Final Report

Project Code: 2012MC03

Carbon Inventory of Navi Mumbai

Prepared for

Navi Mumbai Municipal Corporation (NMMC)

The Energy and Resources Institute

...towards global sustainable development

Suggested format for citation

T E R I. 2013
Mumbai: Carbon Inventory of Navi Mumbai. 68 pps
[Project Report No. 2012MC03]

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Acknowledgements

At the ouset TERI would like to thank Navi Mumbai Municipal Corporation for undertaking a city level carbon inventory report under its "Eco-City" initiative. We would like to express our gratitude to Shri. A. L. Jarhad, *Honourable Municipal Commissioner,* NMMC (Navi Mumbai Municipal Corporation) for extending his co-operation and appreciating the efforts taken by TERI for compiling the carbon inventory report of Navi Mumbai. Our sincere thanks are also due to Shri. Bhaskar Wankhade, *Honourable Ex- Municipal Commissioner* NMMC, for his constant encouragement and guidance, while developing the concrete action plan for the "Eco-City"project.

We would further like to thank Shri. Mohan Dagaonkar, *City Engineer, NMMC* for his constant support, timely guidance and a providing a thorough insight while conceptualizing the thematic plan for the Eco City. We sincerely acknowledge the help extended by Shri. Subodh Muley, *Dy. City Engineer, NMMC,* for co-ordinating with various departments and officials of NMMC and sharing the requested information.

TERI owes its sincere gratitude to the cooperation and support extended by Mr. S.B.Sahasrabudhe, *Joint Transport Commissioner*, MVDM (Motor Vehicles Department, Government of Maharashtra), Mr. V.S. Bhakre, *Deputy Controller of Rationing*, Thane, *Superintendent Engineer*, Vashi Circle, MSEDCL (Maharashtra State Electricity Distribution Company Limited), Mr. G. C Mangale, *Transport Manager*, NMMT (Navi Mumbai Municipal Transport), Mr. D Chandrashekhar, *Regional Manager*, BPCL(Bharat Petroleum Corporation Limited), Mr. Charudatta Dharmik, *Regional Manager* (Retail), HPCL(Hindustan Petroleum Corporation Limited), Mr. A M Parate, *Terminal Manager* (Direct Sales), HPCL, A. Sundara Vadan, *Area Sales Manager-Thane*, (Direct Sales), HPCL, Mr Samir Ekka, *Manager Sales* (LPG), HPCL. Mr. Krishnendu Mukherjee, *Chief Area Manager*, IOCL(Indian Oil Corporation Limited) and Mr. Milind Ranade, *Chief Manager* (O & M), Mahanagar Gas.

A well-coordinated support from these stakeholders in sharing information on number of vehicles, sale of fuels, and consumption of electricity and so on was the key to the success of the whole exercise.

We would further like to acknowledge all the Head of departments of NMMC, officials of MVDM, IOCL, BPCL, HPCL, Mahanagar gas, Rationing office - Thane, who have been directly and indirectly associated with us and have extended all the possible support to TERI's team during the course of this assignment.

Last but not the least we would like to thank Dr. R K Pachauri, *Director General*, TERI for his continual support and constant encouragement.

TERI

Navi Mumbai, December 2013

Preface

TERI in collaboration with NMMC has drafted a plan to develop Navi Mumbai as an "Eco city". Upon getting the necessary approvals from NMMC officials, the program was launched on July 28th, 2012 at the hands of **Shri. Sharadchandraji Pawar**, *Hon'ble Union Minister of Agriculture, Government of India,* in the presence of **Shri. Ganesh Naik**, *Hon'ble Minister of State for Excise and Non–Conventional Energy, Government of Maharashtra.*

It has been proposed that the project will implement programs and conduct feasibility studies in key sectors which include residential, commercial, industrial, and government. In this first phase of the project, TERI has developed a carbon inventory report for Navi Mumbai to identify a baseline quantifiable value and set a benchmark value for further analysis. This report shall also help in mapping the current trend of the sectoral carbon emissions.

The study shall help in identifying critical sectors and strategize interventions at various levels across the city. The strategies thus planned under Phase-I shall be implemented in Phase-II of the project. Similarly, an impact assessment report of the project shall be developed to determine the impact and extrapolate the projections of the initiatives as against the BAU (Business As Usual) scenario. Certain indicators like per capita emissions, emissions per 1000 household, could be developed for NMMC to periodically assess and map the trend of GHG (Greenhouse gas) emissions.

Since carbon emissions, are a global concern and major emissions being attributed to cities across the globe, Navi Mumbai could be at the forefront along with other international cities to help reduce GHG emissions.

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Abbreviations

ATF	Aviation Turbine Fuel
BEE	Bureau of Energy Efficiency
BPCL	Bharat Petroleum Corporation Limited
CACP	Clean Air and Climate Protection
CAGR	Compound Annual Growth Rate
CEAI	Central Electricity Authority of India
CH_4	Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide equivalent
DINK	Double Income and No Kids
EPA	Environment Protection Agency
FO	Furnace Oil
GHG	Greenhouse Gas
GWh	Gigawatt-hour
GWP	Global Warming Potential
HCV	Heavy Commercial Vehicles
HFC	Hydrofluorocarbons
HPCL	Hindustan Petroleum Corporation Limited
HSD	High Speed Diesel
HT	High tension (Used in the context of electricity distribution above 650 V)
ICLEI	International Council for Local Environmental Initiatives
IEA	International Energy Agency
IOCL	Indian Oil Corporation Limited
IPCC	Intergovernmental Panel on Climate Change
ISDGGEC	International Standards for Determining Greenhouse Gas Emissions for Cities
LCV	Light Commercial Vehicles
LDO	Light Diesel Oil
LED	Light-emitting diode
LPG	Liquefied petroleum gas
LT	Low tension (Used in the context of electricity distribution below 250 V)
MJ	Megajoules
MLD	Millions of Liters Per Day
MMT	Million Metric Tonnes
MGL	Mahanagar Gas Limited
MoEF	Ministry of Environment and Forests
MS	Motor Spirit
MSEDCL	Maharashtra State Electricity Distribution Company Limited
MT	Metric tonnes
Mtoe	Million Tonnes of Oil Equivalent
N_2O	Nitrous Oxide
NATCOM	India's National Communication of Emissions to the UNFCCC

NMMC	Navi Mumbai Municipal Corporation
NUSP	National Urban Sanitation Policy
PD	Permenant Disconnect
PDS	Public Distribution System
PFC	Perfluorocarbons
PMC	Pune Municipal Corporation
PWW	Public Water Works
RDF	Refuse Derived Fuel
RTO	Regional Transport Office
SF_6	Sulfur hexafluoride
SKO	Superior Kerosene Oil (Kerosene)
STP	Sewage Treatment Plant
SWD	Solid Waste Disposal
tCO_2e	Tonne Carbon-di-oxide equivalent
TERI	The Energy and Resources Institute
TPD	Tonne per day
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USEPA	United States Environmental Protection Agency
VKT	Vehicle Kilometers Travelled
WB	World Bank
WBCSD	World Business Council for Sustainable Development
WRI	World Resources Institute
WTP	Water Treatment Plant

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Executive Summary

With its world class infrastructure, Navi Mumbai is one of the largest planed cities in the world which has been specially developed to cater to the growing demand for urbanization within the Mumbai Metropolitan Region. While still at nexus of the development, the city holds tremendous potential to integrate the principles of sustainable development. Given this fact, TERI and NMMC have jointly launched the Eco City program in 2012. As a first step, the municipal level carbon footprint- which is a baseline value of the GHG (Greenhouse gas) emissions has been evaluated for the year 2011-12. Thus, after Pune Municipal Corporation, NMMC is the second ULB in the country to have assessed its carbon emissions at municipal level.

The total GHG emissions from Navi Mumbai city were estimated to be around 2.8 MMTCDE (Million Metric Tons CO_2 equivalent) and per capita emissions were around 2.51 tCO_2e (Tons CO_2 equivalent), as against the national average of 1.50 tCO_2e. The higher per capita emission could be attributed to the presence of TTC (Trans-Thane Creek) industrial belt within the city limits as well as lesser population of the city as compared to other cities.

Around 70% of the total GHG emissions (1986.18 thousand tCO_2) were because of electricity consumption followed by emissions from usage of petroleum products having a share of around 26% (752.47 thousand tCO_2) of the total emissions in Navi Mumbai. Given the fact that NMMC has world class infrastructure for managing its waste (municipal solid and sewage), the GHG emission from waste attributed to a mere 4% (106.76 thousand tCO_2).

The footprint estimation has been further used to devise sector specific strategies, mainly for residential, transport and industrial sectors. This would focus not only on reducing the overall emissions and carbon footprint but also to get a long term perspective for sustainable planning of the city.

Industrial sector:

The industrial sector accounted to almost 43% (1217.93 thousand tCO_2) of the city level emissions. Of the total emissions from the industrial sector, 90% (1095.07 thousand tCO_2) of the emissions were on account of electricity consumption Out of the total HT (High Tension) consumption in Navi Mumbai, the industrial usage accounted to almost 80%. In the last 5 years the emissions from electricity usage in industrial sector of the city has increased by almost 1.25 times. Combustion of petroleum products like diesel, FO (Furnace oil), LDO (Light Diesel Oil) and PNG (Piped Natural Gas) accounted to 10% of the emissions from the industrial sector.

Electricity consumption in industrial sector being a key source of emission, regular energy audits and promotion of energy efficiency in industrial sector is highly recommended. Renewable Energy applications like roof top solar could be promoted in the industrial sector to partially meet the low tension electricity demands within the premises of the industrial units.

Transport:

The total number of vehicles plying on roads in Navi Mumbai has increased by more than 3 times in the last 5 years and correspondingly the consumption of petroleum products for transport, especially diesel and petrol also increased by 1.14 and 1.33 times respectively, during the same period. The transport sector consumed 164.55 thousand MT of petroleum

products in Navi Mumbai. This translated to around 18% (509.47 thousand tCO_2) of the total GHG emissions, as against the global share of 22% and national share of 12% of GHG emissions from the transport sector. Consumption of diesel in transport accounted to 320.06 thousand tCO_2, 63% of the emission.

It is interesting to note that CNG (Compressed Natural Gas) vehicles account to mere 1% of the total vehicles in Navi Mumbai, however the emissions from CNG usage accounts to 10% (53.90 thousand CO_2) of the emission in transport sector. This is majorly attributed to use of CNG is public transport vehicles (buses, auto-rickshaws, taxies and so on) which are although less in number have higher number of trips.

A major boost in the intra-city public transport is required to reduce dependence on private vehicles. Mass rapid transit systems and innovative public transport systems should be integrated especially for intra city movement. Battery operated vehicles (vehicles similar to golf carts) could be deployed for point to point service for places with high footfall, especially in commercial places like the Belapur CBD and institutional areas like Nerul.

Residential:

Almost 20% of the total emissions (563.92 thousand tCO_2) were attributed to the usage of fossil fuel in form of electricity and petroleum products like LPG (Liquefied Petroleum Gas), Kerosene and PNG in the residential sector. In the sector, electricity consumption accounted to around 80% of the emissions (444.70 thousand tCO_2).

Larger complexes and group housing in NMMC could take advantage of solar rooftop systems, especially for lighting in common areas. NMMC may consider a policy level integration for installation of solar roof top PV to reduce the dependency on grid supply.

Positives initiatives implemented by NMMC:

NMMC has undertaken many pro-environmental initiatives to curb the city level emissions Such as efficient waste management and energy efficient street lighting.

In a remarkable effort to distribute water through gravity, NMMC has successfully reduced its electricity consumption for water distribution by 2% translating to emission reduction of more than 200 tCO_2 annually. Due to management of both municipal solid waste and sewage, in the city, the emissions from waste accounted to a mere 4% and the per-capita emissions from sewage was 8 times less as compared to per capita GHG emissions from untreated sewage in Pune city.

Navi Mumbai being regarded as a city of the new millennium, can definitely set emission reduction targets and map the same against its development. Consolidated and overarching initiatives encompassing all the sectors shall definitely help in achieving a global impact and set an example for other cities to follow.

Navi Mumbai is one of the biggest planed cities in the world and with a sustainable plan in place the city has world class infrastructure to cater to the growing population. Under its "Eco-City" initiative, NMMC (Navi Mumbai Municipal Corporation) for the first time estimated the city level carbon footprint- a baseline value of the GHG (Greenhouse gas) emissions for the year 2011-12 mainly from residential, transport and industrial sectors. The footprint estimation has been further used to devise sector specific strategies which would focus not only on reducing the overall footprint but also to get a long term perspective for sustainable planning of the city.

Emissions from combustion of fossil fuels and disposal of bio-degradable waste are the main sources of GHG emissions for any city. Petrol, Diesel and CNG are the main fossil fuels consumed within the city. Coal is indirectly consumed in the form of electricity usage. Hence, to estimate the carbon footprint for Navi Mumbai city, the trends of fossil fuel sales and electricity consumption were analysed in details.

The total GHG emissions from Navi Mumbai city were estimated to be around 2.8 MMTCDE (Million Metric Tons CO_2 equivalent) and per capita emissions were around 2.51 tCO_2e, which is almost one and a half times that of the national average of 1.50 tCO_2e. The higher range of per capita emission could be attributed to the presence of TTC (Trans-Thane Creek) industrial belt within the city limits as well as lesser population of the city as compared to other metro cities.

Around 70% of the total GHG emissions (1986.18 thousand tCO_2e) are attributed to electricity consumption mainly by Industries (55%). Out of the total HT (High Tension) consumers, the industrial usage accounted to almost 80% share. In the last 5 years the emissions from electricity usage in industrial sector of the city has increased by almost 1.25 times.

Usage of about 245,295 Metric Tons of petroleum products resulted in 26% (752.47 thousand tCO_2) of the total emissions in the year 2011-12 in Navi Mumbai. Given the fact that the total number of vehicles plying on road in Navi–Mumbai increased more than 3 times in merely 5 years, the consumption of petroleum products for transport, diesel and petrol also increased by 1.14 and 1.33 times respectively, during the same period.

The transport sector accounted to around 18% of the total GHG emissions from Navi Mumbai city as against the global share of 22% and national share of 12% of GHG emissions from the transport sector. The petroleum products are also used in domestic as well as commercial sector for thermal applications. However their share is around 32%. A major boost in the intra-city public transport is required to reduce dependence on private vehicles. Mass rapid transit systems are required and innovative public transport systems should be integrated especially for intra city movement.

Owing to world class infrastructure for managing the waste in the city, both municipal solid waste and sewage, the emissions from waste accounted to a mere 4% as compared to almost 8% of the emissions coming from a city like Pune. The GHG emissions from solid waste in Navi Mumbai were less than 52% than that of Pune city and the per-capita emissions from sewage was 8 times less as compared to per capita GHG emissions from untreated sewage in Pune city

1. Navi Mumbai City GHG Inventory

Navi Mumbai is one of the largest planned cities of India. Being developed as a "Twin City" to act as a counter magnet to Mumbai Metropolitan Area, Navi Mumbai has been successful in attracting people from across the country because of its employment and education opportunities, world class infrastructure, convenient connectivity to other major cities such as Mumbai and Pune, as well as for its pleasant climatic conditions.

Famously referred to as the city of the 21st century, Navi Mumbai is a well-balanced city with well-defined residential areas and industrial zone. Furthermore, Navi Mumbai also harbours many natural spaces such as forests, parks, and wetlands within the city limits. This natural paradise of the city has been cherished by the residents of the city for many years. Numerous upcoming projects like the upcoming International Airport, International Container Port, Nhava-Sewri Sea-link, Special Economic Zones (SEZ's), amongst several others are expected to act as a booster for rapid growth of the city. On considering the potential of Navi Mumbai in terms of its development, one can practically envision Navi Mumbai as a city having equilibrium between its economy and its ecology.

The brief details of Navi Mumbai city is provided in the following **Table 1.**

Table 1: Basic details of Navi Mumbai city

Longitude	19°05′ and 19° 15′ North
Latitude	72°55′ and 73° 5′ East
Navi Mumbai city (NMMC limits)	
Total area[1]	108.638 sq. km
Population[2]	11,19,477

1.1 Objectives

The objectives of documenting the carbon inventory for Navi Mumbai city are as follows:

- To determine the baseline carbon inventory and estimate the carbon footprint of Navi Mumbai city
- To map the sources of GHG emissions in Navi Mumbai
- To develop a source apportionment of the GHG emissions
- To develop a recommendation and action plan for reducing the GHG emissions over a set time frame

[1] NMMC (2012), *Environmental Status Report 2011-12,* Chapter 2, page 3, Navi Mumbai: Navi Mumbai Municipal Corporation

[2] Census of India 2011

1.2 Study area

The carbon inventory has been undertaken for the NMMC area. All key urban activities taking place within the administrative boundaries of NMMC, have been considered while estimating the carbon emissions. Sale of petroleum products, consumption of electricity and generation of waste have been considered while developing this report.

1.3 Methodology

The inventory methodology designed for the study draws from the carbon inventories and the general guidelines reviewed in Chapter 1 and the **Appendix 1**. The methodology developed also had to take into account specificities of Navi Mumbai city (data limitations, size of the area, etc.). Hence, different existing methods were combined and adapted in order to come up with a coherent and rigorous framework that respects the main guidelines of the IPCC (2006) as well as the guidelines given by the UNEP, UN–HABITAT, and World Bank.

1.3.1 Time period

This carbon inventory report has been developed for the financial year 2011-12. However, to determine a trend and time series data, the time period chosen to document the inventory spans between 2007–08 and 2011–12. This is the largest time frame on which data could be retrieved and compared for various sectors and categories.

1.3.2 Study scope

Scope 2 is chosen for this inventory of Navi Mumbai, i.e., emissions released at the point of use within the city, as well as, emissions released outside the city boundaries, but related to energy consumed within the city.

The inventory includes carbon emissions from energy consumption (electricity and petroleum), emissions arising from municipal waste disposal sites and sewage treatment. It is acknowledged that there may be a few other activities within the city that may contribute to carbon emissions; however, the contribution of these activities is understood to be very small. These small activities may include use of coal[3] for tandoors in hotels, use of fire wood by population Below Poverty Line (BPL). Hence, it was decided to consider only sources of energy consumption, municipal waste disposal, and sewage treatment sites while estimating the carbon emissions from Navi Mumbai.

[3] TERI conducted a cursory survey for estimating the coal consumption in Navi Mumbai city. It was noted that, total estimated sale of coal in city is around 1000 MT/year. The coal is consumed mainly in hotel tandoors

A schematic depicting the sources of carbon emissions mapped while developing the carbon inventory for Navi Mumbai city is presented below in Figure 1.

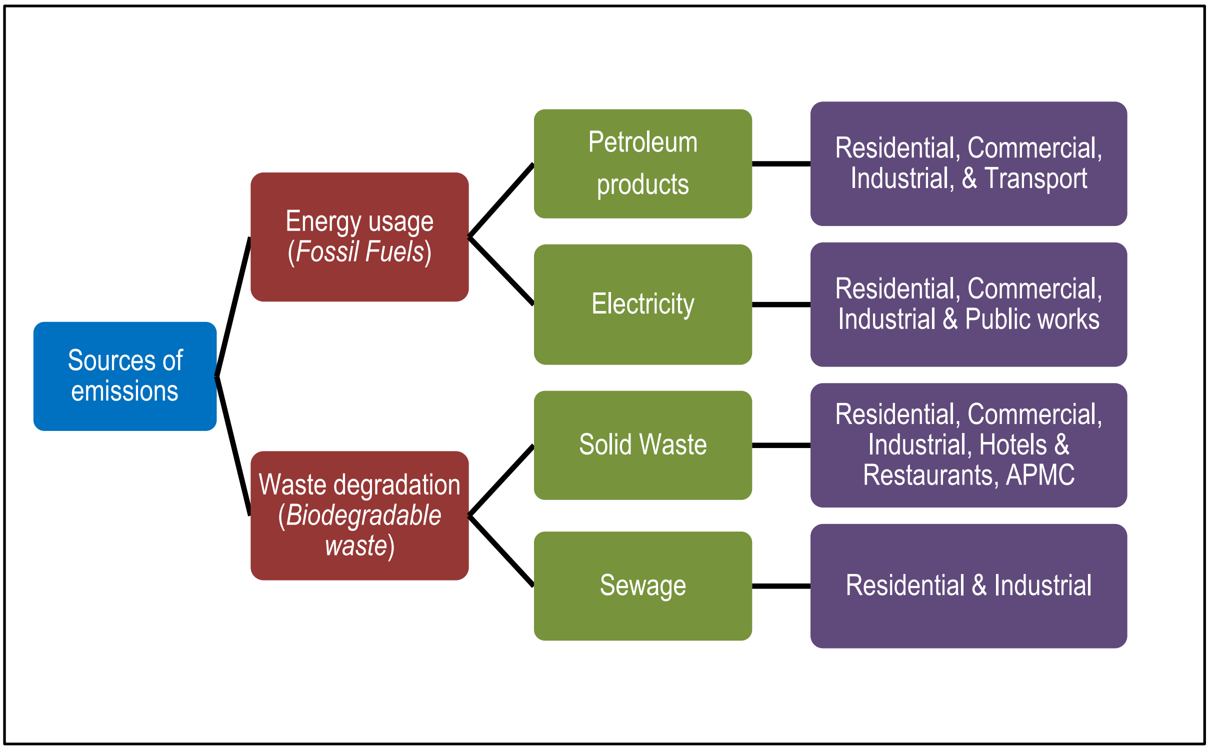

Figure 1: Sources of emissions for Navi Mumbai city

The embodied carbon in consumption of goods and services which is present on account of their production/delivery is not accounted in the carbon inventory, to avoid any double counting. It is understood that if the goods are being produced within the city limits, the carbon emissions due to their production and delivery, will be reflected in emissions of manufacturing and transportation sectors of the city. If goods are being produced outside the city, their carbon impact will be accounted in the inventory of their place of production and not in the Navi Mumbai city inventory.

1.3.3 Sectors of activity

The sectors identified for the study and the energy sources considered in each of these sectors are given in Table 2

Table 2: Sectors identified for carbon inventory

Sector	Emission from consumption/generation of
Residential	Electricity, LPG, PNG, Kerosene,
Commercial	Electricity, LPG, PNG, Kerosene,
Industrial	Electricity, LPG, PNG, Kerosene, Diesel, Furnace oil, LDO,
Transport	Petrol, Diesel, CNG, LPG
Municipal services	CNG, Petrol, Diesel, Electricity
Waste	Municipal Solid Waste, Sewage

*Note: Apart from the sectors listed above, various uncategorized heads have been considered as "**Others**". The specific inclusion of heads under this category has been specified as it appears in the report.*

1.3.4 Greenhouse gases included for assessment

As defined by the IPCC, a GHG is a gas in the atmosphere that absorbs and emits radiation within the thermal infrared range and this process is the fundamental cause of the greenhouse effect. The primary GHGs arising due to anthropogenic activities are CO_2, CH_4, and N_2O. The sources of emissions at the city level can be segmented into emissions from energy usage (fossil fuel) and waste generation (Figure 1). The nature of emission profile from both these activities, are very different which are discussed below.

Carbon inventory of energy consumption

The carbon inventory of energy consumption in the end-use form of electricity or petroleum products focuses on CO_2 emissions only. It does not include CH_4 and N_2O emissions due to energy consumption. In a recently conducted study by TERI[4] on estimating the carbon footprint of urban energy use, it was observed that the CH_4 and N_2O emissions released due to urban energy consumption activities, are insignificant compared to CO_2 emissions. As per this study, the share of CH_4 and N_2O in the per capita CO_2 equivalent emissions from urban energy use in Jaipur city was less than 4%. IPCC (guidelines 2006) also states that CO_2 emissions account typically for 95% of the energy sector emissions with CH_4 and N_2O responsible for the balance.

Carbon inventory of municipal waste disposal sites and sewage treatment

The carbon inventory of municipal waste disposal sites and sewage treatment within the city focuses on CH_4 emissions. These activities release significant amount of CH_4 on account of anaerobic digestion or fermentation of biodegradable materials.

[4] TERI (2009) *Estimating Carbon footprint of urban energy use in India and China (Phase II)*: New Delhi: The Energy and Resources Institute, 124 pp, project code 2008UD04

1.4 Emission factors

The study uses the Tier 2 emission factors, in line with the IPCC (2006) guidelines. The calculation of carbon emissions is based on national emission factors, assuming a single conversion technology for each fuel in residential, commercial, and transportation sectors.

1.5 Main assumptions

1.5.1 Fuel sales data is equal to fuel combustion

In order to calculate CO_2 emissions, data on fuel combusted in different sectors is needed. Since it is difficult to obtain the data on actual fuel combusted; it is assumed that the fuel sold in the city is equal to the fuel combusted.

There may be cases where fuel sold within the city is used outside the city. Ideally this fuel consumption should be discounted from total fuel consumption but since it is difficult to estimate this amount of fuel, we assume all fuel sold within the city is being used for the city activities only. It may also be possible that some part of the fuel used in the city is bought from outside the city limits but used within the city. Ideally, this fuel consumption should be added to the fuel consumption data for the city but since it is difficult to estimate this data, it is not included in the city estimates. This approach is consistent with IPCC guidelines 2006, which recommends that the emissions from fuel should be attributed to the place where the fuel is sold.

1.5.2 Petrol, CNG, and Auto LPG are used for transportation only

It is assumed that the petrol, CNG, and Auto LPG sold at fuel stations (petrol pumps) are used for the transport sector only. There may be cases that some part of these fuels sold at fuel stations is used for purposes other than transport. However, it is felt that the share of this fuel will be very small and hence it is assumed that 100% of petrol, CNG, and Auto LPG sold at fuel stations are used for transport sector only.

1.5.3 Diesel engines (mobile and stationary) have similar emissions profile

In addition to its use in the transport sector, some part of diesel sold at petrol pumps may be used in diesel generators used for power back-up. Since it is difficult to segregate the diesel sales, it is assumed that all diesel sold at petrol pumps is used in diesel engines (mobile and stationary) that have the similar emissions profile.

2. Electricity: Consumption and Emissions

2.1Electricity consumption

2.1.1 Structure of electricity supply in Navi Mumbai

Navi Mumbai city lies under the national grid (erstwhile western regional grid)[5] which supplies power to the state of Maharashtra. Power is distributed through the state utility, Maharashtra State Energy Distribution Co. Ltd (MSEDCL). The electricity supply to Navi Mumbai city (NMMC limits) is through Vashi and Nerul division of Vashi circle under Bhandup zone, of MSEDCL. A schematic of the electricity distribution network in Navi Mumbai city is presented in Figure 2.

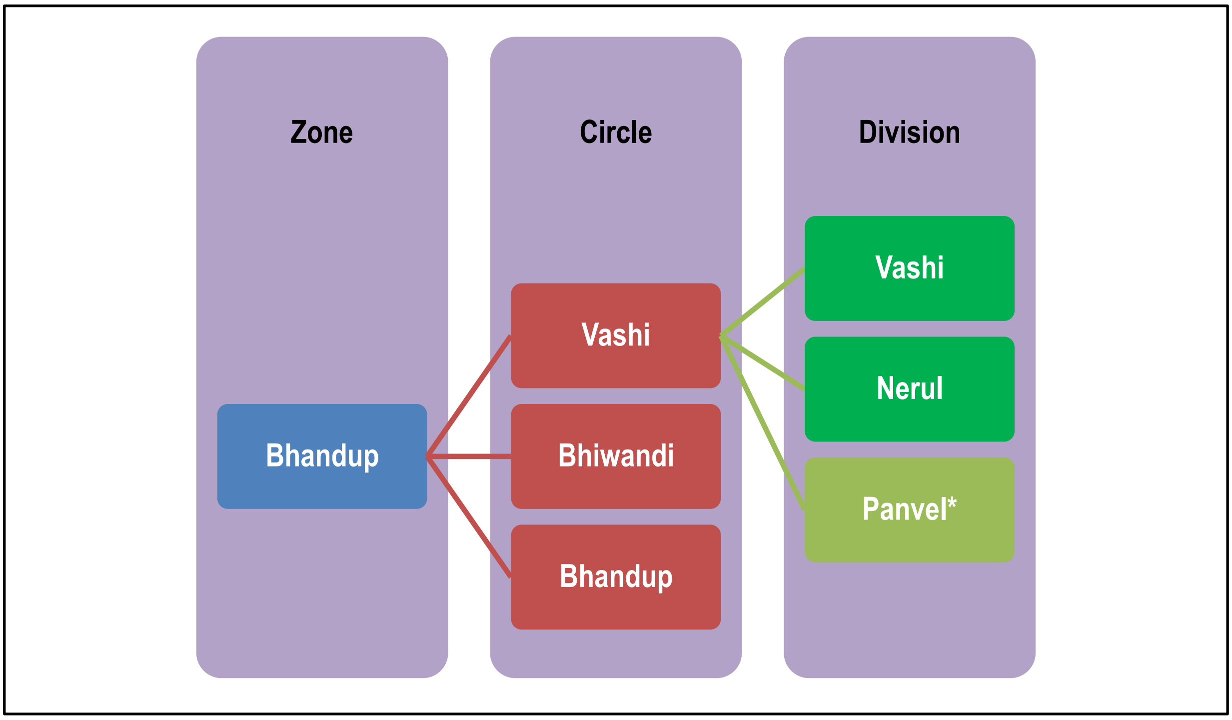

Figure 2: Electricity distribution network in Navi Mumbai city [6]

*Note: * Panvel division of Vashi circle does not supply electricity to consumers in NMMC limits The Vashi circle is spelt as "Washi" circle by MSEDCL. For convenience it has been retained as Vashi.*

[5] GoI (2011) CO_2 Baseline Database for the Indian Power Sector, CEAI, New Delhi, Ministry of Power
[6] As per data procured from MSEDCL Vashi circle in 2012

2.1.2 Sector wise classification of electricity consumers

Being a planned city Navi Mumbai has an equal balance of residential and industrial areas. On one hand the city is the most preferred destination for new properties and migratory population while on the other hand the Thane–Belapur industrial belt has been a booster for industrial sector. The residential sector has been planned along the west side of the city while the industrial sector lies along the east side of the city. Given the rise in commercial activity in the form of Small and Medium enterprises (SME's), malls, shops and commercial complexes commercial activities in the city are also on the rise.

Hence, to determine sector wise consumption and emissions, the consumers in Navi Mumbai have been classified as per data provided in Table 3**.** The consumers considered in the sectors are as per conventional consumer classification by MSEDCL.

Table 3: Electricity consumers considered under various sectors for the study

Sector	Consumers included
Residential	HT – Group housing, LT- Domestic and LT – Domestic (BPL)
Industrial	HT – Industrial (Express & non express), LT- Industrial
Commercial	Hoardings & Advertisement, HT – Commercial complex, HT – commercial and LT – commercial
Municipal services	HT – PWW (Express & non express), LT- PWW and Street lights
Others	HT - Railways traction, HT - Temp supply, HT - poultry/sp.ag, HT - P.D. consumers, LT – powerloom, LT – Agriculture (Metered and Unmetered), LT - temp. connections, Crematorium/burial, LT - P.D. consumers, Mismatch rcpts.

Note: HT – High tension, LT – Low tension, BPL – Below poverty line, PWW – Public Water Works, SP. Ag – Special Agriculture, P.D – Permanent Disconnect, Temp – Temporary, Rcpts - Receipts.

2.1.3 Trend in electricity consumption

Owing to the city's growing infrastructure and population growth there has been a remarkable increase in the energy consumption pattern of Navi Mumbai. In the past five years; i.e between fiscal years 2007-08 and 2011-12, the total electricity consumption increased at a Compound Annual Growth Rate (CAGR) of 9.16%[7]

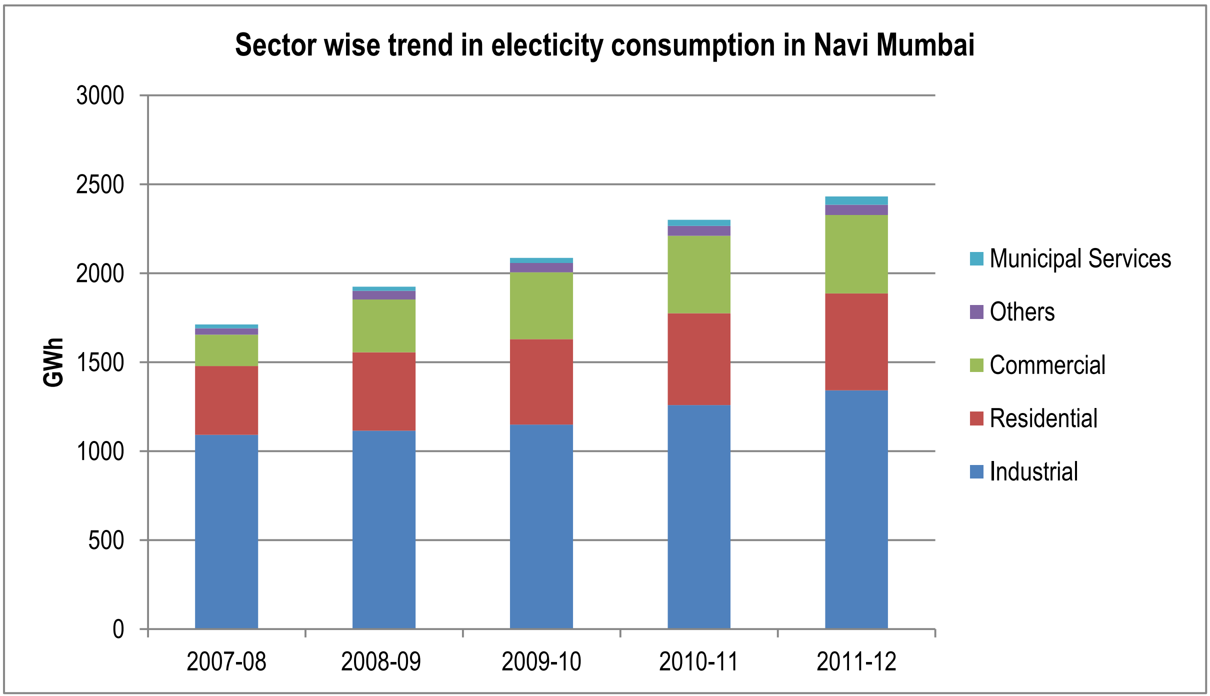

Figure 3: Sector wise trend in electricity consumption in Navi Mumbai[8]

As seen in Figure 3, one may note, that industrial consumers (HT and LT included) dominate the share of electricity consumption, which is evident owing to the presence of a strong industrial sector. In the Trans-Thane Creek (TTC) industrial belt there are almost 2200 industrial units from various categories engaged in manufacturing of chemicals, dyes, dye-intermediates, bulk drugs, pharmaceuticals, pesticides, petrochemicals and so on.

The energy consumption by municipal services more than doubled in the last 5 years from 21.25 to 48.12 MU (Million Units) within the NMMC limits. This includes electricity consumption for public water works and streetlights.

There has been a gradual ascent in industrial and residential electricity consumption in the last five years, between 2007-08 and 2011-12. However, the power consumption by commercial consumers has grown by more than 2.5 times, i.e from 174.89 GWh to 440.91 GWh in the same period.

[7] CAGR = [(t_n/t_0) ^(1/No of years)] – 1
= t_n = Consumption in 2011-12, t_0 = Consumption in 2007-08 , No of years = 4, ^ = raise to the power
= [(2433.13/1713.246) ^ (1/4)] – 1
= 0.0916574
= 9.16%

[8] As per data procured from MSEDCL Vashi circle in 2012

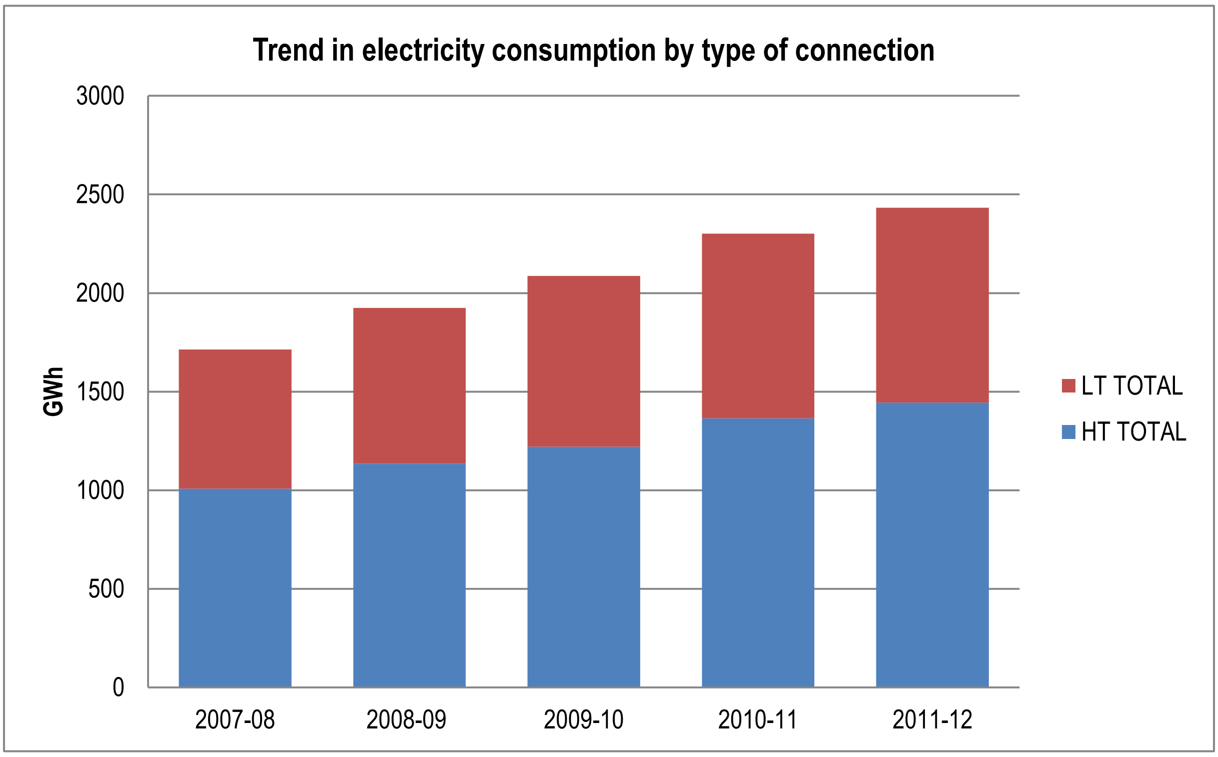

Figure 4: Trend in electricity consumption by type of connection[9]

As against the CAGR of 9.16% in overall electricity consumption, the rate of increase in electricity consumption by HT consumers and LT consumers is significantly different. Over the last four years, between fiscal years 2007-08 and 2011-12, the growth in HT consumption is recorded at a CAGR of 9.39% and growth in LT consumption has increased at a CAGR of 8.83%. The trend in electricity consumption by type of connection is presented in Figure 4.

2.1.4 Status of electricity consumption in Navi Mumbai

The total electricity consumption in Navi Mumbai for the year 2011-12 was recorded to be 2433.13 Million Units (MU) or Giga-watt hours (GWh). Sector wise and division wise consumption is presented in Table 4. Vashi division is the larger division as compared to Nerul division and was responsible for almost 75% of the share of electricity consumption.

Vashi division predominantly supplies electricity to industrial consumers of Thane Belapur Industrial Belt and accounts for more than 92% of the power supply to industrial consumers whereas for the other sectors, (residential, commercial and municipal services), the figures for consumption of electricity for both the divisions are almost comparable.

[9] As per data procured from MSEDCL Vashi circle in 2012

Out of the total electricity consumption in the city, industrial sector consumers accounted for almost 55% of the share followed by residential and commercial, accounting for 23% and 18% respectively Figure 5.

Table 4: Electricity consumption in Navi Mumbai city in 2011-12

Division	Industrial	Residential	Commercial	Others	Municipal Services	Total
Vashi	1243.23	296.26	221.52	26.37	24.76	1812.14
Nerul	98.8	248.73	219.39	30.71	23.36	620.99
Total	**1342.03**	**544.99**	**440.91**	**57.08**	**48.12**	**2433.13**

Source: MSEDCL, 2012

Note: units in GWh

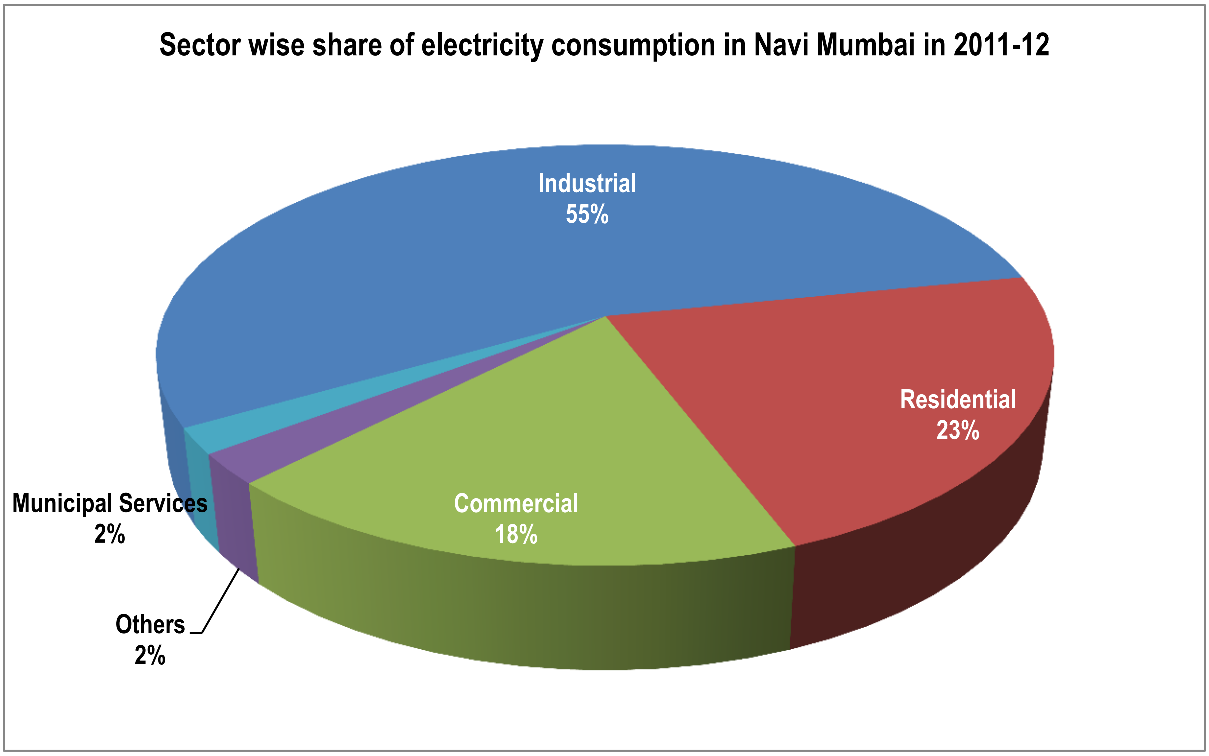

Figure 5: Sector wise share of electricity consumption in Navi Mumbai in 2011-12

Source: MSEDCL, 2012

Note: The percentages have been rounded off for convenience

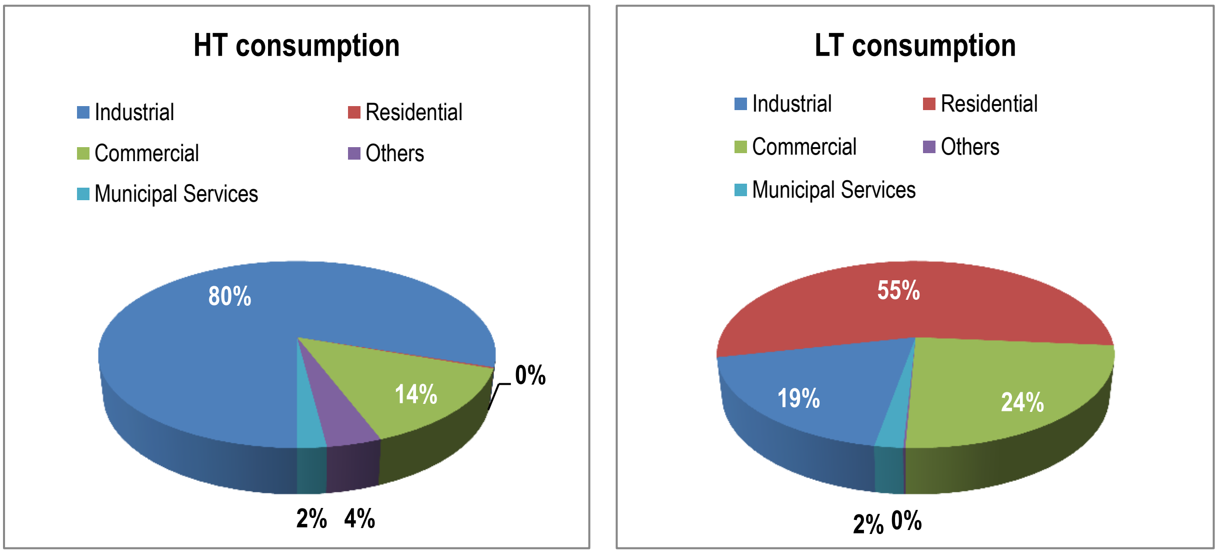

Figure 6: Consumption share by type of connection in Navi Mumbai (2011-12)

Note: The percentages have been rounded off and hence the values below 0.5 appear as zero

In the year 2011-12, almost 59% of the electricity consumption was made by HT consumers and the LT consumers were responsible for the remaining (41%) electricity usage. A sector wise breakup of the HT and LT consumption pattern is provided in Figure 6. Among the HT consumers industrial users dominated the consumption with almost 80% share followed by commercial sector (14%). Other major HT consumers like railways and PWW accounted to around 6% of the consumption.

2.2 Emissions from electricity usage

The amount of CO_2 emissions from electricity consumption is directly dependent on the manner in which the electricity is generated. The National Grid, that Navi Mumbai is a part of, derives electricity from thermal, hydro, gas-fired, nuclear and, wind-based power plants. Higher the amount of coal based power supplied to the grid, greater would be the emissions. A breakup of electricity generation capacity in India, corresponding to 156,475 MW as in March 2011 is presented in Figure 7 and it's evident that coal based power plants have a major share of almost 60% in electricity generation in India.

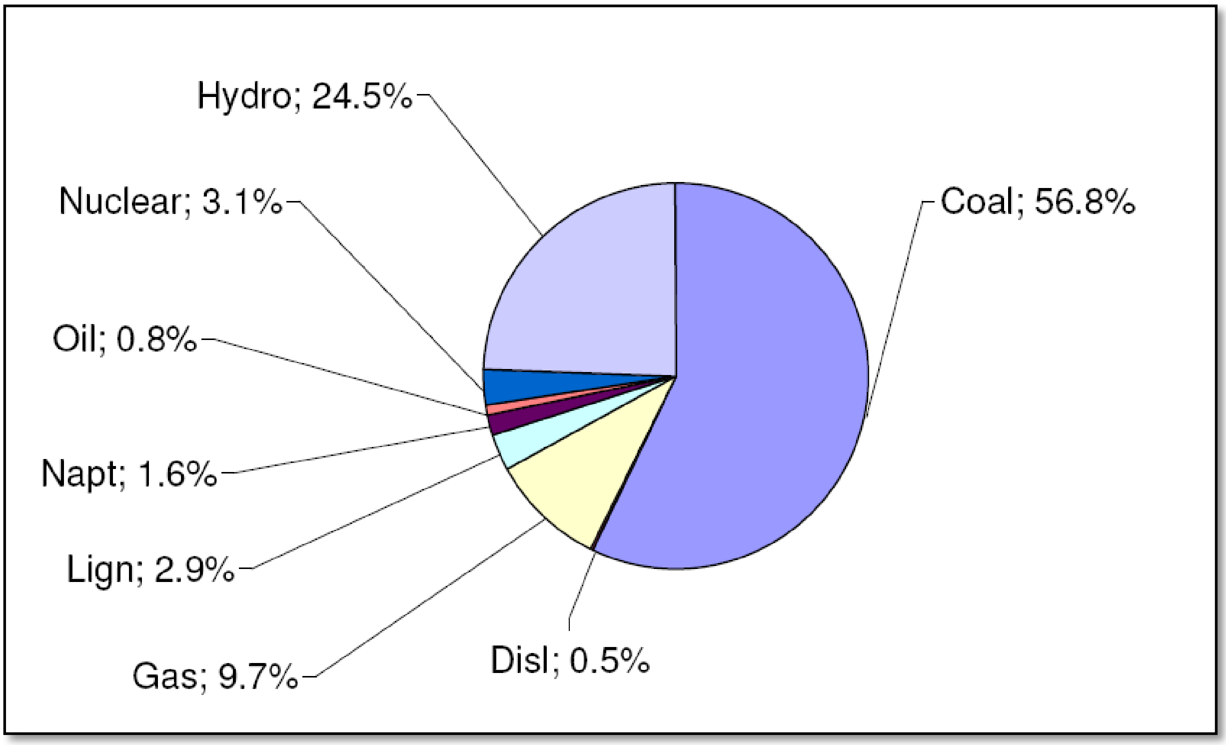

Figure 7: Share of electricity generation capacity in India as on 2011

Source: CEA, Government of India

Central Electricity Authority (CEA), under Ministry of Power, Government of India compiles a database to determine the CO_2 emissions for all grid-connected power stations in India. These emission factors are based on the average mix of the generation from different sources and are well-accepted nationally and internationally. Presented below in Table 5 are the emission factors given by CEA in the last seven years. This study makes use of the annual CO_2 emission factors generated and published by CEA in January 2012[10].

[10] CEA (2012), *CO_2 Baseline Database for the Indian Power Sector*, User Guide, Version 7: New Delhi, Ministry of Power, Government of India

Table 5: CO_2 emission factors for NEWNE (National Grid)[11]

	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12*
tCO_2/MWh	0.84	0.82	0.81	0.83	0.82	0.80	0.82
tCO_2/GWh	840	820	810	830	820	800	820

*Note: *Since emission factors for 2011-12 have not been published, average emission factor for the same year has been derived based on trend of emission factors for recent six years*

The emission factors are then multiplied to the electricity consumption to determine/ estimate the carbon emissions. An example is provided in **Equation 1** to help understand the calculations.

Electricity consumption in residential sector	(A)	=	544.99 GWh
Emission factor for the year 2011-12	(B)	=	0.82 tCO_2/MWh
		=	820 tCO_2/GWh
Emissions from Residential sector in 2011-12		=	(A) X (B)
		=	544.99 X 820
		=	446891.80 tCO_2

Equation 1: Calculation of CO_2 emissions from electricity use in Navi Mumbai

The calculation presented in **Equation 1** has been used to determine the emission for other sectors and various years. The following section 2.2.1 discusses the trend in emissions and section 2.2.2 presents the status of emissions in 2011-12, the reporting year.

[11] CEA (2012), CO_2 Baseline Database for the Indian Power Sector, User Guide, Version 7: Appendix C – Grid Emission Factors, Table B, Weighted Average Emission Rate (tCO2/MWh) (incl. Imports) New Delhi, Ministry of Power, Government of India

2.2.1 Trend in emissions from electricity consumption

In the last five years the emissions from electricity consumption in Navi Mumbai have increased from 1.38 million tCO_2 in 2007-08 to 1.98 million tCO_2 in 2011-12, almost 1.4 times, with a CAGR of 9.37%[12]. One may observe from Figure 8 that trend in emissions are not constant throughout and fluctuates in the last five years. It may be because of two reasons, one- that the emission factors are not constant across the years and the other being implementation and adoption of many energy efficient initiatives.

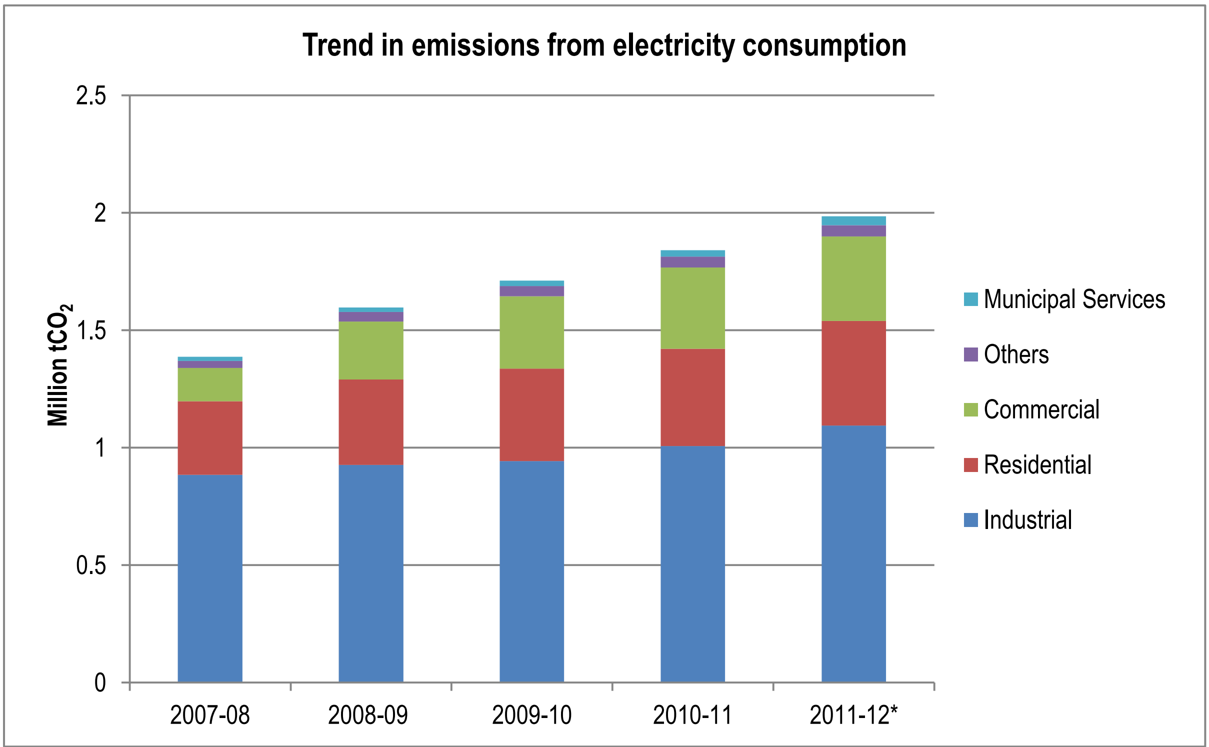

Figure 8: Trend in emissions from electricity consumption

**Note: Emission Factors have been averaged for the last five years since data for 2011-12 was not available while preparation of this report*

[12] CAGR = [(t_n/t_0) ^(1/No of years)] – 1
= t_n = Emissions in 2011-12, t_0 = Emissions in 2007-08 , No of years = 4, ^ = raise to the power
= [(1986182.38/1387729.26) ^ (1/4)] – 1
= 0.0937765
= 9.37%

2.2.2 Emissions from electricity usage in 2011-12

As per the calculation explained in Equation 1, the carbon emissions from electricity usage in Navi Mumbai for the year 2011-12 were recorded to be 1986182.38 tCO_2 (1.98 million tons). A sector wise share of the emissions is presented in Figure 9 and the total values and per-capita emissions are provided in Table 6.

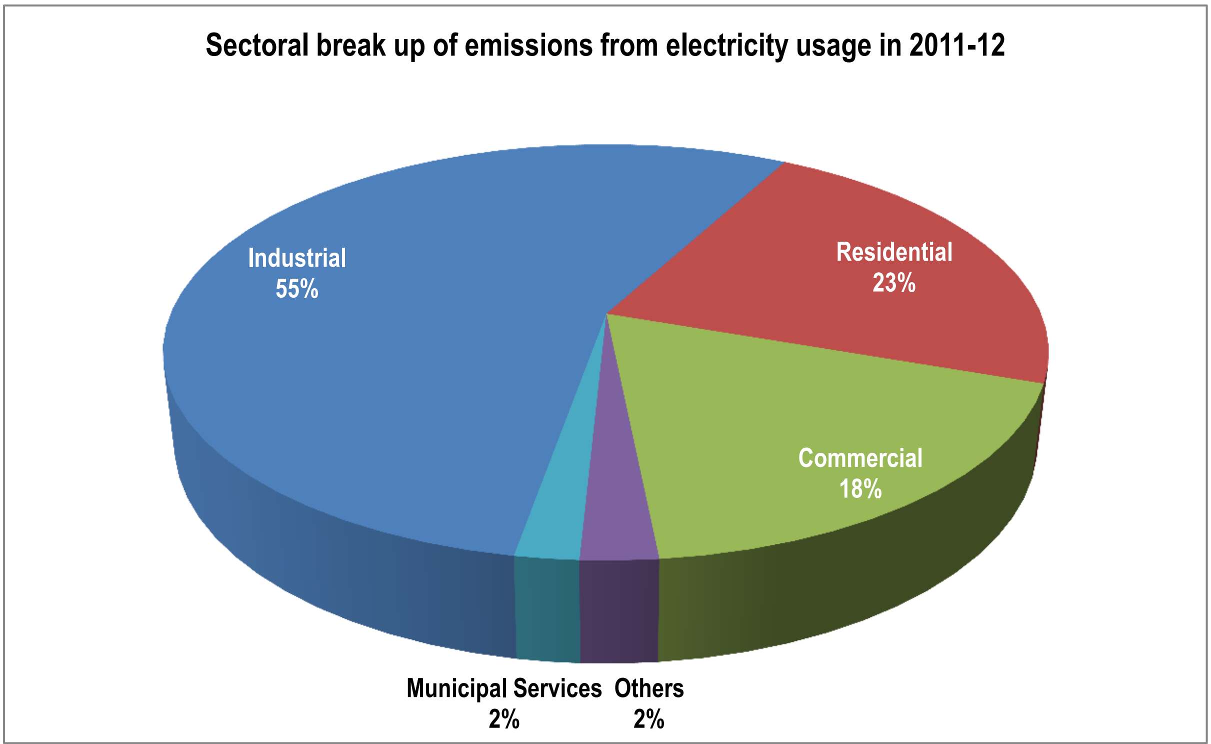

Figure 9: Sectoral break up of emissions from electricity usage in 2011-12

Note: The percentages have been rounded off for convenience

Table 6: Emissions from electricity usage in Navi Mumbai in 2011-12

Sectors	Total (Metric tCO_2)	Total (Thousand Metric tCO_2)	Share (%)
Industrial	1095068.15	1095.06	55.13
Residential	444700.33	444.70	22.38
Commercial	359773.25	359.77	18.11
Others[13]	47375.73	473.75	2.38
Municipal Services	39264.90	392.64	1.97
Total	**1986182.37**	**1986.18**	**100**

Note: The figures have been retained to only two decimal places hence total may not tally.

[13] HT - Railways traction, HT - Temp supply, HT - poultry/sp.ag, HT - P.D. consumers, LT – powerloom, LT – Agriculture (Metered and Unmetered), LT - temp. connections, Crematorium/burial, LT - P.D. consumers, Mismatch rcpts.

3. Petroleum: Consumption and Emissions

Petroleum products are now an indispensible part of our daily routine. Transport, industrial sector and residential sectors are all dependant on the consumption of petroleum fuels. As per the Key World Energy Statistics report, in the year 2010 almost 3570 Million tonne of oil equivalent (Mtoe) of petroleum products were consumed globally[14]. The transport sector was the major consumer of petroleum products accounting to more than 61% of the total oil consumption globally and industrial consumption accounted for 9%.

India accounted to almost 157.66 Million Metric Tonnes (MMT) of petroleum consumption in the year 2010-11[15]. Of the total consumption, High Speed Diesel (HSD) accounted for 38% of total consumption of all types of petroleum products, majorly by transport sector (80% of total HSD consumption), in the same year. This was followed by LPG (9.1%), Petrol (9%), Fuel Oil (7%) and refinery fuel (10.1%).

Petroleum use is directly attributed to the development of a region. The same is true for the city of Navi Mumbai; hence the section discusses the consumption of petroleum products in Navi Mumbai. To develop a sector wise classification for consumption of petroleum products, the fuels have been classified as presented in Table 7 below.

Table 7: Petroleum products considered under various sectors for the study

Sector	Fuels Considered
Industrial	High Speed Diesel (HSD) bulk/direct sales, Furnace oil, Liquefied Petroleum Gas (LPG) Industrial and commercial, Piped Natural Gas (CNG) industrial, Light Diesel Oil and bulk sales of Kerosene
Commercial	PNG to commercial or institutional units
Residential	LPG- Domestic, Kerosene retail (sale from Public distribution System) and CNG- Domestic also known as PNG
Transport	Motor Spirit (MS) commonly known as Petrol, HSD retail sales, Auto LPG, CNG at pumping stations

Note: The categories have been considered as classified by oil companies and Mahanagar gas.

[14] IEA (2012), Key World Energy Statistics, Shares of World oil consumption, page 33: Paris, International Energy Agency

[15] GoI (2012), Energy Statistics 2012, Table 6.6: Trends in Consumption of Petroleum Products in India, page 52: New Delhi, Ministry Of Statistics And Programme Implementation

3.1 Consumption of petroleum products

3.1.1 Vehicular growth in Navi Mumbai

The heavy use of personalized transport, four wheelers and two wheelers, has caused a rapid growth in the overall demand for petroleum products within the city. Since the establishment of a dedicated RTO, Navi Mumbai has seen a rapid increase in number of vehicles within the city. Figure 10 depicts that the number of vehicles on road as on March 31 (financial year end) has increased by almost 3.75 times in the last 5 years.

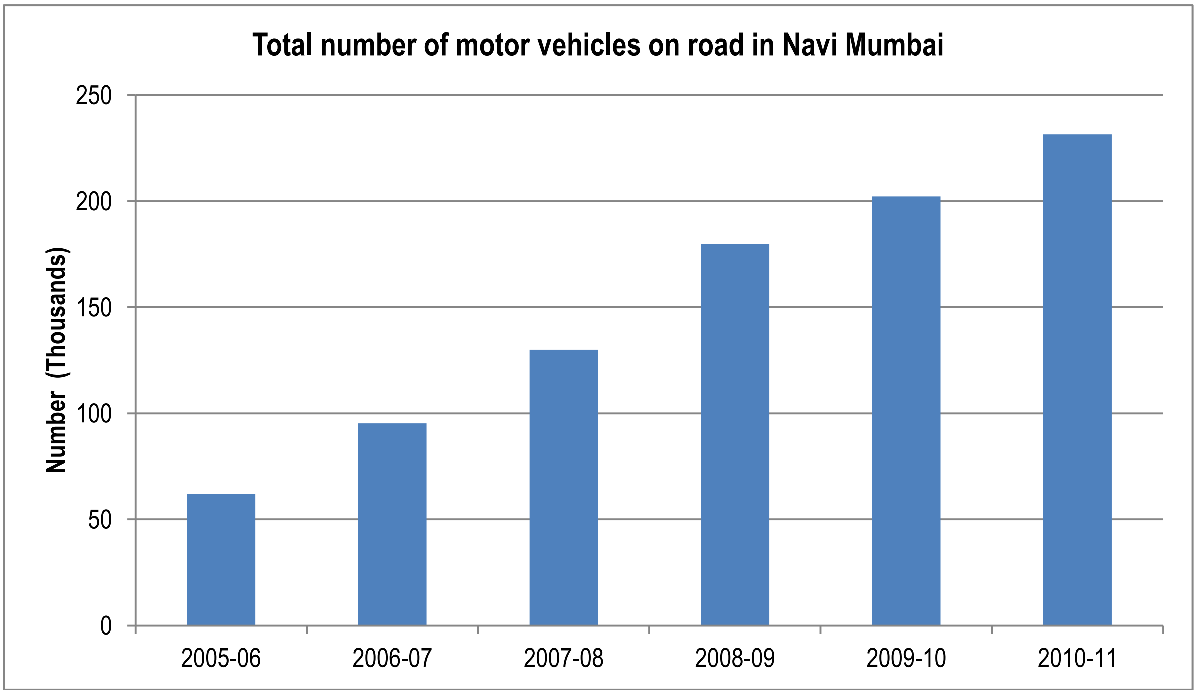

Figure 10: Increasing trend in total motor vehicles on road in Navi Mumbai[16]

Source: MVDM, 2012

Out of the total registered vehicles in Navi Mumbai, Two wheelers and LMV (Light Motor Vehicles) share the major contribution. The trend in number of new motor vehicles registered in Navi Mumbai is depicted in Figure 11. This overall increasing trend in registration of new motor vehicles directly leads to increasing demand of petroleum fuels. In the year 2011-12, almost 40 two wheelers and 40 LMV's got registered every day in Navi Mumbai.

[16] GoM (2011), *Motor Transport Statistics Of Maharashtra 2010 – 2011*, Table 11, page 43: Mumbai, Motor Vehicles Department Government of Maharashtra

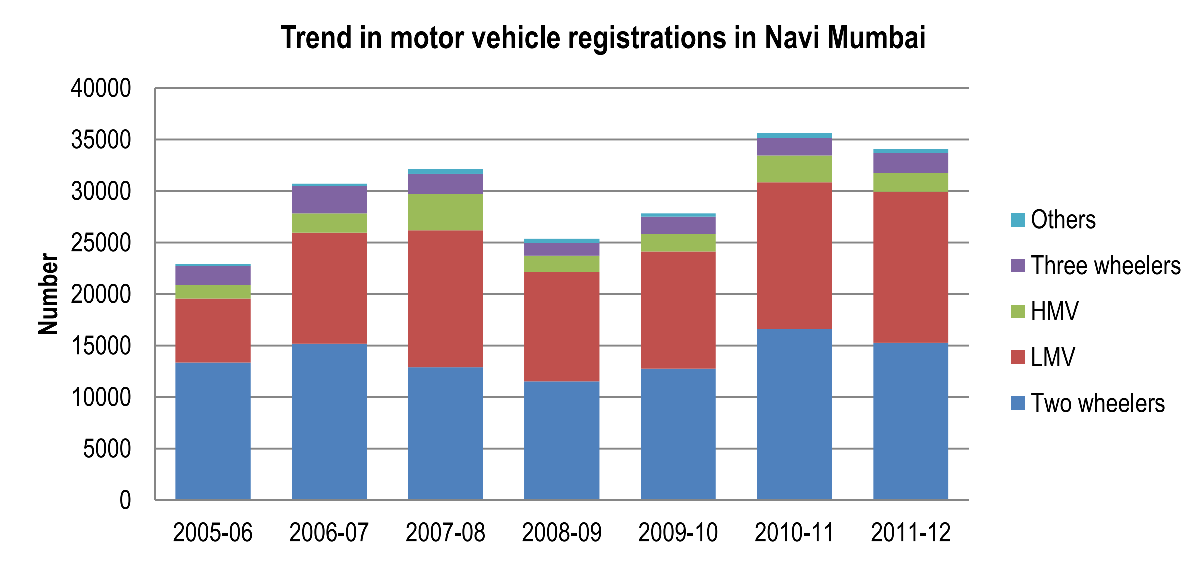

Figure 11: Trend in motor vehicle registrations in Navi Mumbai[17]

Note: Two Wheelers includes Mopeds, Motorcycles, Scooters,

LMV: Light Motor Vehicle, includes cars, jeeps, delivery van 4 wheel, station wagons and taxies

HMV: Heavy Motor Vehicle, includes school busses, Trucks & Lorries, Tankers and Trailors

Others: Tractors, carriages (stage & contract), private service vehicles, Arti. & Muli. Vehicles, ambulances and other uncategorised vehicles

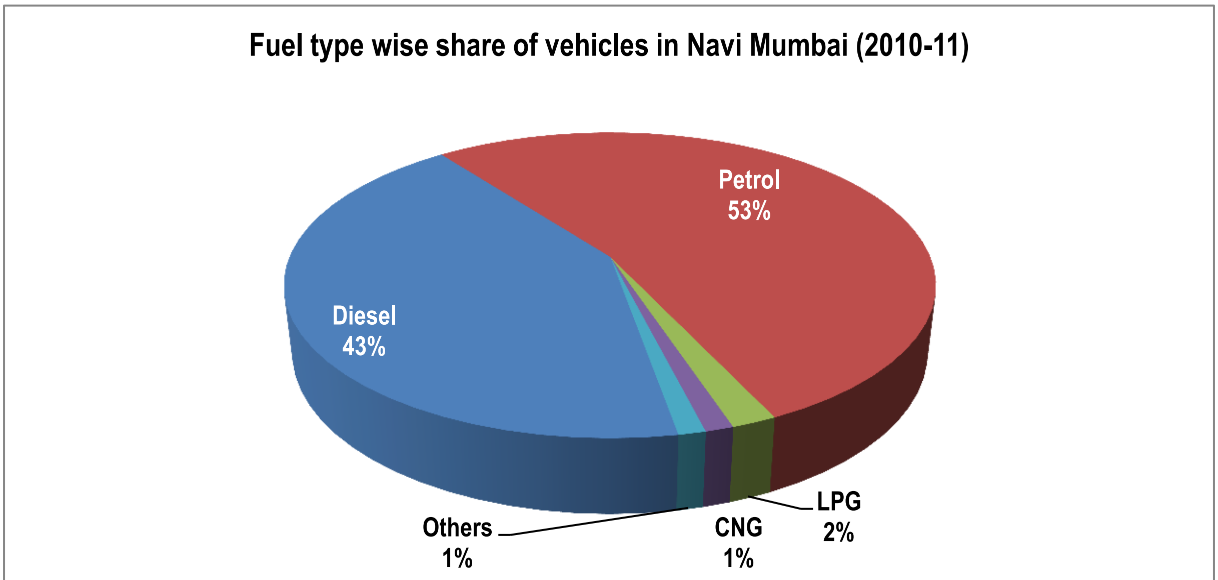

Figure 12: Fuel type wise share of vehicles in Navi Mumbai (2010-11)[18]

As seen in Figure 12, out of the total, 231449 (Figure 10) motor vehicles in Navi Mumbai, petrol consuming vehicles account to more than 53% followed by diesel consuming vehicles having a share of 43%. Vehicles running or retrofitted with kits which consume LPG (Liquefied Petroleum Gas) and CNG (Compressed Natural Gas) 2% and 1% respectively.

[17] As per data procured from RTO through personal correspondence

[18] GoM (2011), *Motor Transport Statistics Of Maharashtra 2010 – 2011*, Table 13 (A), page 68: Mumbai, Motor Vehicles Department Government of Maharashtra

3.1.2 Consumption of petroleum products in transport sector

Motor Spirit (MS) commonly known as petrol, HSD, CNG and Auto-LPG are the commonly used fuels in transport sector. The public transport in Navi Mumbai including taxies, auto-rickshaws, and busses owned by Navi Mumbai Municipal Transport (NMMT) either consumes CNG or Diesel. Increasing vehicular growth exerts demand for fuel and it is clearly reflected from Figure 13. The sale of petroleum products has increased with a CAGR of almost 8% in the last 5 years. The total sale of petroleum products in transport sector for year 2011-12 accounted to almost 164.55 thousand metric tons.

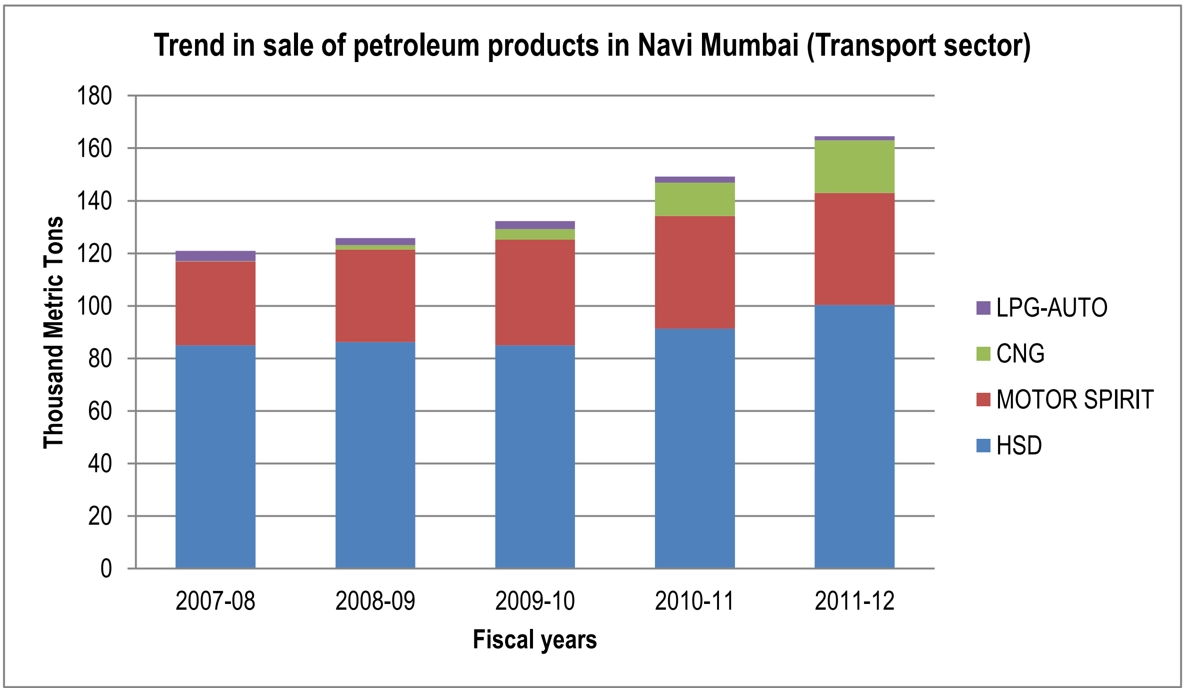

Figure 13: Trend in sale of petroleum products in Navi Mumbai (Transport sector) [19]

It is distinct that the sale of Auto LPG has decreased and there is a remarkable rise in the sale of CNG in Navi Mumbai city. The sale for CNG has increased almost 11 times in the last 4 years; i.e between 2008-09 and 2010-12 whereas the sale for both Motor spirit (MS) and High Speed Diesel (HSD) has grown by 33% and 18% respectively in the last five years. The increase in sale of CNG can be attributed to the switching option to dual fuel types and it being mandatory for auto rickshaws, taxis and many busses owned by NMMT to use CNG.

[19] As per data obtained through correspondence with IOCL, BPCL, HPCL and Mahanagar Gas

3.1.3 Consumption of petroleum products in industrial sector

Owing to the presence of TTC industrial belt within NMMC limits, there is a huge demand for petroleum products like LDO, FO and HSD in industries. The total sale of petroleum products in 2011-12 was around 41.03 thousand metric tons and the sale in Navi Mumbai has grown at a CAGR of 10.16% between fiscal years2007-08 to 2011-12. With only a slight dip in the year 2009-10, there has been an increasing trend in consumption of fuels in industrial sector.

It is remarkable to note from Figure 14 that there has been a decline in the sale of LDO and Kerosene by almost 63% and 93% respectively in last five years. These fuels have been replaced by LPG and PNG. The sale of LPG during the same has more than doubled and the sale of CNG has been significant in the same period. The annual sale of HSD in industrial sector has also decreased by 6%in last five years. However the sale of furnace oil has registered a growth of more than 50%.

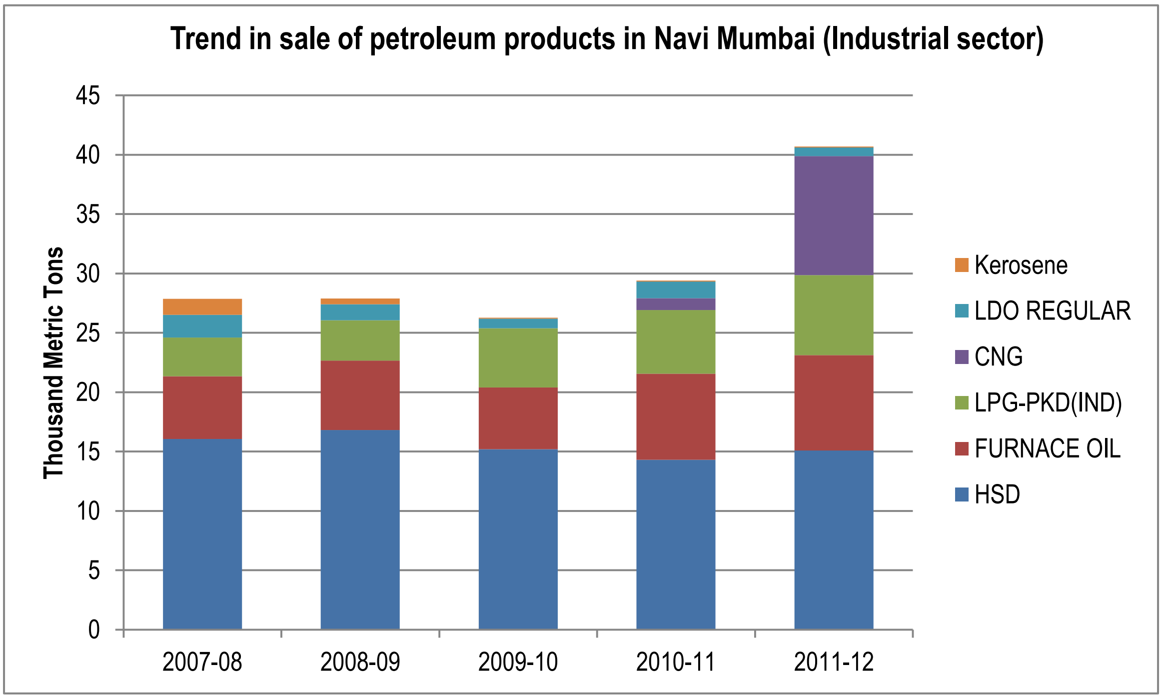

Figure 14: Trend in sale of petroleum products in Navi Mumbai (Industrial sector)[20]

Note: The sale of CNG includes both industrial and commercial & institutional sale of CNG as categorized by Mahanagar gas. HSD sale includes bulk sales made by fuel companies.

[20] As per data obtained through correspondence with IOCL, BPCL, HPCL and Mahanagar Gas

3.1.4 Consumption of petroleum products in residential sector

LPG, Kerosene and Piped Natural Gas (PNG) are the main fuels used in residential sector. Together they aggregated for a sale of 39.70 thousand metric tons in the year 2011-12. PNG was introduced in Navi Mumbai in the year 2010 and hence its sales are reflected significantly only in the year 2011-12. However, being economical and cheap, its demand has increased drastically in the residential sector and has already registered a growth of more than 4 times in two years.

In case of LPG sales, there has been a growth of almost 18%, from 27 thousand MT in 2007-08 to 32.03 thousand MT in the year 2011-12. Kerosene supply in Navi Mumbai is made through public distribution system and is used predominantly by urban poor. Vashi and Thane office under the Thane division are responsible for supplying kerosene to the Authorized Rationing Shops from Belapur to Digha. Almost 68.14 thousand MT of kerosene was distributed in Navi Mumbai in the year 2011-12. The total sale of fuel in residential sector has increased by 21% between 2007-08 and 2011-12 (**Figure 15**).

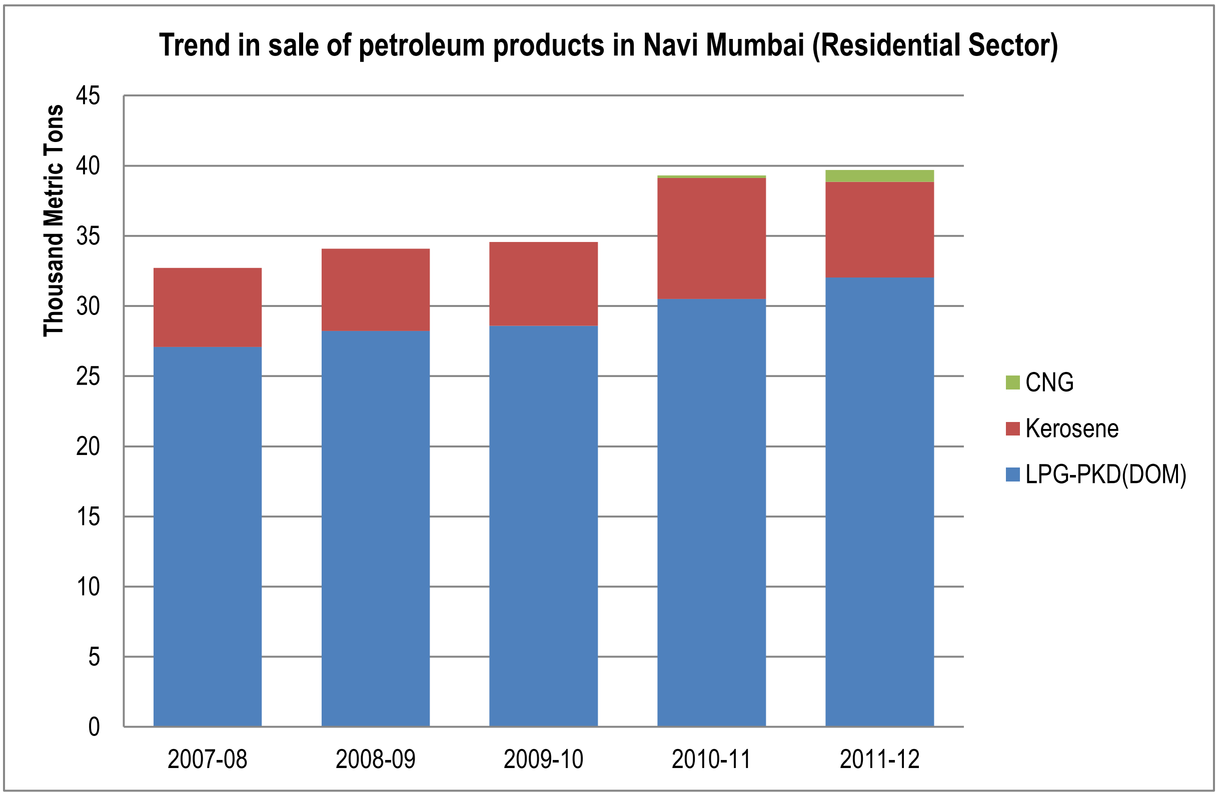

Figure 15: Trend in sale of petroleum products in Navi Mumbai (Residential sector)[21]

Note: LPG includes supply of LPG to agencies of respective oil companies within Navi Mumbai

[21] As per data obtained through correspondence with IOCL, BPCL, HPCL and Mahanagar Gas

3.2 Emissions from consumption of petroleum products

The increasing growth in sale of petroleum products in Navi Mumbai has resulted in increased levels of CO_2 emissions. This section gives the calculations carried out to estimate CO_2 emissions on account of use of petroleum products in the city.

3.2.1 Emission calculations for petroleum products

Emissions from petroleum are calculated using Indian fuel specific emission factors used in India's National Communication to the UNFCCC Secretariat. The product specific fuel sales information that was provided by different fuel companies were first converted into a uniform unit of metric tonnes (MT) for ease of calculations. Once assimilated in the uniform units of mass, the subsequent data is converted into CO_2 equivalent emission values using Indian fuel-specific emission factors as shown in Table 8.

Table 8: Derivation of petroleum emission factors from energy content

Petroleum Product	Emissions by energy content (tCO_2/MJ)	Calorific value (MJ/kg)	Emissions by weight (tCO_2/kg)	Emissions per tonne (tCO_2/MT)
Diesel	74.10	43.00	3,186	3.19
Petrol	69.30	44.30	3,070	3.07
Kerosene	71.90	43.80	3,149	3.15
Furnace oil	77.40	40.40	3,127	3.13
LPG	63.10	47.30	2,985	2.98
CNG	56.10	48.00	2,693	2.69

The emissions are subsequently calculated by multiplying the amount of fuel sales in units of mass with the CO_2 emission factors per tonne. One complete example of the conversion is given in Equation 2.

Petrol Sales in Navi Mumbai in 2010-12	[A]	: 42602.496 MT
Emissions factors for Petrol	[B]	: 3.06999 tCO_2 /MT
Emissions from Petrol sales in 2011-12	[A X B]	: 130,789.25 tCO_2

Equation 2: Calculation of emissions from petroleum products

3.2.2: Emissions from the use of petroleum products

An increasing trend in consumption of fuel has led to increase in emissions from fuel usage. About of 752.46 thousand MtCO_2 was generated in Navi Mumbai in the year 2011-12. Out of this, transport sector accounted for a major share of almost 67%. The domestic and industrial sectors accounted for almost equal carbon emissions in the same year (Figure 16).

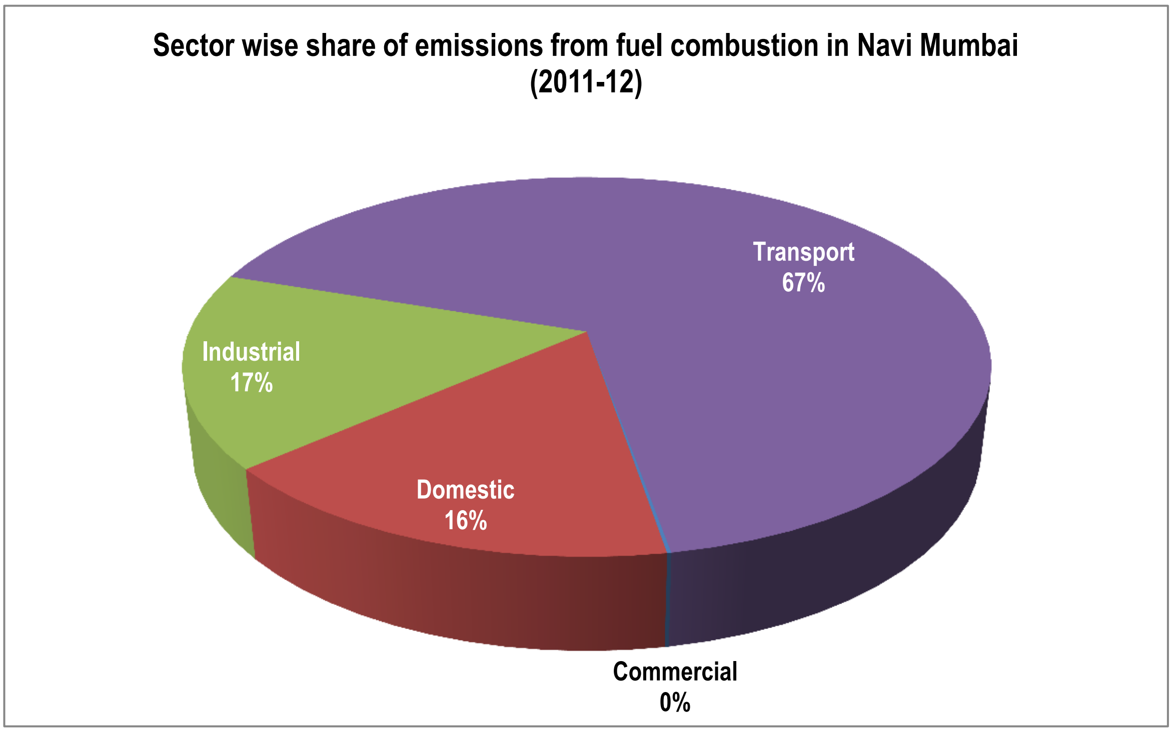

Figure 16: Sector wise share of emissions from fuel combustion in Navi Mumbai (2011-12)

Note: The percentages have been rounded off and hence the values below 0.5 appear as zero.

In terms of emissions, transport sector accounted to almost 509.47 thousand MT in 2011-12 whereas industrial and residential sector were responsible for 122.86 and 119.21 thousand MT of CO_2 in the same period. In terms of total emissions from fuel combustion there has been an increase by almost 32% in the last four years, from 567 thousand MT to more than 752 thousand MT in 2011-12.

As seen in **Figure 17**, the emissions from HSD have increased by 14% and although emissions from petrol consumption are less than that of HSD, the emissions from petrol have increased by more than 33% i.e more than double than that of HSD. There is also remarkable growth in emissions from consumption of furnace oil and the emissions have increased by more than 50% and the emissions from industrial LPG has more than doubled in last 5 years.

Emissions from Auto LPG, LDO and Kerosene have all registered a net negative growth. A trend in the emission from various fuels is presented in Figure 17. The summary of emissions from usage of petroleum product in Navi Mumbai is presented in Table 9.

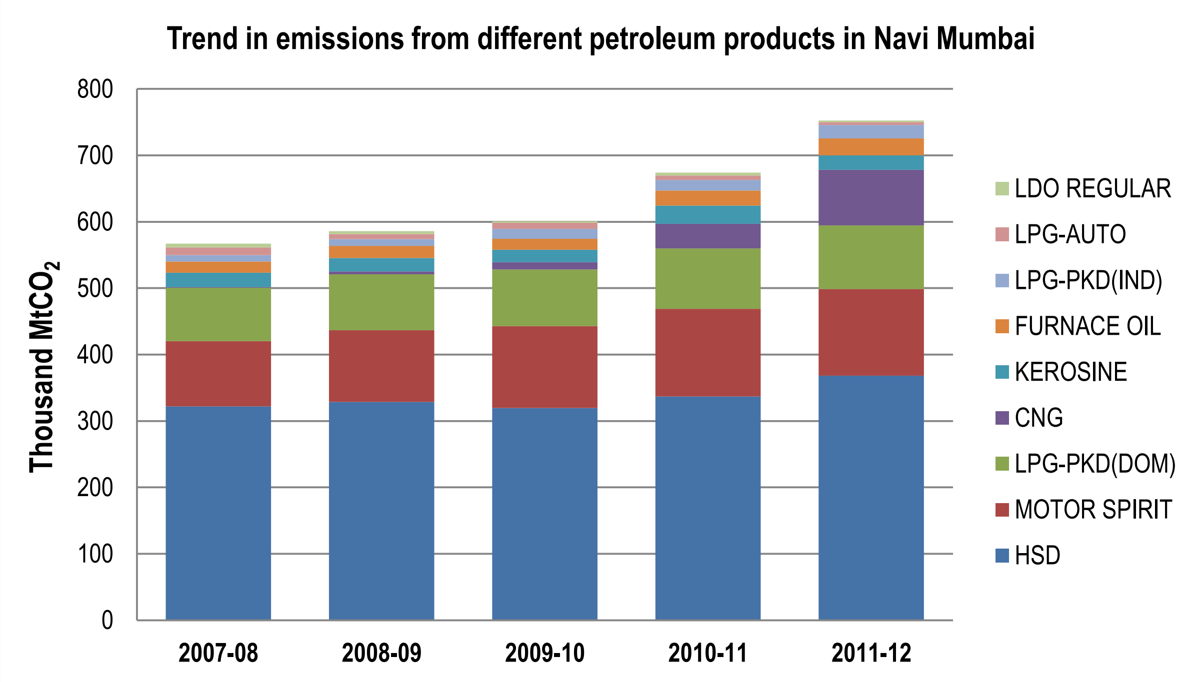

Figure 17: Trend in emissions from different petroleum products in Navi Mumbai

Table 9: Emissions from petroleum product usage in Navi Mumbai (2011-12)

Sector	Products	Consumption (MT)	Emission (Thousand $MtCO_2$)
Commercial		**340.45**	**0.92**
	CNG	340.45	**0.92**
Residential		**39700.36**	**119.22**
	LPG-PKD(DOM)	32031.48	95.45
	KEROSENE	6814.58	21.47
	CNG	854.30	2.30
Industrial		**30674.50**	**122.86**
	HSD	15077.55	48.10
	CNG	10023.40	26.96
	FURNACE OIL	8041.62	25.17
	LPG-PKD(IND)	6754.32	20.13
	LDO REGULAR	707.31	2.21
	KEROSENE	93.71	0.30
Transport		**164557.21**	**509.47**
	HSD	100333.50	320.06
	MOTOR SPIRIT	42602.50	130.79
	CNG	20037.65	53.90
	LPG-AUTO	1583.56	4.72
Total		**235272.51**	**752.47**

4. Waste: Generation and Emissions

One of the major challenges faced by any urban centre is the disposal of waste, both solid-wastes as well as sewage. Rapidly increasing population with higher per capita incomes and changing lifestyles has resulted in larger quantities of waste being generated at the residential and commercial units, restaurants, shops, industrial zones and so on.

Overall, the emission from waste contribute <5% of global GHG emissions[22]. Methane (CH_4), from land fill sites, is attributed to be the major source of GHG emission from waste as it does have tenacious impact even years after its disposal at the dumping site. CH_4 is also released in sewerage lines, during transportation of sewage and at sewage treatment plants (STP's). Human sewage and waste water degradation form a major source of Nitrogen-di-oxide (N_2O) emissions and a small source of CO_2 emissions is attributed to incineration of non-biomass portion of the municipal solid waste.

Navi Mumbai, being a planned city has been very effective in managing its waste, both solid waste and sewage. The following section discusses the brief on waste generation, its treatment and the subsequent emissions from the same in Navi Mumbai.

4.1 Municipal Solid Waste

4.1.1 Generation, Collection and Treatment

Since 1997, NMMC has taken charge from CIDCO to collect waste from residential areas in Navi Mumbai. It has further taken the responsibility to collect waste from Thane–Belapur industrial belt in 2004. Approximately 600 Metric Tons (MT) of municipal solid waste is generated per day in Navi Mumbai city. Following Table 10 provides a breakup of the waste generate from various areas in Navi Mumbai.

Table 10: Area wise breakup of solid waste generation in Navi Mumbai city[23]

Sr No	Area	Sector	Net weight (Kg)	Share
1	NMMC residential area	Residential	458270	76.33%
2	Agricultural Produce Market Committee (APMC) market	Commercial	96255	16.03%
3	Thane-Belapur industrial area	Industrial	44490	07.41%
4	Others (commercial, urban poor, unorganised sector)		1345	00.22%
	Total		**600360**	

Note: The areas have been divided in sectors for developing for including them in the sectors and develop a sector wise estimate of emissions for the city from waste degradation.

[22] http://www.ipcc.ch/publications_and_data/ar4/wg3/en/ch10s10-3.html

[23] NMMC(2012), *Environmental Status Report 2011-12*, Table 2.7.1, Chapter 7 Solid Waste Management: Navi Mumbai, Navi Mumbai Municipal Corporation

In Navi Mumbai the collection and transportation of waste has been outsourced to a private contractor. The solid waste is transported, using mechanical compactors of various capacities, to Turbhe landfill site, weighed and further bio-stabilised using bio-culture. The NMMC carried out sampling and analysis of solid waste generated in Navi Mumbai during 2011-12.

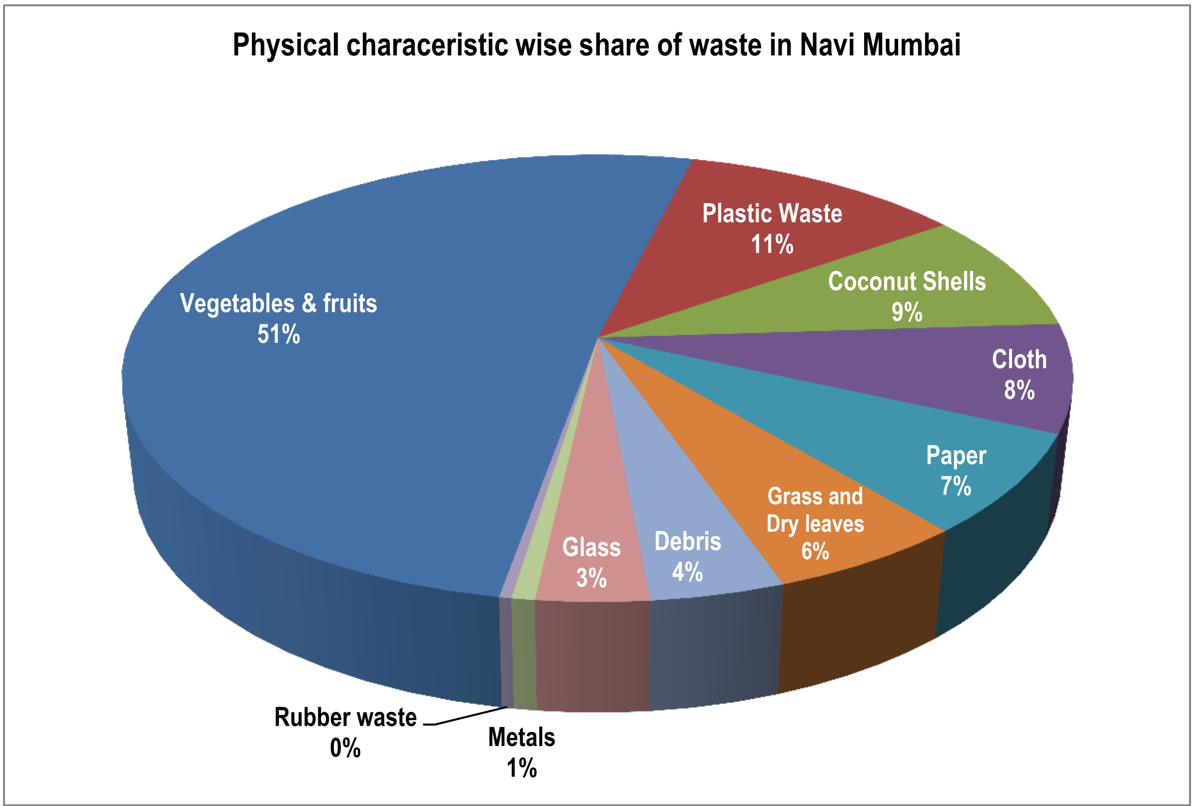

Figure 18: Physical characteristic wise share of waste in Navi Mumbai[24]

Note: The percentages have been rounded off and hence the values below 0.5 appear as zero

Out of the total waste generated in Navi Mumbai, more than 66% of the waste (vegetables, fruits, coconut shells, grass, cloth and dry leaves) is organic in nature (Figure 18). A major portion of the waste comes from APMC market which comprises predominantly of vegetables and fruits. NMMC has a 500 MTPD processing plant for production of Refuse Derived Fuel (RDF) which is under construction and the first phase of the same has already been commissioned on Public Private Partnership (PPP) basis. The processing plant produces an average of 40-50 tonne of RDF and around 100 tonne of compost per day.

In addition to this, Navi Mumbai city generates around 3620.59 Kg (3.6 Metric Tonnes) of Biomedical Waste (BMW). To handle this, NMMC has outsourced its treatment to a private contractor who is responsible for incineration and autoclaving of certain categories of BMW. The BMW treatment plant is situated at Taloja landfill site.

[24] NMMC(2012), *Environmental Status Report 2011-12*, Chapter 7 Solid Waste Management: Navi Mumbai, Navi Mumbai Municipal Corporation

4.1.2 Emissions from MSW

Navi Mumbai generates around 600 MTPD of MSW of which around 66% is biodegradable. This would translate to around 396 MT of biodegradable waste per day, or 144540 MT of biodegradable waste per annum. The remaining constituent of the waste (around 34%) is made up of either inert or recyclable materials like metal, glass, paper, plastic, rubber, leather and debris that go back to dumping sites.

The biodegradable portion of the waste is segregated and treated. At present the plant treats around 500 MT of waste per day. The remaining 100 MT of waste is sent to land fill site and consists majorly of debris and inert material and biodegradable waste. It is estimated that only 8% of the total MSW, which translates to around 50 MT of biodegradable waste, is disposed at the land fill site per day. This fraction of waste is used to calculate the emissions from MSW.

The following calculative methodology presented in Equation 3Error! Reference source not found., as prescribed in the IPCC 2006 guidelines for GHG emissions inventory for estimating the emissions from SWD, is used to calculate the emissions in Navi Mumbai.

Methane emissions (MT/yr) = MSWT x MSWF x MCF x DOC x DOCF x F x (16/12) – R x (1- OX)

where:

MSWT = total MSW generated (MT/yr)

MSWF = fraction of MSW disposed to solid waste disposal sites

MCF = methane correction factor (fraction)

DOC = degradable organic carbon (fraction)

DOCF = fraction DOC dissimilated

F = fraction of CH_4 in landfill gas (default is 0.5)

R = recovered CH_4 (MT/yr)

OX = oxidation factor (fraction - default is 0)

Equation 3: Calculation used to determine emissions from solid waste for Navi Mumbai

Note: Default factors are given by IPCC

Based on the Equation 3 the emissions for Navi Mumbai city for the year 2011-12 have been tabulated below in Table 11.

Table 11: Emissions from municipal solid waste disposal in Navi Mumbai

Variable	Value
Total MSW generated[25]	219131.4 MT
% of MSW disposed to landfill sites	16.67%
Methane correction factor*	0.6
Degradable organic carbon	66%
Fraction DOC dissimilated*	0.5
Fraction of CH_4 in landfill gas*	0.5
Recovered CH_4	0%
Oxidation factor	0
Calculated CH_4 emission	**4821.85 MT/year**
Total CO_2 #equivalent emissions (2011-12)	**101258.95 MT/ year**

Note   ** These are IPCC default correction factors.*

 # CH_4 emissions are multiplied 21 times[26] to determine CO_2 equivalent emissions

The default methane correction factors have been used for calculating the emissions based on the methodology suggested in the IPCC 2006 guidelines. Given the 100% MSW collection efficiency by NMMC, it has been assumed that 100% of the waste that is generated within the city is collected every day and dispatched to the appropriate treatment facilities In terms of collection and treatment efficiencies Navi Mumbai is technologically well equipped and efficient as compared to other cities in India. However, about 16.67% of the waste generated in NMMC limits is sent to scientifically monitored landfill sites, and that is the only portion of waste responsible for generating emissions from solid waste.

As per calculations presented in Table 11, about 4821.85 MT/year of CH_4 emissions from Navi Mumbai's SWD in the year 2011–12. To make the emissions from solid waste comparable with emissions from other sources, the methane (CH_4) emissions are translated to CO_2e numbers. This results in 101,258.95 MT of CO_2 equivalent emissions from Navi Mumbai. In per capita terms this translates into 0.09 tCO_2e emissions for the same year 2011–12.

[25] As per data obtained from Solid waste department, NMMC
[26] This is the lifetime global warming potential of CH_4 as compared to CO_2 over a period of hundred years

4.2 Sewage Management

4.2.1 Sewage generation and collection

Navi Mumbai city generates about 278 Million Litres per Day (MLD) of sewage[27]. Developed as a planned city, more than 99% of the developed nodes in NMMC are connected through underground sewerage network. The total length of sewer lines in Navi Mumbai is about 308.40 km. A break up of the network is provided in Table 12**.**

Table 12: Length of sewer lines in Navi Mumbai city[28]

Sr No	Area	Length (Km)
1	CBD - Belapur	60.49
2	Nerul	32.77
3	Vashi	36.11
4	Koparkhairne	62.51
5	Turbhe	79.40
6	Ghansoli	10.38
7	Airoli & Digha	26.77
	Total	**308.43**

The Government of India (GoI) has defined a service level benchmark for toilet coverage and the benchmark value for this indicator is 100%. It states that, the citizen should have access to toilet whether individual or community in a service area. For the safe management of human excreta, achieving 100% toilet coverage is a must. Through installation of group toilets, community toilets and public toilets, NMMC aspires to achieve the objective of making Navi Mumbai Open Defecation Free (ODF) by March 2013.

There are total 366 community and public toilets in the city having total 4331 seats. Out of these seats 2068 (47.74%) are for women & 2263 (52.25%) seats are for men. Remaining 85 (1.96%) seats are available for the handicapped. There are120 septic tank systems and 1652 seats attached to it. The septic tank is cleaned by vacuum tankers and the waste is transported to the Sewage Treatment Plant (STP).

[27] NMMC(2012), *Environmental Status Report 2011-12*, Chapter 5 Sewerage: Navi Mumbai, Navi Mumbai Municipal Corporation

[28] NMMC(2012), City Sanitation Plan, Table 6.1: Details of Sewer Lines in NMMC Area, Chapter 6, Sewerage Management: Navi Mumbai, Navi Mumbai Municipal Corporation

4.2.2 Sewage Treatment

Out of the generated sewage, NMMC treats almost 78% of the sewage (216 MLD). This is achieved through 6 STP's in Navi Mumbai city. The balance sewage (~62 MLD) generated from the *gaonthans* and slum areas are let off without collection and treatment.

All the STP's are based on the Cyclic Activated Sludge Treatment (C-TECH), an advanced Sequencing Batch Reactor (SBR) process. It provides highest treatment efficiency possible in a single step biological process. The system operates in a batch reactor mode and thus eliminates all the inefficiencies of the continuous processes and ensures 100% treatment. The complete process takes place in a single reactor, within which all biological treatment steps take place sequentially. A brief detail of the STP's in Navi Mumbai under NMMC is provided in Table 13. Being a planned city, Navi Mumbai the STP's designed to cater to the city a larger set of population. However at present the STP's have a current load less than the designed capacity and taken together for all the STP's the present load adds up to 216 MLD and the total sludge generated from the same is around 120 tons/day.

Table 13: Capacity of STP's in Navi Mumbai[29]

Sr No	STP (Location of Sewage Treatment Plant)	Total Capacity (MLD)
1	CBD-Belapur	19
2	Nerul	100
3	Vashi	100
4	Sanpada	37.5
5	Koparkhairne	87.5
6	Airoli	80
	Total	**424**

[29] NMMC(2012), City Sanitation Plan, Table 6.5, Adequacy of Sewage Treatment Capacity, Chapter 6, Sewerage Management: Navi Mumbai, Navi Mumbai Municipal Corporation

4.2.3 Emissions from sewage

Since, NMMC collects and treats the sewage with almost 100% efficiency; emissions from sewage have been calculated as per the IPCC guidelines 1996. The emissions from waste water are calculated as per Equation 4**.**

Methane emission from waste water = TOW X EF – MR

Where:

WM	=	Total methane emissions from wastewater (kgCH4)
TOW	=	Total organic waste for wastewater (kgDC/yr)
EF	=	Emission factor for wastewater (kgCH4/kgDC)
MR	=	Total amount of methane recovered or flared from wastewater (kgCH4)

Equation 4: Calculation of methane emissions from waste water

The step-by-step calculations are explained below:

Step 1

The population of the city is multiplied with the average amount of degradable organic compound that is generated per person per year to calculate the total fermentable waste generated in the city.

Step 2

The total waste generated as sludge from the treatment plants is multiplied with the default methane conversion factor of the anaerobic treatment system.

Step 3

The maximum methane producing capacity of the resulting treated wastewater and the sludge is multiplied with the released output to arrive at the number for total methane produced from sewage in Navi Mumbai.

An important variable in the whole calculation (Table 14) is the assumption for the default number for per capita BOD contribution for the city of Navi Mumbai. The BOD contribution for urban centres in the State of Maharashtra, i.e., 13.87 kg BOD/person/year has been assumed for Navi Mumbai[30].

[30] MoEF (2007). *Ministry of Environment and Forests*. Retrieved 12 March 2012

Table 14: Calculations for determining emissions from sewage

	Sewage Generation	Values	Remarks
A	Population	1,119,477	
	Maharashtra Per capita BOD (gBOD/day)	38	Default factor by MoEF
B	Kg BOD/person/year	13.87	
C	Fraction removed as sludge	0.0005	Default factor by IPCC
D	Organic waste water	15,519,382	A X B (1-C)
	Organic sludge	7,763.57	A X B X C
	Fraction of waste water treated	100%	
	Methane conversion factor (MCF)	0.75	
E	***Wastewater Treated***	100%	
F	Maximum methane producing capacity	0.6	Default factor by MoEF
G	Emission Factor for Domestic wastewater	0.6	E X F
H	**Emissions from wastewater (Kg CH4)**	**9,311,629**	**G X D**
	Sludge		
I	Fraction of sludge treated	100%	
J	Methane conversion factor (MCF)	0.0562	Default factor by MoEF
K	maximum methane producing capacity (kg CH_4/kg BOD)	0.6	Default factor by MoEF
L	Emission Factor for domestic sludge	0.03372	J X K
M	**Total Emissions (Kg CH_4)**	**261.79**	**A X B X C X L**
N	**Total Emissions (MT CH_4)**	**0.26**	**M/1000**
	Total Emissions (MT CO_2)*	**5.50**	

Note: * *CH_4 emissions are multiplied 21 times*[31] *to determine CO_2 equivalent emissions*

As per the calculations and given the fact that NMMC has efficient treatment facilities to treat the sewage in Navi Mumbai the annual emissions from sewage were estimated to be around merely 5.50 MT of CO_2e.

The initiatives implemented and effective management of municipal sewage by NMMC is commendable.

[31] This is the lifetime global warming potential of CH_4 as compared to CO_2 over a period of hundred years

5. Municipal Services and Institutional Emissions

The municipal services of NMMC majorly deal with supply of water, sewage treatment, public transport, provision of streetlights and so on. Through this report an emission estimate for the year 2011-12 has been determined for activities which are directly under control of NMMC. Energy consumption at public water works, sewage treatment plants, streetlights and buildings owned by NMMC have been considered while determining emissions from electricity usage by NMMC. Fuel consumption by vehicles owned by NMMC has been considered for calculating emissions from use of petroleum products.

5.1 Electricity consumption by NMMC

The total electricity consumption by NMMC, in the year 2011-12, was around 83.5 million units. Streetlights shared the major share with 38% (30.67 MU) followed by the water supply network (Figure 19) which includes pumping of water from Morbe dam, its treatment and supply to the city.

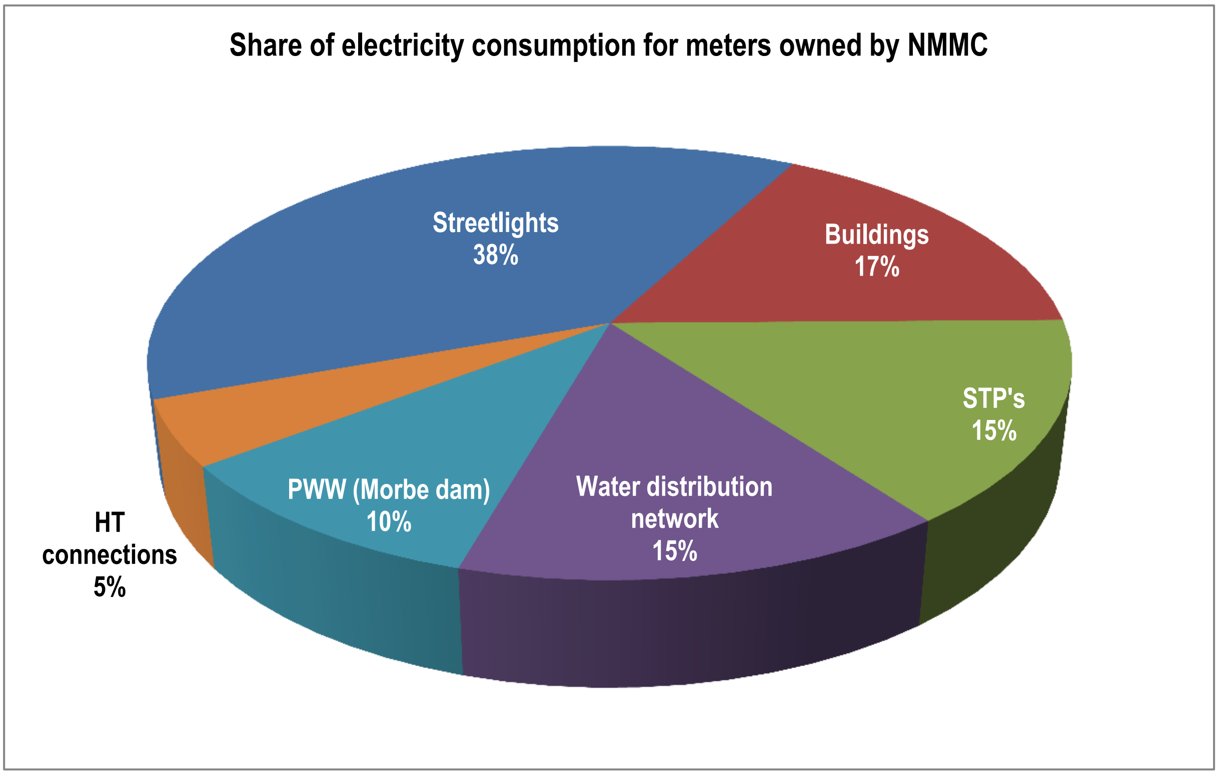

Figure 19: Share of electricity consumption by NMMC[32]

[32] Data obtained through Electrical, City engineering, Public Health Engineering departments of NMMC

5.1.1 Streetlights

There are 38,749 streetlights in Navi Mumbai, under NMMC. HPSV (High pressure Sodium Vapour) lamps share a major portion of all the types of streetlights installed by NMMC (Figure 20). The annual energy consumption by streetlights under NMMC is estimated to be around 30671823.6 kWh (30.67 GWh). NMMC has installed 450 Street light pillars for energy saving & management which ensures energy savings potential of around 25-30%.

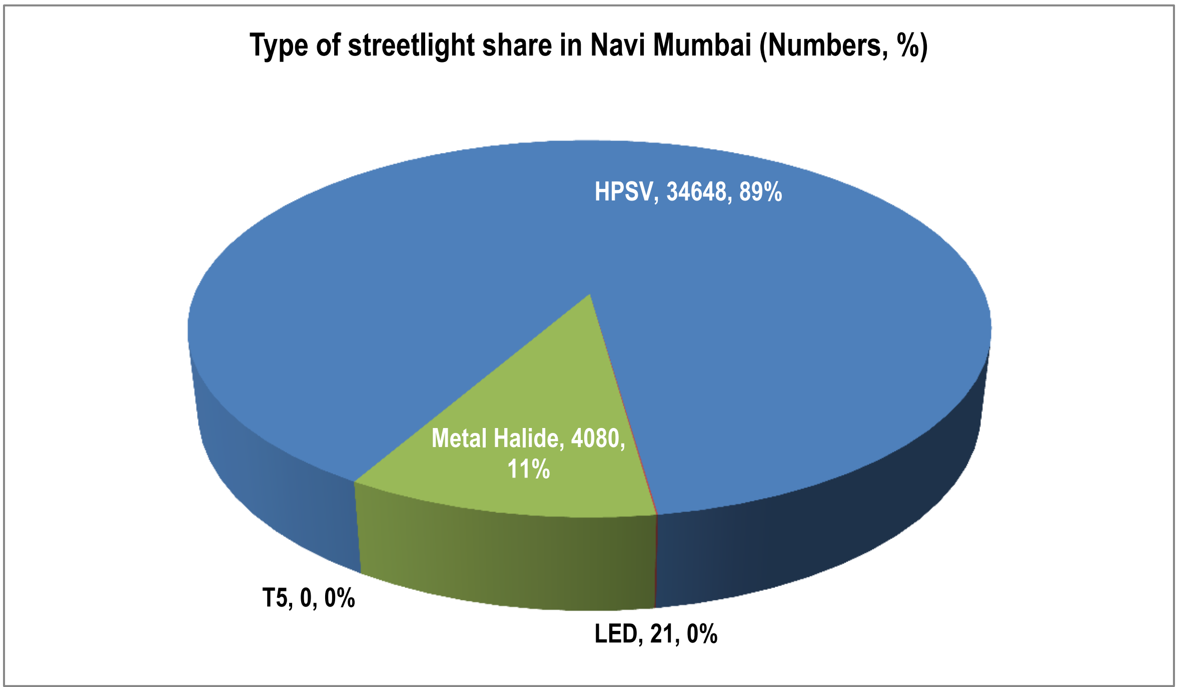

Figure 20: Type of streetlight share in Navi Mumbai[33]

5.1.2 Water distribution system

Navi Mumbai city receives water from Morbe dam and the water is supplied through an appropriate distribution network. The water supply consumes electricity at two stages – firstly for pumping of water from the dam to the treatment plant and secondly for its distribution. To reduce the dependence on electricity for water distribution in Navi Mumbai, NMMC has started using gravitational force to supply water and thus reduced its dependence on electrical pumps. Consequently, the electricity consumption in the year 2011-12 decreased by more than 2% (Figure 21) as compared to the previous fiscal year. The major zones in which the decrease in electricity consumption was observed is depicted below in Figure 22.

[33] Data obtained through Electrical department of NMMC

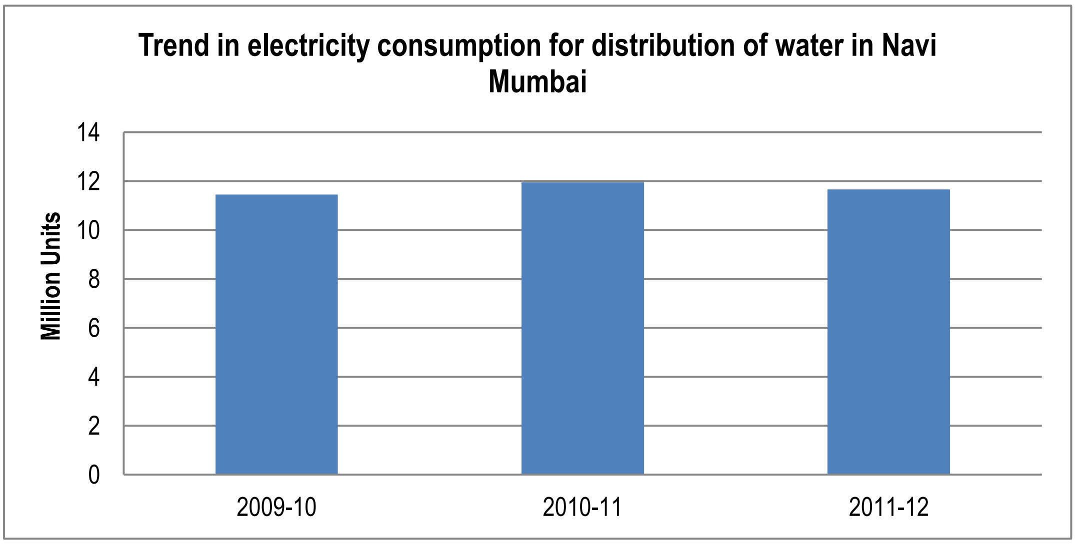

Figure 21: Trend in electricity consumption for distribution of water in Navi Mumbai

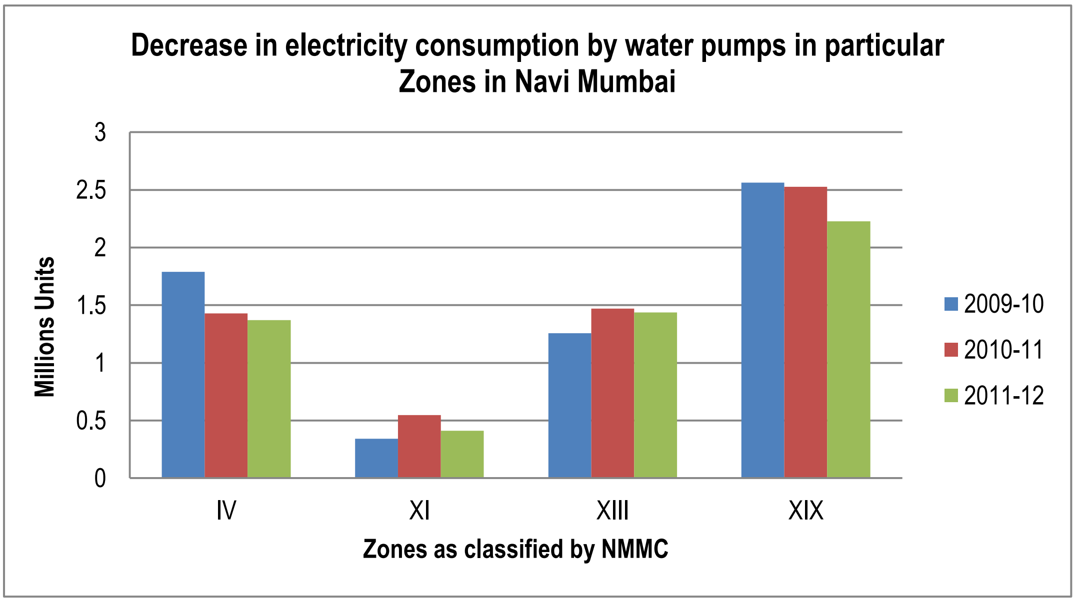

Figure 22: Decrease in electricity consumption by water pumps in particular Zones in Navi Mumbai

Note: The type of pump and its location is provided in table below:

Zone	Location	Type of pump
IV	Sect. 22 Nerul.	MBR
XI	Sect. 20 Turbhe.	ESR/GSR
	Sect. 20 Turbhe.(New)	ESR/GSR
	Sect.19 -Vashi.	ESR APM PH- II
XIII	Sect. 10 Airoli.	ESR/GSR
	Sect. 19 Airoli.	ESR/GSR
	Sect. 3 Airoli.	ESR/GSR
	Sect. 5 Airoli.	ESR/GSR
XIX	Sect. 19 Nerul.	MBR

5.1.3 Electricity consumption in STP's

NMMC has a total of 6 STP's under its jurisdiction. The details of the STP's have arlready been discussed in section 4.2 of this report. This section presents the share of electricity usage by those STP's (Figure 23) and the corresponding emissions have been tabulated in Table 15.

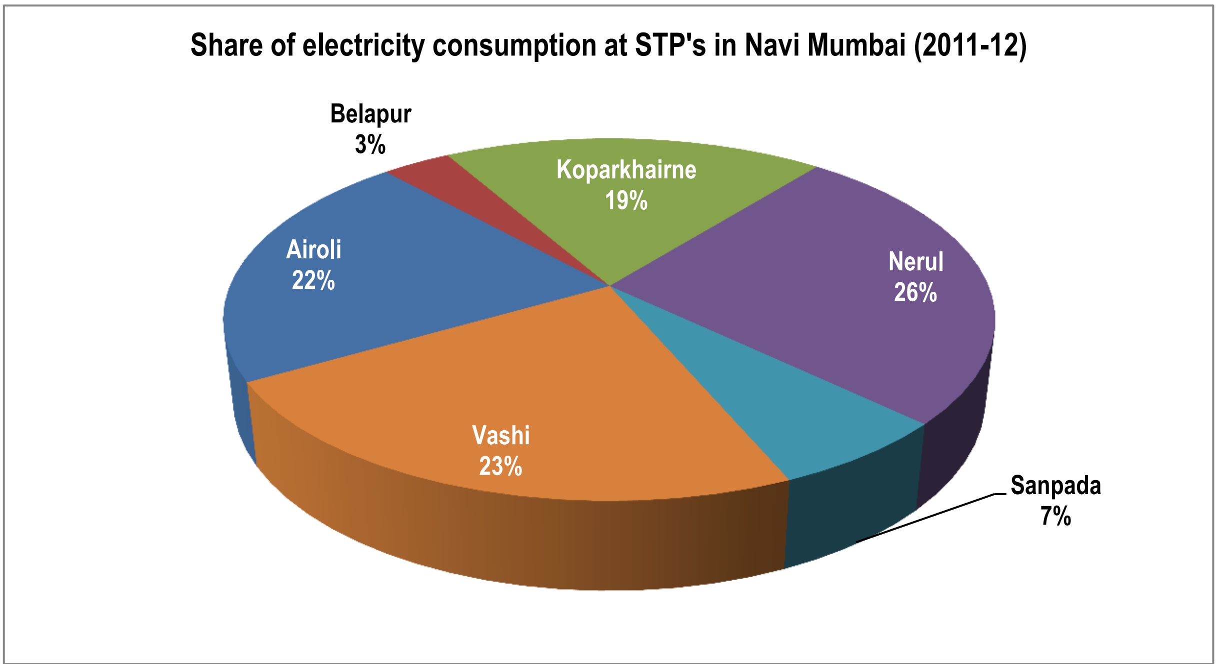

Figure 23: Share of electricity consumption at STP's in Navi Mumbai (2011-12)

Table 15: Emissions from STP's in Navi Mumbai in 201-12

Location of STP	Total units consumed (Gwh)	Emissions (tCO_2)
Airoli	2.61	2141.63
Belapur	0.41	340.19
Koparkhairne	2.29	1884.60
Nerul	3.18	2608.40
Sanpada	0.78	641.40
Vashi	2.78	2286.45
Total	**12.07**	**9902.70**

5.2 Petroleum consumption by NMMC

5.2.1 Vehicles owned by NMMC

The petroleum consumption by vehicles owned by NMMC has been considered for determining the emissions. As per data received from NMMC, they currently own a fleet of 113 vehicles, including both diesel and petrol engine types. A total of around 300 MT of petrol and diesel was consumed by the vehicles owned by NMMC. The consumption of fuels and the corresponding emissions have been tabulated in Table 16.

Table 16: Emissions from use of petroleum products in vehicles owned by NMMC

Fuel	No of Vehicles	Fuel consumed (MT)	Emissions (tCO_2)
Diesel	71	210.12	670.29
Petrol	42	89.29	274.14
Total	**113**	**299.42**	**944.44**

Source: NMMC

Note: Decimals rounded off to two decimal places hence total may not tally

5.2.2 NMMT buses for public transport

Currently NMMT has 336 buses in its fleet. They cater to the passengers and the network route is across Navi Mumbai and Mumbai areas. On an average NMMT buses consume 13 Kiloliters of diesel and 10,000 MT of CNG per day. The emission from the same have been calculated and presented in Table 17.

Table 17: Fuel Consumption and Emissions by NMMT buses 2011-12

Item	Type	Units	Value	Fuel Consumption (MT)	Emissions (tCO_2)
No. of buses Non-AC	Diesel	Nos	145		
	CNG	Nos	161		
No Of Buses (AC)	Diesel	Nos	30		
	CNG	Nos	0		
Annual Diesel consumption		Lts	45,53,779	3763.45	**12005.41**
Annual CNG consumption		Kg	44,08,897	4408.89	**11859.93**

Source: NMMT 2012

Note: Decimals rounded off to two decimal places

5.3 Summary of emissions from municipal services

Usage	Emissions (Thousand MtCO2)	Share to total emissions (%)
Electricity	**65.63**	**72.57**
Streetlights	*25.15*	27.81
Buildings owned by NMMC	*11.16*	12.34
STP's in Navi Mumbai	*9.90*	10.95
Water distribution network	*9.56*	10.57
PWW (Morbe dam)	*6.67*	7.38
HT connections	*3.19*	3.53
Petroleum	**24.81**	**27.43**
Vehicles owned by NMMC	*0.94*	1.04
NMMT buses	*23.87*	26.39
*Vehicles rented by NMMC**		
*LPG usage in canteen**		
Total Emissions	**90.44**	**100.00**

** Note: Emissions from rented vehicles and emissions from usage of LPG in canteen is very negligible and hence not considered in the calculations*

6. Summary

The total emissions from Navi Mumbai city accounted to about 2.806 Million Metric Tons of CO_2 equivalents, which translates to about 2.51 tCO_2 per capita emissions. The industrial sector accounts to a maximum share of 43% of the total GHG emissions, as seen in Figure 24, followed by emission share from residential (20%) and transport sector (18%) in Navi Mumbai. In terms of electricity and petroleum usage (Figure 25), Electricity usage in the city accounted for more than 70% of the emissions whereas petroleum usage (transport, residential and industrial sectors) accounted for almost 26% of the emissions. A summary of the emissions in Navi Mumbai city in the year 2011-12 is presented in Table 18.

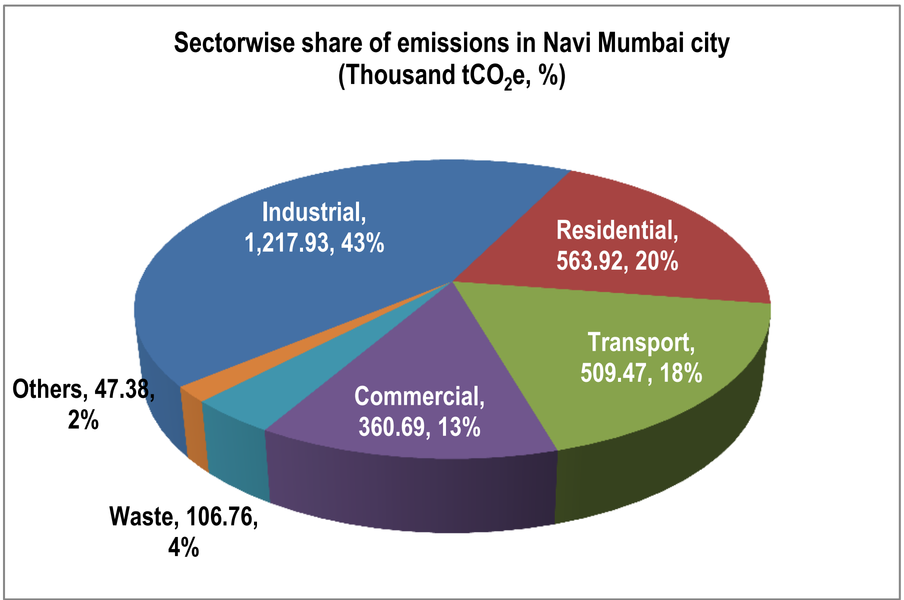

Figure 24: Sector wise share of emissions in Navi Mumbai city

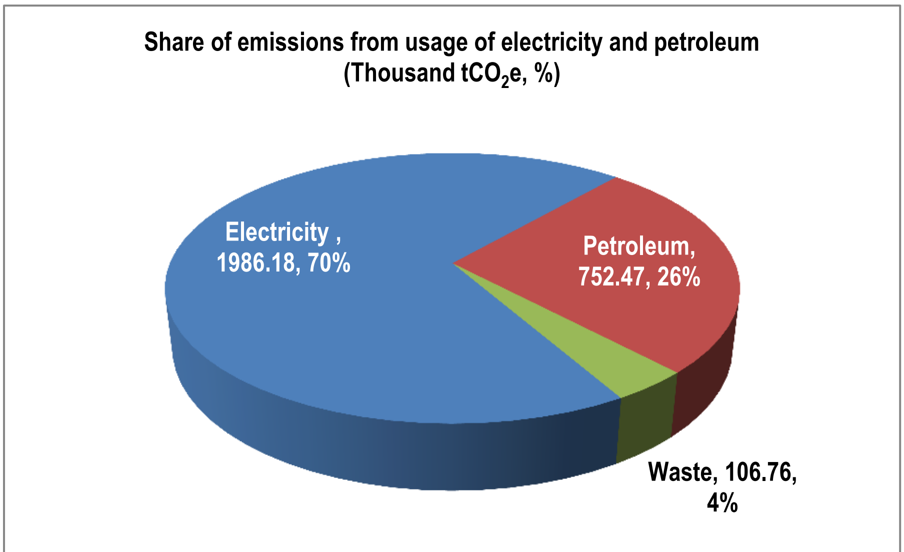

Figure 25: Share of emissions from usage of electricity and petroleum usage in Navi Mumbai

Table 18: Sector wise summary of emissions in Navi Mumbai; 2011-12

Categories	tCO_2e emissions (2011–12)	Thousand $MTCO_2e$	Per capita tCO_2e emissions	Share
Residential	**563,918.13**	**563.92**	**0.50**	**20.10%**
Electricity	*444,700.33*	444.70	0.40	15.85%
Petroleum	*119,217.80*	119.22	0.11	4.25%
Transport	**509,473.82**	**509.47**	**0.46**	**18.16%**
Commercial	**360,689.06**	**360.69**	**0.32**	**12.85%**
Electricity	359,773.25	359.77	0.32	12.82%
Petroleum	915.81	0.92	0.00#	0.03%
Waste	**106,756.49**	**106.76**	**0.10**	**3.80%**
Solid Waste	*1,01,258.95*	101.26	0.09	3.61%
Sewage	*5,497.54*	5.50	0.00*	0.20%
Industrial	**1,217,928.59**	**1,217.93**	**1.09**	**43.40%**
Electricity	1,095,068.15	1,095.07	0.98	39.02%
Petroleum	122,860.44	122.86	0.11	4.38%
Others	**47,375.73**	**47.38**	**0.04**	**1.69%**
Grand Total	**2,806,141.82**	**2,806.14**	**2.51**	

*Note: # 0.000818 tCO_2e * 0.0049 tCO_2e*

7. Recommendations

Navi Mumbai is regarded as one of the modern and planned cities of India and hence it has been designed to efficiently manage the urban challenges. However, since it is a city of the new millennium and aspiring to be an "Eco-City", we recommend some innovative strategies, based on the observations from the Carbon Inventory study, to further reduce the carbon foot print of Navi Mumbai city. Sector wise suggestions are provided below.

Industrial Sector

- Since industrial sector in Navi Mumbai accounts for a major share in electricity consumption, especially HT (High Tension) consumption, Energy Audits need to be made mandatory. .Furthermore, the strategies recommended in the audit report need to be implemented by the industry units.
- RE (Renewable Energy) applications for industrial sector should be made compulsory. LT (Low Tension) power consumption, within their premises could be met with RE applications. Captive power generation plants especially Rooftop solar photovoltaics plants may be promoted.
- FO (Furnace Oil) and HSD (High Speed Diesel) contribute to around 60% of the emissions, hence dependence on FO and HSD which are mainly used for thermal energy applications should be reduced. Alternatively, technologies like biomass gasifier or solar thermal concentrator systems could be used to meet thermal energy demands in the industries and the RDF pellets manufactured from the processing of MSW in Navi Mumbai could be used in the industries as fuel.

Transport Sector

- Although public transport vehicles in NMMC (buses owned by NMMT) have a good share of CNG operated buses newer CNG hybrid busses could be added to the fleet for public transport.
- Efficient public transport system for intracity transport needs to be explored. Special buses running on CNG could be utilized for transport.
- Electric vehicles for short distance and small vehicles intra-city transport should be explored. Places with high footfall during peak hours like Belapur CBD station to sector 15, Vashi station to sector 17, Vashi, Nerul station to institutional area in Nerul could have point to point pick up and drop facility.
- CNG vehicles in the city have a share of mere 1%. Their sales could be boosted by offering incentives on cess for vehicles being registered by Navi Mumbai residents. Similarly CNG fuelling stations could be offered some incentives to promote sale of CNG.
- RTO may be roped in to offer incentives for retro-fitting, and use of CNG for vehicles.

Waste Management

Decentralized biodegradable waste processing units

- Bio-methanation processing at each node is recommended. The food waste from hotels, vegetable markets of that node could be collected and processed in the nodal bio-menthanation plant. The energy thus produced could be used for various applications depending upon the end use requirement (thermal or power) such as lighting of streets or supplying gas to local hotels/ small restaurants/ food processing units.
- Coconut shells share around 9% of the total waste generated in Navi Mumbai which accounts to almost 54 tons/day. Major source of coconut shells waste generation is from temples. A network of temples in a node could be mapped and the shells could be collected and processed in a central processing unit. Bio-mass gasifier technology could be used to process this waste to generate power for various applications like street lighting.

Renewable energy applications

- ***DPR for Solar Rooftop***: Jawaharlal Nehru National Solar Mission has set a huge target of installations in this segment. Under this scheme there are both national and state level initiatives and policies to promote decentralized solar power generation. Detailed study needs to be carried to determine the actual potential and practical feasibility of solar Rooftop systems in NMMC region.
- ***NMMC as a solar city***: The solar city aims at minimum 10% reduction in projected demand of conventional energy in five years by enhancing supply from renewable energy sources in the city. Central government provides assistance up to INR 50 Lakh for preparation of master plan, set up solar city cell and build capacities to promote use of solar energy. In addition, solar cities are eligible to avail financial and fiscal incentives available under various government programs, for installation of renewable energy projects, systems and devices. A detailed feasibility report can be prepared in this regard.

Appendix 1: Carbon inventories of cities from the US and UK

This section highlights some of the international case studies of cities that have undertaken their carbon inventories using the methodology as described in the chapter on methodology.

A.1.1 New York City, USA: Scopes 1, 2, and 3[34]

New York City undertook an inventory of its GHG emissions in 2007. It was performed by the municipal offices (office for long-term planning and sustainable development), following a carbon inventory work started in 2001 and as part of the Cities for Climate Protection Campaign of ICLEI. It, thus, mainly follows ICLEI's methodology and uses ICLEI's Clean Air and Climate Protection (CACP) software package.

The study body is divided into four sections[35]: (*i*) a summary of local and international drivers and impacts of climate change; (*ii*) a methodology part; (*iii*) the results divided into community and municipality; and (*iv*) past and projected mitigation measures.

Given the earlier work done by the New York City (NYC) municipality, the time frame chosen spans from 1995 up to 2030 - hence the forecast is on a period of twenty years, as recommended by ICLEI. In order to derive transportation emissions, authors used the VKT approach and made a series of assumptions on the characteristics of the fleet. Emissions factors are taken from IPCC (2006).

The study incorporates all the sectors included in the municipal and community categories and also includes emissions from maritime freight and aviation. As stated by the authors, this is for comparison purposes only since the level of precision for these sectors is low and the possibility of double counting is high. Nevertheless, for such a large city and economic hub, it is relevant to include these "Scope 3" sectors.

A.1.2 Anacortes, USA: Scopes 1 and 2

Anacortes undertook preparation of a climate action plan, including a GHG inventory as part of the ICLEI CCP campaign in 2006. The inventory was performed by ICLEI in co-ordination with the municipality. The study body is divided into four sections: (*i*) climate change science and legislation; (*ii*) the emissions inventory divided into community results and municipality results; (*iii*) a reduction target; and (*iv*) past and projected mitigation measures. It thus follows almost the same structure as NYC's inventory, except that the modelling/forecast section is separate from the inventory itself for ensuring greater clarity. It uses the CACP software to process the data. The main difference from the New York City inventory is that it only focuses on Scopes 1 and 2. It does not take into account aviation or any kind of freight. The analysis is thus more straightforward. In fact for a city of this size, this choice appears relevant. The time frame chosen is 2000–20, i.e., fifteen year ahead forecast and five year back-cast. Each recommendation is presented with a cost-benefit analysis performed in current dollars and in projected CO_2 emissions reductions. On the basis of this analysis, the conclusion prioritizes the propositions made in the recommendation section.

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[34] MCNY (2010). *Inventory of New York City Greenhouse Gas Emissions*. New York:

[35] Executive summary and conclusion are not counted in the sections (this will be the case for all inventories which all display these two distinguished sections).

A.1.3 Davis, USA: Scopes 1 and 2

The city of Davis performed a GHG inventory in 2008. It was carried out by the PWD as part of the CCP campaign. The report follows the same general structure as the two previously mentioned and uses the CACP software package to treat the data.

In terms of scope, the study is similar to that of Anacortes, with a deliberate focus on Scopes 1 and 2 for clarity and relevant concerns. The timeframe chosen spans from 1990 to 2015, from 20 years back to 5 years ahead.

A.1.4 Bloomington, USA: Scopes 1 and 2

The city of Bloomington carried out a GHG inventory in 2009 in association with the ICLEI. The study updates a report made in 2006 and applies the newer ICLEI/IPCC methodology. It only focuses on scopes 1 and 2 like Anacortes and Davis.

A.1.5 Eugene, USA: Scopes 1, 2, and 3

The city of Eugene undertook a GHG inventory of municipal emissions in 2009. The study was prepared by the Facility Management Division of the municipality and follows ICLEI's, guidelines as well as uses the ICLEI software CACP. Community emissions are not included in the survey, but unlike the studies reviewed above, Eugene's inventory includes embedded emissions from the purchase of goods by the municipality. In order to do so, the authors relied on a wider model developed at the Duke University providing data on the carbon content of goods consumed by average Americans. The model was thus adapted to the city itself, as a fraction of the American economy. The results are at best approximate, but they give an order of magnitude within which embodied emissions would actually be likely to fall.

This report is not structured in the same way as the others: the methodology is followed by the presentation of the Scope 1 and 2 results, followed by Scope 3 results, and then past and projected mitigation strategies. The report displays emissions per sector, per type of fuel, and per combination of both, a very clear way of delivering the message.

A.1.6 London, UK: Scopes 1, 2, and 3

London developed a GHG Inventory database in 2008. The database consists of geographically referenced datasets on energy consumption and estimates of emissions for the main six GHGs. The delivery is very different from what is presented above: the municipality dedicated a whole website to the information, with a visual map on which it is possible to trace CO_2 emissions at a good geographical level of precision.

Appendix 2: GHG inventories in India

A.2.1 India: Greenhouse Gas Emissions 2007 (national level)[36]

In 2004, a well-coordinated and dedicated effort was made to assess GHGs of anthropogenic origin from sectors such as Energy, Agriculture, Industry, Land Use-Land Use Change and Forestry (LULUCF) and Waste. Efforts were also made to assess the climate change impacts and vulnerability of key sectors in India through National Communication to the UNFCCC (NATCOM, 2004). A snap shot of the GHG emissions in 2007 is presented below.

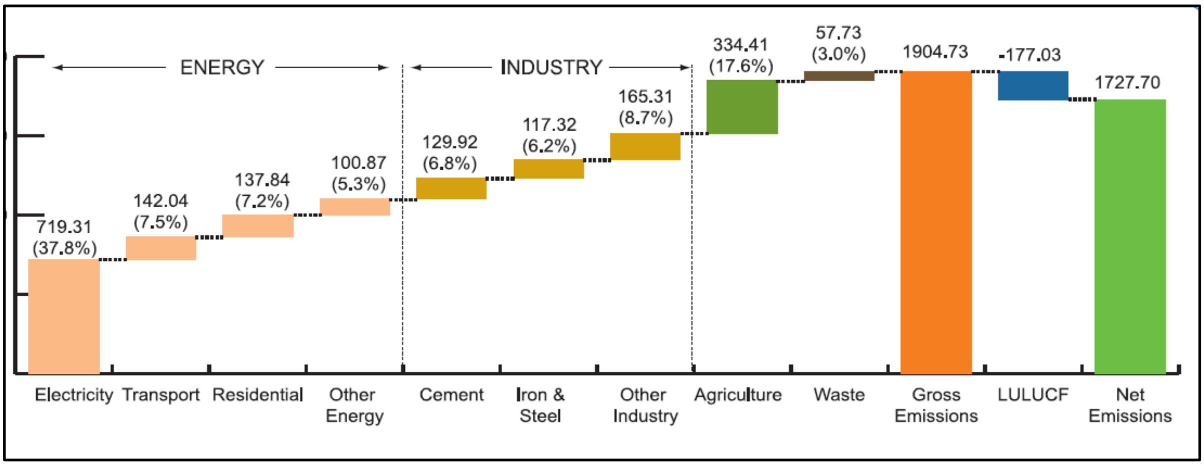


Figure A.2.1 Emissions from various sectors in India

Note:
Other Energy: includes GHG emissions from petroleum refining, manufacturing of solid fuel, commercial & institutional sector, agriculture & fisheries and fugitive emissions from mining, transport and storage of coal, oil and natural gas.
Other Industry: includes GHG emissions from production of glass and ceramics, soda ash, ammonia, nitric acid, carbides, titanium dioxide, methanol, ethylene oxide, acrylonitrile, carbon black, caprolactam, ferro alloys, aluminium, lead, zinc, copper, pulp and paper, food processing, textile, leather, mining and quarrying, non-specific industries and use of lubricants and paraffin wax.
Agriculture: includes GHG emissions from livestock, rice cultivation, agricultural soils and burning of crop residue.
Waste: includes GHG emissions from municipal solid waste (MSW), industrial and domestic waste water.
LULUCF: includes GHG emissions and removals from changes in forest land, crop land, grass land, wet land, settlements and combustion of fuel wood in forests.

The key highlights of the report are enlisted below:

- The net GHG emissions from India, that is emissions with LULUCF, in 2007, were 1727.71 million tonnes of CO_2e of which
  - CO_2 emissions were 1221.76 million tonnes;
  - CH_4 emissions were 20.56 million tonnes; and
  - N_2O emissions were 0.24 million tonnes
- GHG emissions from Energy, Industry, Agriculture, and Waste sectors constituted 58%, 22%, 17%, and 3% of the net CO_2e respectively.
- Industry sector emitted 412.55 million tonnes of CO_2 e.
- LULUCF sector was a net sink. It sequestered 177.03 million tonnes of CO_2.
- India's per capita CO_2 e emissions including LULUCF were 1.5 tonnes/capita in 2007.

[36] GoI (2010) India: Greenhouse Gas Emissions 2007, New Delhi, MoEF

A.2.2 Estimation of Tamil Nadu's carbon footprint (state level)[37]

The GHG Emission Inventorisation in Tamil Nadu was carried out based on the IPCC Guidelines for National Greenhouse Gas Inventories by various sources and removal sinks which fall under state boundaries. The "India Greenhouse Gas Emissions Report 2007" has been taken as reference to define the GHG inventorization boundaries for the state. This approach has been adopted to avoid uncertainties and to ensure that the report on GHG Inventorization for Tamil Nadu state is aligned with the *India Greenhouse Gas Emissions Report 2007*. The emission factors used in this study were a mix of country/state specific emission factors and default factors from IPCC. Default factors were used only in the absence of country specific factors. Tamil Nadu Carbon Footprint study indicates a total GHG emission from the state during the baseline year 2009–10 as 111.86 million tonnes. With a state population during this period at 70.3 million, the state per capita GHG emission stands at 1.59 Tonnes of CO_2 per citizen of Tamil Nadu. The break-up of emission estimated is as under:

Table A.2.2.1 Summary of Emissions in Tamil Nadu, 2009–10

Summary of Emissions in Tamil Nadu, 2009-10

Emission Source	Total Emissions (MT)	Per Capita Emission	Share of Emissions, %
Energy	84,721,082.1	1.20	75.73
Agriculture	16,424,465.4	0.23	14.95
Waste	2,205,323.2	0.03	2.01
Industry Sector	18,125,505.6	0.25	16.07
LULUCF	-9,614,084.1	-0.13	-8.75
Total	**111,862,292.2**	**1.59**	
Population	70,299,535*		

* India census report & CAGR Based

[37] http://moodle.tce.edu/drupal6/E-books/civil/TN%20Carbon%20Foot%20Print%20Repot%202012.pdf

A.2.3 Energy and carbon emissions profiles of 54 South Asian cities (city level)[38]

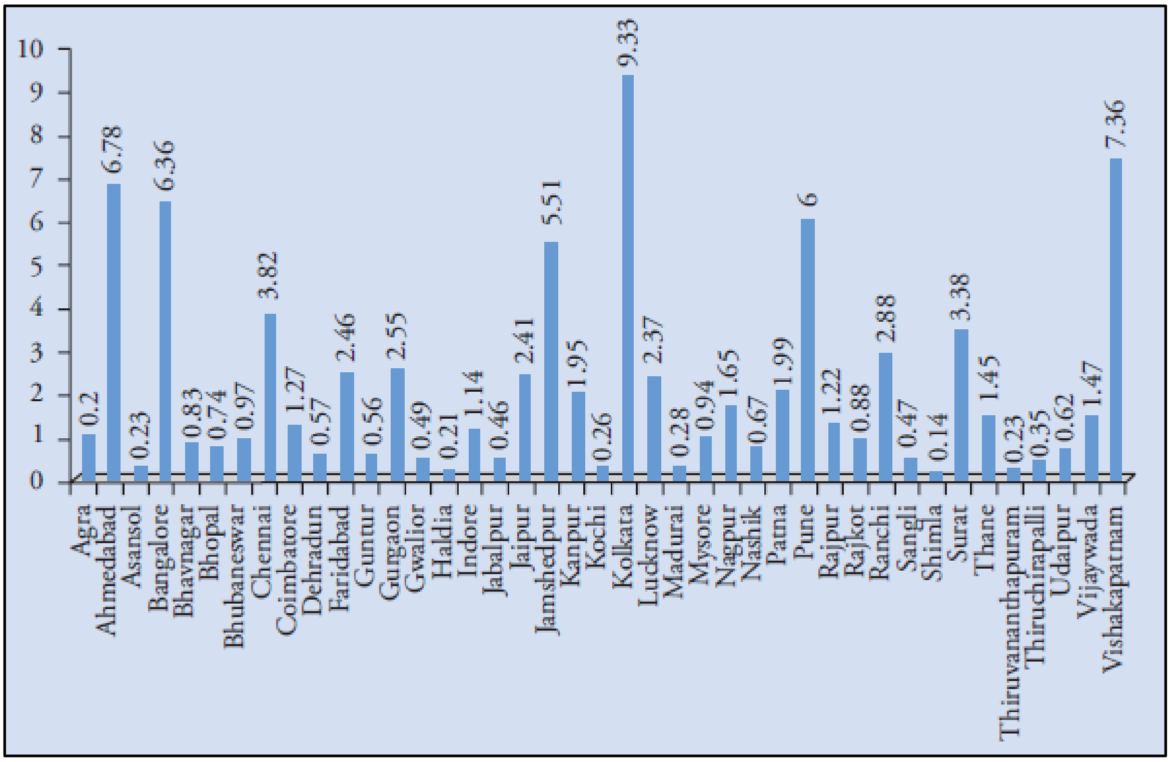
This report is an output of the 'Roadmap of South Asian Cities and Local Governments for the Post 2012 Global Climate Agreement and Actions' project and is prepared by ICLEI-South Asia with support from the British High Commission. This report provides a brief inventory of energy status and carbon emissions of 54 South Asian cities.

A total of 14 cities from India were considered for the study. Based on this data, cities were supposed to develop plans to combat climate change at the local level. These actions included efficient water usage, effective solid waste management, generating clean energy, and thereby decrease air pollution.

The following action plans were suggested and discussed with cities (through sample surveys) to reduce carbon emissions in the following broad areas:

- Street lighting Energy Efficiency programme which has high potential of energy savings (20–25 per cent)
- Building and facilities energy-efficiency programme
- Pumping system-efficient projects for water supply and drainage pumping stations
- Residential/commercial and industrial sectors
- Transportation system
- Public awareness
- Others—Integration of renewable energy (RE) and EE measures in public places.

Table A.2.3 Carbon Emissions in 41 Indian cities, 2007–08 (MT)



[38] ICLEI (2009) *Energy and Carbon Emissions Profiles of 54 South Asian Cities* New Delhi: British High Commission

A.2.4 Ahmedabad's low carbon vision study[39]

In October 2009, Indian Institute of Management (IIM), Ahmedabad, in collaboration with Kyoto University, Mizuho Information and Research Institute, and National Institute for Environmental Studies, Japan, documented a report *Low Carbon Society Vision 2035* for the city of Ahmedabad. The study has tried to determine the emissions for the year 2005 and had estimated the emissions for the city to be in the range of 10.2 million tCO_2 without going into any further break-up or details. The report further made projections for the year 2035 with respect to the baseline year 2005. Taking into account the sector-wise energy demands, the report envisages that by adopting various counter measures, the GHG emissions could be reduced by almost 66.67% in 2035 as compared to the BAU scenario in the same year.

[39] IIM (2009) *Low Carbon Society Vision 2035*:AHMEDABAD, Indian Institute of Management (A)

Appendix 3: Global Warming potential of GHGs

The Global Warming Potential (GWP) is a useful metric for comparing the potential climate impact of the emissions of different GHGs. Global Warming Potentials compare the integrated radiative forcing over a specified period (e.g., 100 years) from a unit mass pulse emission and are a way of comparing the potential climate change associated with emissions of different GHGs. There are well-documented shortcomings of the GWP concept, particularly in using it to assess the impact of short-lived species.

GHG	Chemical formula	Lifetime (years)	Global Warming Potential (Time Horizon in years)		
			20	100	500
Carbon dioxide	CO_2	variable §	1	1	1
Methane *	CH_4	12±3	56	21	6.5
Nitrous oxide	N_2O	120	280	310	170
HFC-23	CHF3	264	9100	11700	9800
HFC-32	CH2F2	5.6	2100	650	200
HFC-41	CH3F	3.7	490	150	45
HFC-43-10mee	C5H2F10	17.1	3000	1300	400
HFC-125	C2HF5	32.6	4600	2800	920
HFC-134	C2H2F4	10.6	2900	1000	310
HFC-134a	CH2FCF3	14.6	3400	1300	420
HFC-152a	C2H4F2	1.5	460	140	42
HFC-143	C2H3F3	3.8	1000	300	94
HFC-143a	C2H3F3	48.3	5000	3800	1400
HFC-227ea	C3HF7	36.5	4300	2900	950
HFC-236fa	C3H2F6	209	5100	6300	4700
HFC-245ca	C3H3F5	6.6	1800	560	170
Sulphur hexafluoride	SF6	3200	16300	23900	34900
Perfluoromethane	CF4	50000	4400	6500	10000
Perfluoroethane	C2F6	10000	6200	9200	14000
Perfluoropropane	C3F8	2600	4800	7000	10100
Perfluorobutane	C4F10	2600	4800	7000	10100
Perfluorocyclobutane	c-C4F8	3200	6000	8700	12700
Perfluoropentane	C5F12	4100	5100	7500	11000
Perfluorohexane	C6F14	3200	5000	7400	10700

Source: UNFCCC[40]

§ Derived from the Bern carbon cycle model.
* The GWP for methane includes indirect effects of tropospheric ozone production and stratospheric water vapour production.

[40] http://unfccc.int/ghg_data/items/3825.php

Glossary

Anaerobic digestion: This is a biological process making it possible to degrade organic matter by producing biogas which is a renewable energy source and sludge which can be used as fertilizer[41].

ATF (Aviation Turbine Fuel): is a colourless, combustible, straight-run petroleum distillate liquid used as jet engine fuel. The governing specification in India is IS 1571: 2001 (7th Rev.),- (IOCL).

Baseline: Reference for measurable quantities from which an alternative outcome can be measured, e.g., a non-intervention scenario used as a reference in the analysis of intervention scenarios – (*IPCC Assessment Report Four, 2007).*

Biodegradable: Capable of being decomposed by the action of biological processes.[42]

Carbon dioxide emission: Carbon dioxide (CO_2) is a colourless, odourless, and non-poisonous gas formed by combustion of carbon and in the respiration of living organisms and is considered a GHG. Emissions mean the release of GHGs and/or their precursors into the atmosphere over a specified area and period of time[43].

Climate Change: A change of climate which is 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. The UNFCCC, thus, makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes– (UNFCCC in its Article 1).

CNG (Compressed Natural Gas): CNG is nothing but natural gas compressed for the use of transport sector. Principal constituents of natural gas are Methane and Ethane, but most gases contain varying amounts of heavier hydrocarbons that are normally removed by processing (MNGL).

CO_2 e (Carbon dioxide equivalent): A metric measure used to compare the emissions from various GHGs based upon their global warming potential (GWP). Carbon dioxide equivalents are commonly expressed as "million metric tons of carbon dioxide equivalents ($MMTCO_2Eq$)". The carbon dioxide equivalent for a gas is derived by multiplying the tons of the gas by the associated GWP– (USEPA).

Connected load: (Electricity) The sum of the continuous power ratings of all load-consuming apparatus connected to an electric power distribution system or any part thereof.

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[41] http://www.biogas-renewable-energy.info/anaerobic_digestion_definition.html
[42] http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/guide_waste_definitions.pdf
[43] http://stats.oecd.org/glossary/detail.asp?ID=6323

Double counting: When two or more companies hold interests in the same joint operation and use different consolidation approaches, emissions from that joint operation could be double counted– (A Corporate Accounting and Reporting Standard, WRI, and WBCSD).

Embodied emissions: The term "embodied" (or "indirect") is used to investigate the emissions that take place outside a country or a region of study and which are embodied in products consumed at the place of analysis.

Emission Factor: A factor allowing GHG emissions to be estimated from a unit of available activity data (e.g., tonnes of fuel consumed, tonnes of product produced) and absolute GHG emissions.

Emissions: The release of GHG into the atmosphere.

Furnace Oil: It is a dark, viscous residual fuel oil which is obtained by blending residual products with suitable diluent usually middle distillates. In India, it is sold under BIS specification under IS 1593-1982, Medium Grade 2 (BPCL).

***Ghanta*–trucks:** Small trucks designed to carry wet and dry waste during daily waste collection routine organized by the local municipal corporation. The salient feature of this truck is the bell placed on the front side of the vehicle, which rings as a reminder to the household members to give out their household waste for collection.

GHG (Greenhouse Gases): GHGs are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelength within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary GHGs in the earth's atmosphere. Moreover, there are a number of entirely human-made GHGs in the atmosphere, such as the halocarbons, sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

GHG Inventory: A quantified list of an organization's GHG emissions and sources.

Global warming Potential (GWP): A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2.

Global warming: refers to the recent and on-going rise in global average temperature near earth's surface. It is caused mostly by increasing concentrations of greenhouse gases in the atmosphere. (USEPA)

High tension: Having a high voltage, or designed to work at or sustain high voltages. HT wires used to carry electrical power over long distances sustain voltages over 200,000 volts.

IPCC (Intergovernmental Panel Climate Change): It is the leading international body for the assessment of climate change. It was established by the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) in 1988 to provide the world with a clear scientific view on the current state of knowledge in climate change and its potential environmental and socio-economic impacts. (http://www.ipcc.ch)

Kerosene: Kerosene is a distillate fraction of crude oil mainly used for domestic purposes of heating and lighting and also for manufacture of insecticides/herbicides/fungicides to control pest, weeds, and fungi. The Indian Standard, governing the properties of kerosene, is IS 1459:1974 (2nd Rev)– (IOCL).

Kyoto Protocol: The Kyoto Protocol to the UNFCCC was adopted at the Third Session of the Conference of the Parties (COP) to the UNFCCC, in 1997 in Kyoto, Japan. It contains legal binding commitments, in addition to those included in the UNFCCC. Countries included in Annex B of the Protocol (most OECD countries and countries with economies in transition) agreed to reduce their anthropogenic GHG emissions (CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6) by at least 5% below 1990 levels in the commitment period 2008 to 2012.

LDO (Light Diesel Oil): It is an industrial fuel which is a blend of distillate components and small amounts of residual components mostly used in diesel engines. In India, it is marketed under the BIS 1460-2000 specification for diesel fuels (BPCL).

LPG (Liquefied Petroleum Gas): consists of propane, propylene, butane, and butylenes. There are three grades of LPG available as heating fuels: commercial-grade propane, engine fuel-grade propane (also known as HD-5 propane), and commercial-grade butane. In chemical industry, it is used as petrochemical feedstock. – (EPA).

Metropolis: A metropolis is a very large city or urban area which is a significant economic, political and cultural centre for a country or region, and an important hub for regional or international connections and communications.

Mitigation: Technological change and substitution that reduce resource inputs and emissions per unit of output. Although several social, economic, and technological policies would produce an emission reduction, with respect to climate change, mitigation means implementing policies to reduce GHGs emissions and enhance sinks (*IPCC Assessment Report Four*, 2007).

National emission factors: These emission factors may be developed by national programmes already measuring emissions of indirect GHGs such as NOx, CO and NMVOCs for local air quality[44].

Organic Waste: The biodegradable component of the waste stream that is of biological origin but does not contain any listed waste, radioactive waste or hazardous waste.

Refused Derived Fuel: It is a fuel produced by shredding and dehydrating solid waste with a waste converter technology.

Scope 1 inventory: Organization's direct GHG emissions.

[44] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_2_Ch2_Stationary_Combustion.pdf

Scope 2 inventory: A reporting organization's emissions associated with the generation of electricity, heating/cooling, or steam purchased for own consumption.

Scope 3 inventory: A reporting organization's indirect emissions other than those covered in scope 2.

Scope: Defines the operational boundaries in relation to indirect and direct GHG emissions.

Tiers: A tier represents a level of methodological complexity. Usually three tiers are provided. Tier 1 is the basic method, Tier 2 intermediate, and Tier 3 most demanding in terms of complexity and data requirements. Tiers 2 and 3 are sometimes referred to as higher tier methods and are generally considered to be more accurate (*Introduction to the 2006 Guidelines*, IPCC).

UNEP (United Nations Environment Programme): It is the leading environmental authority within the UN system that provides leadership and encourages partnership in caring for the environment by inspiring, informing, and enabling nations and people to improve their quality of life without compromising that of future generations (http://www.unep.org).

UNFCCC (United Nations Framework Convention on Climate Change): The Convention was adopted on 9 May 1992 in New York and signed at the 1992 Earth Summit in Rio de Janeiro by more than 150 countries and the European Community. Its ultimate objective is the stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system.

Vermicomposting: Vermicomposting is biotechnological process of composting involving the degradation of waste by earthworms.

WMO (World Meteorological Organization): The WMO is a specialized agency of the United Nations. It is the UN system's authoritative voice on the state and behaviour of the earth's atmosphere, its interaction with the oceans, the climate it produces, and the resulting distribution of water resources (http://www.wmo.int).

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