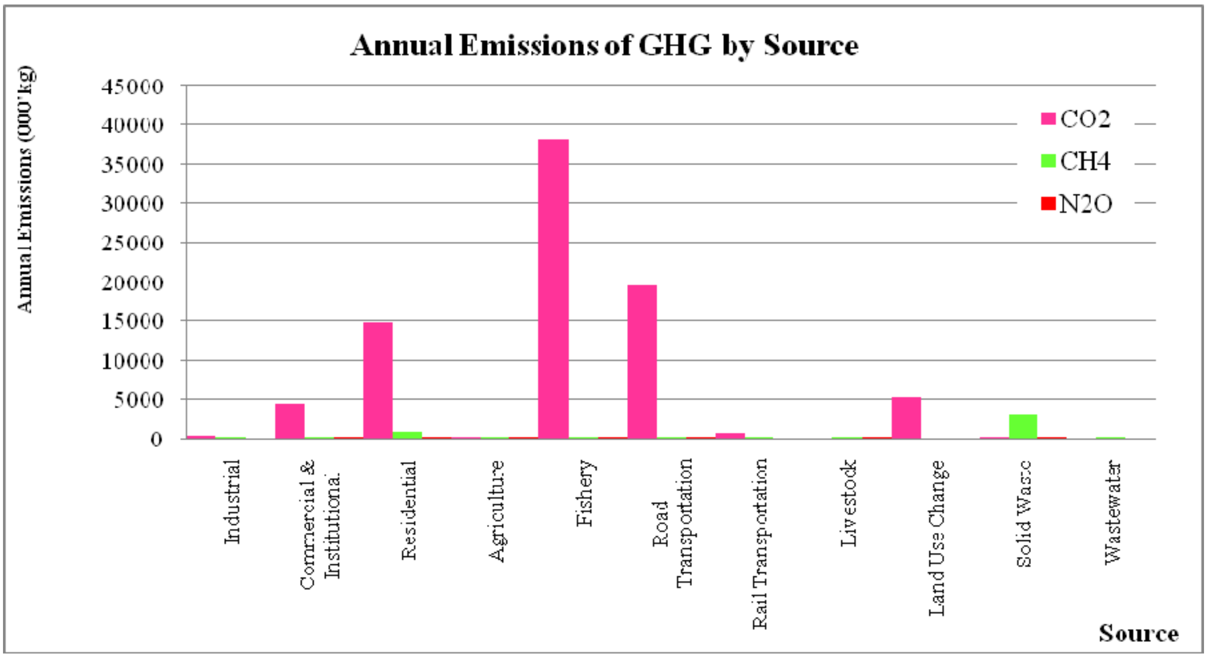


Figure 4.9 ..: Percentage Distribution of Annual Emissions of GHG by Source

Fisheries sector has emited nearly 40,000 metric tons of CO_2 during considered year (2010). This is a nationally important figure because fish harvest of the study area represent 15% of national fish production. Transport and residential sectors contribute about 20,000 and 15,000 metric tons of CO_2 a year respectively.



Even though Methane and Nitrous Oxide are less in quantity, it has higher contribution to Global warming.

The global warming potential (GWP) depends on both the efficiency of the molecule as a greenhouse gas and its atmospheric lifetime. GWP is measured relative to the same mass of CO2 and evaluated for a specific timescale. Thus, if a gas has a high GWP on a short time scale (say 20 years) but has only a short lifetime, it will have a large GWP on a 20 year scale but a small one on a 100 year scale. Conversely, if a molecule has a longer atmospheric lifetime than CO2 its GWP will increase with the timescale considered. Average estimated atmospheric life time of identified GHGs is stated below.

Atmospheric lifetime

The atmospheric lifetime of a species therefore measures the time required to restore equilibrium following an increase in its concentration in the atmosphere. Individual atoms or molecules may be lost or deposited to sinks such as the soil, the oceans and other waters, or vegetation and other biological systems, reducing the excess to background concentrations. The average time taken to achieve this is the mean lifetime

Species	Chemical formula	Lifetime (years)	Global Warming Potential (Time Horizon)		
			20 years	100 years	500 years
CO_2	CO_2	variable **	1	1	1
Methane *	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170

Source: Climate Change 1995, The Science of Climate Change: Technical Summary of the Working Group I Report, page 22
*The GWP for methane includes indirect effects of tropospheric ozone production and stratospheric water vapour production
** Derived from the Bern carbon cycle model.

Following tables summarize the GHG emissions in CO_2 equivalents. This brings a comparable picture of GHG emissions among sectors considering the GWP potentials. Both the table were computed considering the GWP potential for 20 year time horizons because it likely to occur in near future which need to take immediate action.

Table 5.51.: Summary of GHG Emissions by Sector for 20 Year time Horizons

Sector	Gas Emissions (kt CO_2 e.)
Electricity (incl. T&D losses)	7.57
District energy, CHP, and energy from waste	-
Commercial & Institutional	0.13
Residential	55.66
Manufacturing Industries & Construction	0.18
Fishery	44.61
Agriculture	0.09
Road transportation: LDVs	-
Road transportation: trucks	4.71
Road transportation: other	21.57
Railways	0.72
Domestic aviation	-
International aviation	-
Domestic marine	-
International marine	-
Industrial Processes	-
AFOLU	9.17
Solid waste disposal on land	236.94
Wastewater handling	3.29
Waste incineration	-
Total	**384.65**

Accordingly, Solid waste disposal is the main sectors which hold more than 80% share of total emissions.

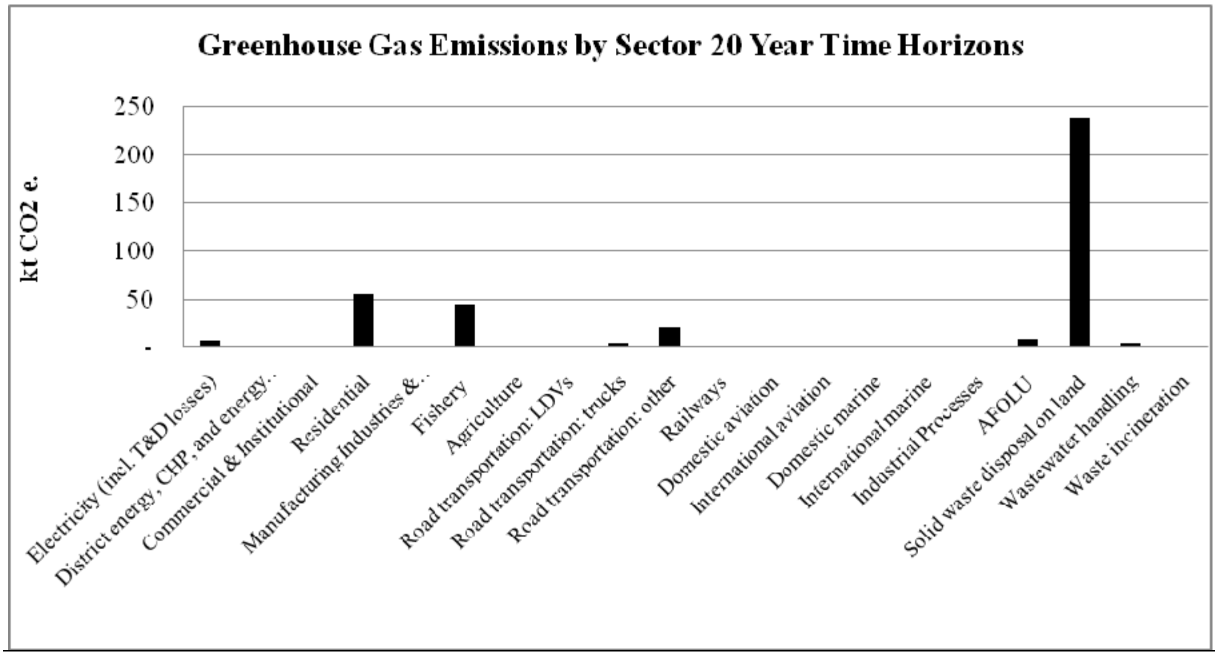


Figure 4.10 ..: Greenhouse Gas Emissions by Sector 20 Year Time Horizons

Table 5.52.: Summary of GHG Emissions by Fuel or Activity Type for 20 Year time Horizons

Fuel or Activity Type	Total GHGs (t CO_2 e)
ENERGY	
Electricity (on-site renewable)	0
Electricity (grid)	7,570.75
Natural gas	0
Fuel oil	0
Coal	0
Gasoline	7,965.03
Diesel	56,932.78
Jet Fuel	0
Marine Fuel	0
Kerosene	24,083.61
LPG	3,921.11
Fuel wood	50,034.60
INDUSTRIAL PROCESSES	
Industrial Products	0
WASTE	
Solid waste disposal on land	221,682,44
Wastewater handling	3,293.27
Waste incineration	0
AFOLU	
Livestock activities	3,769.88
Agriculture activities	159.78
Land use change	5,240.76
TOTAL	**384,654.01**

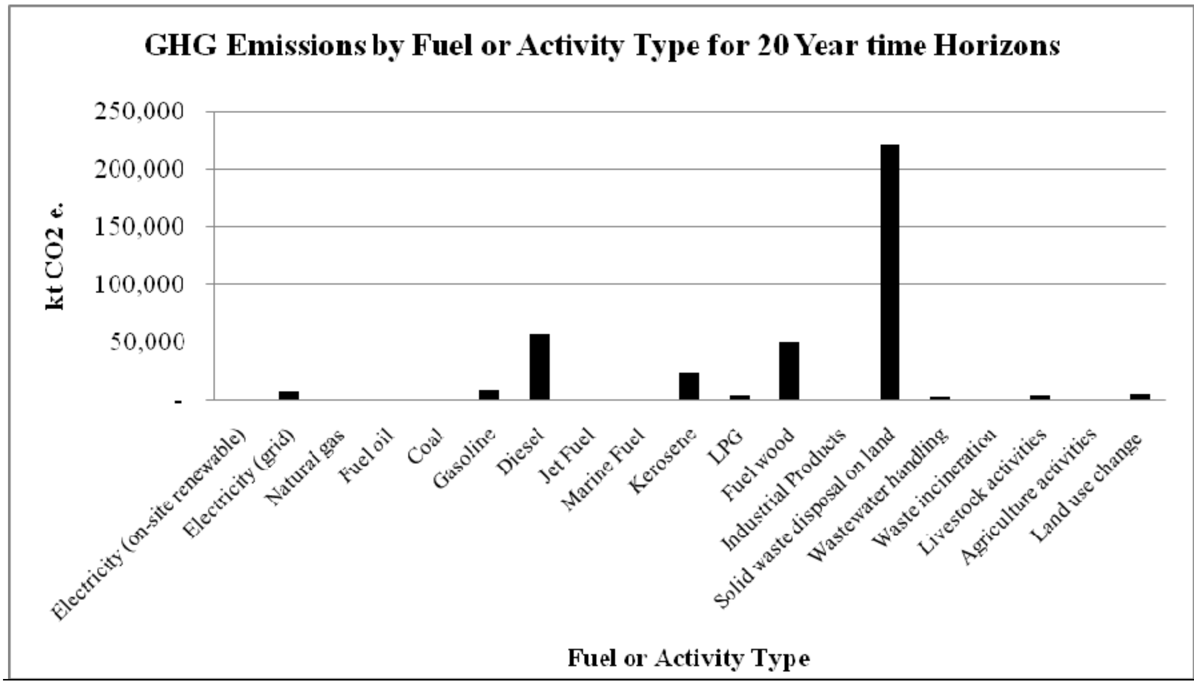


Figure 4.11 ..: GHG Emissions by Fuel or Activity Type for 20 Year time Horizons

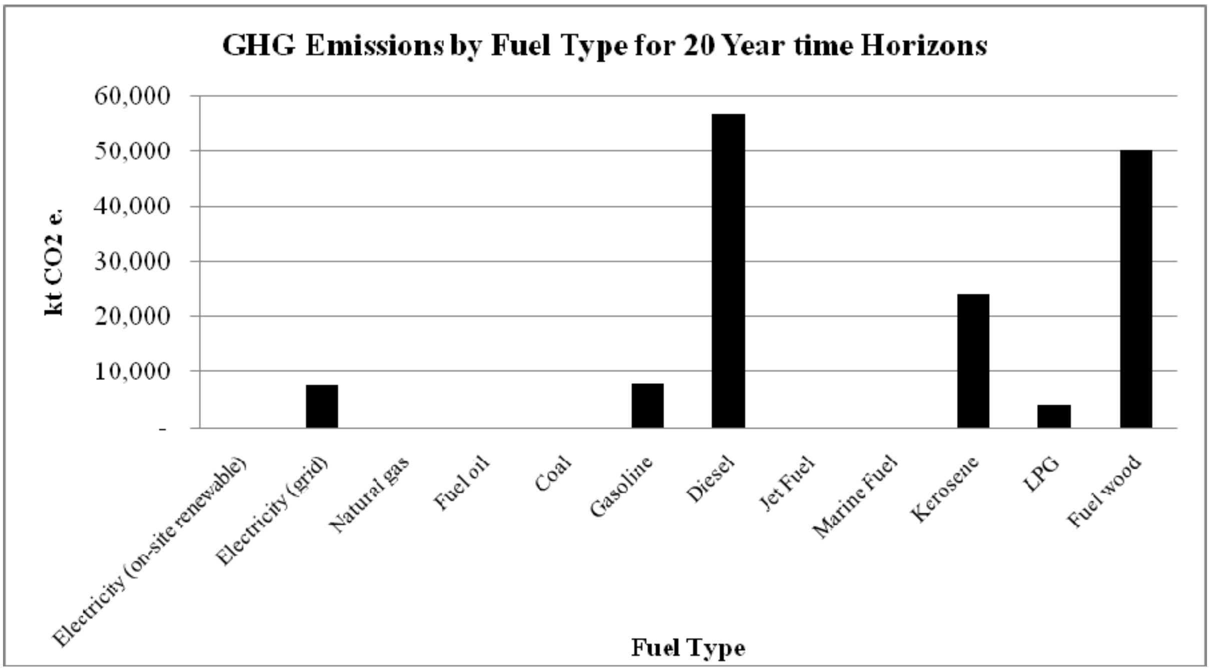


Figure 4.11 ..: GHG Emissions by Fuel Type for 20 Year time Horizons

Solid waste management, diesel consumptions for fishery and road transportation activities; and domestic fuel wood consumption (as energy source for cooking) are the key aspects should thoroughly address in GHG mitigation plan of NMC and surroundings.