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Carbon Inventory of Pune City

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TERI

Pune, 2012

Declaration

- This report is based strictly on the secondary data sourced from various agencies like the PMC, MSEDCL, RTO, IOCL, BPCL, HPCL, MNGL, MEDA and so on. The data sources have been duly acknowledged at relevant sections in the report.
- TERI shall not be responsible for any discrepancy or ambiguity pertaining to the secondary data.
- The city jurisdictions used for the report are as defined by PMC. In addition, cantonment area, although out of the PMC's jurisdiction, has been considered for emission assessment, for two reasons:
    - The urban services like sewage treatment and solid waste collection in cantonment area are provided by the PMC[1], and the data provided by PMC includes cantonment area.
    - The data procured from MSEDCL includes energy consumption in cantonment area which cannot be fragmented.
- The assumptions and disclaimers considered have been clearly stated in the report, at respective sections.

[1] http://www.punecantonmentboard.com/
Solid waste generated in cantonment 10-15 tons/day, Sewage generation in cantonment 7-8 MLD, Population around 75,000

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List of 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
MNGL	Maharashtra Natural 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
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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Preface

Global warming and climate change are issues of serious concern which prompted the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO) to establish the Intergovernmental Panel on Climate Change (IPCC), a special body to provide the world with a clear scientific view on the current state of knowledge in climate change along with its potential environmental and socio-economic impacts. At present, there are 195 member countries under the IPCC most of which have started to take initiatives to combat climate change.

Most studies have attributed the primary reason for climate change and global warming to the increase in Greenhouse Gas (GHG) emissions resulting from human activities. It has also been estimated that the post-industrial era has been a 'forcing' agent for climate change and the CO_2 concentrations in the atmosphere have been recorded to be higher in this era than in the last 600,000 years[2]. Increasing emission levels are leading to increase in temperatures globally. The IPCC estimates that warming beyond 2˚C above pre-industrial temperatures would lead to catastrophic consequences on human and ecological systems.

The phenomenon of global warming and climate change are now no more just predictions; the anticipated effects are already being experienced across the globe. Rapid melting of glaciers in Iceland (2012), droughts in East Africa (2011), increasing instances of tsunamis, hurricanes, and El-Niño's have all been attributed as likely effects of climate change impacts. The IPCC estimates that between 1985 and 2010, the recorded annual losses due to climate-related disasters have ranged from a few billion to above 200 billion USD, with the highest value for 2005 (the year of Hurricane Katrina)[3].

As per the United Nations estimates, cities contribute more than 60% of the global emissions, most of which is a result of consumption of electricity and petroleum products. Moreover, as cities are moving towards globalization, resource demands and emissions are inevitably on the rise. Some of the major cities in the world have already realized the significance of this sensitive issue and have started to take active measures to curb greenhouse gas (GHG) emissions. Pune has always been regarded as a pro-active and forward-looking city as far as pro-environment related initiatives are concerned. Pune Municipal Corporation (PMC) has been documenting and publishing an annual Environmental Status Report (ESR) for the last 15 years. The PMC has also implemented many eco-friendly and innovative projects for managing their resources effectively and responsibly. It is reflected from initiatives like implementation of energy-efficient street lights, installation of bio-methanation plants to treat bio-degradable municipal waste, promoting use of Compressed Natural Gas (CNG) fuel within the public transport system, and so on.

Realizing the significance of GHG inventory and accepting the responsibility of the emissions at municipal level, which may contribute towards global impact, the PMC proactively took an initiative to document the GHG inventory for its municipal limits. This shall help Pune city to quantify and map the emissions from different sources and help develop specific strategies to curb the emissions.

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[2] http://www.epa.gov/climatechange/science/causes.html

[3] http://www.ipcc.ch/docs/COP17/IPCC_chair_speech_COP_17.pdf

Executive Summary

Pune is one of the first cities in India to document a detailed carbon emission inventory at the municipal level and by estimating its cumulative and per capita carbon footprint, it has set a unique example.

Conventionally, carbon footprint[4] is defined as the accounting of the GHG emissions, resulting from the consumption of fossil fuels through various activities like transport, electricity consumption, and municipal solid waste and sewage degradation. Further, the values of GHG emissions are expressed in terms of CO_2 equivalents which help estimate the carbon footprint. The present carbon inventory is carried out for the period 2006–11 to map the overall trend of GHG emissions. However, the specific cumulative emissions and per-capita emissions mentioned in the report are for the year 2010-11. The study adopts the methodology as per the guidelines released by the Inter-governmental Panel on Climate Change (IPCC), United Nations Environment Programme (UNEP), UN-HABITAT, and the World Bank, to carry out carbon inventories at the national and city levels.

As estimated in the study, Pune city generated about 4.7 million tonne of carbon-di-oxide equivalents (tCO_2e) of cumulative and 1.46 tCO_2e per capita emissions in 2010–11. Electricity use had the maximum contribution of 56.38% of the total CO_2e emissions, followed by petroleum products which generated 36.50%. Municipal solid waste and sewage contributed to the rest of the share.

Electricity through low-tension distribution network is primarily used in residential and commercial sectors in the city. With a total city level consumption of 3,244.31 GWh, 1,140.20 GWh was in the residential sector and 490.60 GWh was in the commercial sector. These sectors had a contribution of about 35% and 15% to the overall CO_2e emissions, respectively. The primary consumers of the high tension connections (1,386.87 GWh) included industrial users, water treatment, and sewage treatment plants which generated 43% of the overall CO_2e emissions from electricity usage.

Consumption of petroleum products accounted for the second highest amount of CO_2e emissions in the city. In 2010–11, a total of 0.554 Million Metric Tonne (MMT) of petroleum products were sold in Pune, which are estimated to have generated 1.7 million tCO_2 emissions (0.53 tCO_2 per capita). The transport sector generated 51% of the overall emissions from the use of petroleum products. Petrol and diesel were responsible for about 30% and 19% of the emissions from the petroleum products generating 0.518 million tCO_2 and 0.320 million tCO_2 emissions, respectively. The other large source of emissions was from the consumption of domestic LPG, which generated 0.411 million tCO_2 emissions in 2010–11.

The other two significant sources of CO_2 emissions for the city are solid waste (4.6%) and sewage (2.3%) contributing to a total of emissions of methane (CH_4) of 10,131.43 MT and translating to emissions of 212,760.11 tCO_2e. On the other hand, total untreated wastewater and a small amount of sludge from the treated sewage generated about 119,528 tCO_2e overall emissions.

[4] Definition, as per World Resources Institute & World Business Council for Sustainable Development is provided in glossary section

The major sectors contributing to CO_2 emission and its implied per-capita footprint is summarized below

Sector	tCO_2e emissions (2010–11)	Per capita tCO_2e emissions[5]	Share
Residential	**1,470,788.96**	**0.46**	**31.6%**
Transport	**869,565.25**	**0.27**	**18.7%**
Commercial	**440,870.94**	**0.14**	**9.5%**
Industrial	**367,844.71**	**0.12**	**7.9%**

The previous studies indicate that the emission profile of Pune could be compared with similar cities of India like Bangalore, Kolkata and Thane, where the city ranks 5th among the top five major emitters of CO_2. However, given that the PMC has pro-actively adopted green initiatives such as ban on open dumping, bio-methanation plants for biodegradable waste management and energy efficient street-lighting, Pune could be one of the first cities to target significant emission reductions in the years to come.

[5] The calculations include cantonment area population

1. Introduction

Climate change

As defined by IPCC:[6]

> Climate change refers to a statistically significant variation in either the mean state of the climate or in its variability, persisting for an extended period (typically decades or longer). Climate change may be due to natural internal processes or external forcing, or to persistent anthropogenic changes in the composition of the atmosphere or in land use.

Climate change has many different aspects to it. One can associate climate change with rise in sea water levels, change in atmospheric temperature, changing ecosystems, melting polar ice, and so on. It may be due to either natural or human influences. Scientists from all over the world have been working to find out the cause and impacts of climate change, for more than a century but there are still gaps in our knowledge. However, most of the experts feel that human activities are having an adverse effect on our planet.

Anthropogenic activities related to consumption of fossil fuels are mainly responsible for the GHG emissions. These emissions in the atmosphere are attributed to create a greenhouse effect subsequently leading to global warming.

Greenhouse effect

The earth has atmospheric energy which supports life. The chemical composition of the atmosphere is nitrogen (78%); about 21% is oxygen, which all animals need to survive; and only a small percentage (0.0379%)[7] is made up of carbon dioxide which is required by plants for photosynthesis. To maintain life-sustaining conditions on earth, each day, energy from the sun — largely in the visible part of the spectrum, but also some in the ultraviolet and infrared portions — is absorbed by the earth's atmosphere **Figure 1**.

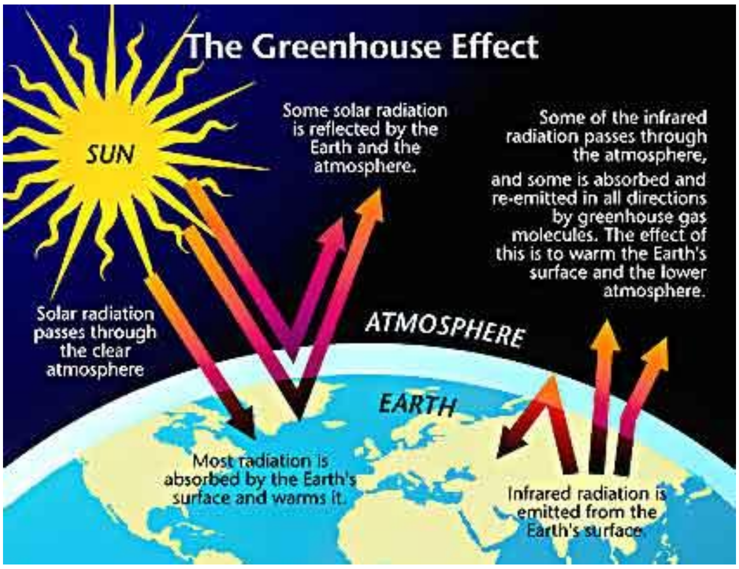

Figure 1: Schematic of Greenhouse gas effect[8]

[6] IPCC http://www.ipcc.ch/ipccreports/tar/wg3/index.php?idp=456
[7] IPCC (2007) *Assessment Report 4*, WG1, Chapter 2 Table 2.1.
[8] Source: http://www.truthmove.org/content/global-warming/

If all this energy were to be absorbed completely, the earth would gradually become hotter. But actually, the earth absorbs and, simultaneously emits/reflects energy in the form of infrared waves (which cannot be seen by our eyes but can be felt as heat). About 31%[9] of incoming energy from the sun is reflected back in space while the rest reaches the earth, warming the air, oceans, and land, and maintaining surface temperature of earth. All this reflected heat is not lost to space, but is partly absorbed by some gases present in very small (or trace) quantities in the atmosphere, called GHGs. These gases re-emit some of this heat to the earth's surface and prevent the escaping of heat from the earth's atmosphere and hence maintain the temperature favourable to support life on earth. However, disproportionate and unjustified increase in the GHG's lead to global warming.

Global warming

It has been observed that, the atmospheric concentrations of CO_2, CH_4, and N_2O have grown by about 31%, 151%, and 17%, respectively, between 1750 and 2000.[10] Since the early 20th century, the earth's mean surface temperature has increased by about 0.8°C (1.4°F), with about two-thirds of the increase occurring since 1980.[11] This effect is termed as global warming which has a direct impact on the global climatic conditions, termed as Climate Change. Warming of the climate system is unequivocal, and scientists are more than 90% certain that it is primarily caused by increasing concentrations of GHGs produced by human activities, such as the burning of fossil fuels and deforestation.[12]

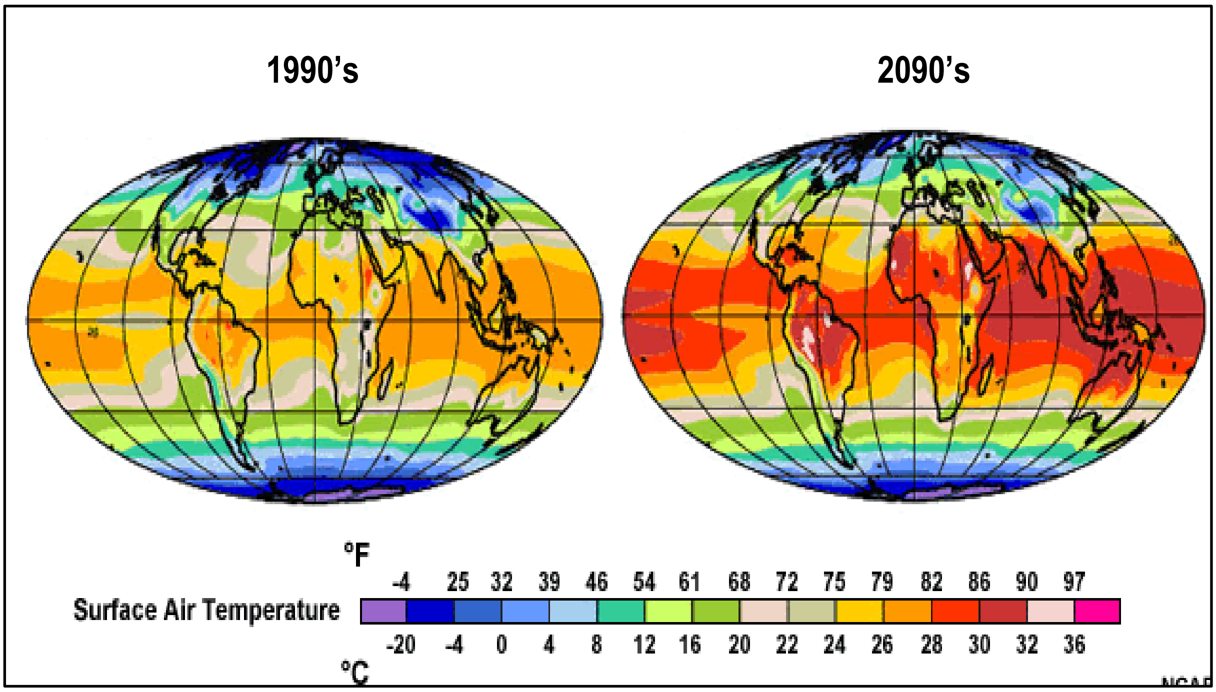

Figure 2: Global temperature projections[13]

[9] IPCC (2001) *Third Assessment Report*, WG1, Section 1.2.1 Natural Forcing of the Climate System. IPCC
[10] IPCC (2001) *Climate Change 2001: The Scientific Basis*, WG1, TAR, Cambridge University Press
[11] *America's Climate Choices*. Washington, D.C.: The National Academies Press. 2011. p. 15. ISBN 978-0-309-14585-5
[12] IPCC (2007) *Synthesis Report*, Section 2.4: Attribution of climate change, in IPCC AR4 SYR 2007.
[13] Source: National Centre for Atmospheric Research

Climate change and cities

The growing residential, commercial, industrial, and transportation activities in cities, have led to a rapid growth in consumption of fossil fuels, contributing to GHG emissions. Thus, cities are attributed as key contributors to these emissions. In the context of concerns about climate change impacts due to increasing GHG emission levels, cities across the globe have started to take concrete initiatives. Cities that take on the challenge of combating global warming by reducing GHG emission will do their part in combating the impacts of global environmental catastrophe. They will also experience tangible local benefits, including healthier habitats and communities with lower water and energy usage (leading to lower costs). Globally, many interventions are already being undertaken by the city governments to curb carbon emissions. In order to understand the impact of these interventions in terms of their ability to reduce carbon emissions, it is important to estimate the current levels of emissions and create a baseline.

In the last few years, various large and small cities around the world have carried out carbon emissions inventories. New York, London, Tokyo, Paris, Toronto, and a host of other cities have not only undertaken carbon inventory baseline studies, but they have also taken several initiatives to reduce the level of their CO_2 emissions. Carbon emissions profiling has, however, not been that prominent in cities in the less developed parts of the world. A few international and domestic carbon inventory preparation initiatives are discussed in Appendix 1

Climate change and India

National Action Plan on Climate Change (NAPCC) was released in June 2008 which emphasised on climate change and eight missions in the context of India. It identifies measures for promoting development objectives while yielding co-benefits for addressing climate change effectively. In August 2009, the Hon'ble Prime Minister of India urged each state government to create its own state-level action plan consistent with strategies in the national plan. In the light of this initiative, a nodal agency under Ministry of Environment and Forests (MoEF) for climate change cooperation and global negotiations was appointed as the Climate Change Division of MoEF. It functions as a nodal unit for co-ordinating the NAPCC. Many other initiatives like preparing the GHG inventory, under the National Communications (NATCOM) for the base year 1994, detailed work on estimation of sectoral GHG emissions, and identification of country-specific emission factors in the vulnerable sectors, have been developed. It also looks at a detailed vulnerability and adaptation assessment as a part of the National Communication Project.

India faces the challenge of providing massive infrastructure to its growing population while adopting a low carbon growth. It is estimated that the current level of per capita carbon dioxide equivalent emissions (CO_2e) in the country, i.e., 1.5 tonne per capita will increase to about 3 to 5 tonne by 2030[14]. As per this report the per capita emission for Pune city is almost equivalent to the national average.

The other state- and city-level estimates are discussed in Appendix 2.

[14] MoEF(2010) *National Workshop on India: Greenhouse Gas Change Emissions 2007* http://moef.nic.in/downloads/others/M%20Karthik.pdf

GHG emissions and Pune city

The PMC aims to understand its current pattern of carbon emissions, in order to plan specific strategies/interventions to reduce the same. Thus TERI has conducted a detailed GHG inventory for the city of Pune (PMC limits).

International Council for Local Environmental Initiatives (ICLEI) has undertaken a similar study for 54 South Asian cities in 2009[15]. Although the methodology followed as well as the area considered by ICLEI and The Energy and Resources Institute (TERI) for their respective studies are different, the cumulative and per capita emissions as estimated by both the studies are comparable. The cumulative emissions for both the studies fall in the range of 4-6 Million tonnes CO_2e whereas per-capita emissions fall in the range of 1.3–1.5 tonne CO_2e. Given the estimations of CO_2 emissions provided by ICLEI for 54 South Asian cities a comparative assessment of cities performance in terms of CO_2 emissions may be undertaken. Pune ranked 5th highest consumer amongst the Indian cities out of the 54 South Asian cities studied by ICLEI which include Bangalore, Chennai, Kolkata, Ahmedabad and Thane.

Report structure

Chapter 2 describes the standard methods and guidelines that are used for estimating and reporting city-level emissions and further presents the estimation methods used in some cities around the world. Chapter 3 gives the methodology used for the carbon inventory of Pune. Chapters 4 and 5 describe the present levels of energy and fossil fuels consumed in the city. The resulting emissions and carbon profile of the city from the use of energy is highlighted in the concluding section of this report.

[15] ICLEI (2009) *Energy and Carbon Emissions Profiles of 54 South Asian Cities* New Delhi: British High Commission http://www.iclei.org/fileadmin/user_upload/documents/Global/Progams/CCP/CCP_Reports/ICLEI_Indian_Cities_2009.pdf

2. Carbon inventories of cities: A literature review

Energy consumption is, by far, the greatest contributor to climate change, representing 80% of GHG emissions[16]. Two-third of world energy demand is consumed in cities[17]. This will increase to higher levels as the current global share of urban population of 50% in 2010, continues to increase[18]. It is, therefore, important that cities track their energy consumption pattern and estimate their GHG emissions in order to identify low carbon growth pathways.

A large number of cities have started to conduct their carbon inventories to evaluate their contribution to climate change. However, while it has been estimated that 81% of the increase in global energy demands by 2050 will take place in cities of the developing world; urban carbon inventories have mostly been limited to cities of the developed world. Cities like New York, Bloomington, London, and cities from the European Union (EU), have been documenting their carbon inventories and set targets to reduce them as against their baseline emissions. A target is the reduction of a specific percentage of GHG emissions from a baseline date, to be achieved by a set date or timetable (e.g., 2008–12). Under the Kyoto Protocol, the EU agreed to reduce its GHG emissions in the commitment period (2008–12) by 8% as compared to their emission levels in 1990.

It is important to undertake these studies in developing countries as well, by taking the lessons and learning from the inventories prepared in the cities of the developed nations, in order to follow the right inventory approach. A study undertaken by ICLEI attempted to estimate the emissions from 54 cities in South Asia. The report documents the estimated emissions from cities of developing countries like India, Bangladesh, Bhutan, Sri Lanka, and Nepal (see Appendix 2). This chapter attempts to understand the internationally accepted practices and case studies and summarizes the key points to be considered while designing an urban carbon inventory.

2.1 Steps for preparing urban carbon inventories

This section describes broadly the steps that have been followed to prepare the carbon inventory:

(i) Understanding internationally followed general guidelines to prepare city-level carbon inventories

(ii) Defining the scope of the study for estimating emissions

(iii) Determining the method and extent of reporting

(iv) Identifying the right data source to estimate the level of emissions

(v) Choosing the appropriate timeframe for the reporting

(vi) Developing the GHG model

[16] IPCC (2007). *Synthesis Report, UNFCCC.* Geneva: International Panel on Climate Change.
[17] IEA (2008). *World Energy Outlook.*: International Energy Agency.
http://www.iea.org/publications/freepublications/publication/weo2008.pdf
[18] United Nations, Department of Economic and Social Affairs: http://esa.un.org/unup/

2.1.1 Internationally followed general guidelines for preparing city-level carbon inventories

The International Standards for Determining Greenhouse Gas Emissions for Cities (ISDGGEC)[19], a joint document by UNEP, the World Bank, and the UN-HABITAT gives guidelines for urban carbon inventories. According to the guidelines, the urban carbon inventories should be "transparent, consistent, comparable, complete and accurate"; they should hence follow IPCC guidelines to determine emissions from major sources (to satisfy transparency and comparability requirements).

A brief description of the terms as defined by IPCC guidelines 2006[20] is presented hereafter:

Transparency

There is sufficient and clear documentation such that individuals or groups, other than the inventory compilers, can understand how the inventory was compiled and can assure that it meets the good practice requirements for national GHG emissions inventories.

Consistency

Estimates for different inventory years, gases and categories are made in such a way, that differences in the results between years and categories reflect real differences in emissions. Inventory annual trends, as far as possible, should be calculated using the same method and data sources in all years and should aim to reflect the real annual fluctuations in emissions or removals and not be subject to changes resulting from methodological differences.

Comparability

The GHG inventory is reported in a way that allows it to be compared with other GHG inventories for other countries, cities or regions. This comparability should be reflected in appropriate choice of key categories.

Completeness

Estimates in the inventory are reported for all relevant categories of sources and sinks, and gases. Where elements are missing their absence should be clearly documented together with a justification for exclusion.

Accuracy

The GHG inventory contains neither over- nor under-estimates. This means making all endeavours unbiased from the inventory estimates.

[19] http://www.unep.org/urban_environment/PDFs/InternationalStd-GHG.pdf
[20] http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html

2.1.2 The scope of the carbon inventory and addressing the issue of double counting

Double counting is one of the main issues with carbon inventories especially that of cities, since activities related to the city are not limited to municipal jurisdiction limits. The ISDGGEC document[21] suggests that while preparing the carbon inventory, emissions generated outside the city (jurisdiction under consideration) from activities such as energy generation (electricity), aviation and marine freight, as well as, from waste that is generated within cities should be integrated in the city's inventory. However, this might result in the problem of double counting. For instance, emissions from waste generation occurring at a particular location may be accounted in the inventory of the location of waste disposal, which might be outside the PMC's jurisdiction. Therefore the scope, of emissions should be defined clearly, in order to identify sources that are included in the inventory, so as to avoid double counting.

The three scopes defined as per the ISDGGEC document are as follows:

- Scope 1: GHG emissions occurring within the territorial boundary of a given area.
- Scope 2: Also includes indirect emissions occurring outside the given area as a result of energy being consumed within the area (e.g., electricity use and solid waste treatment).
- Scope 3: Includes indirect emissions occurring outside the given area, other than those defined in Scope 2. They include electrical transmission and distribution losses, solid waste disposal, waste incineration, wastewater handling, aviation, marine, and embodied emissions upstream of power plants in fuels and in imported materials**.**

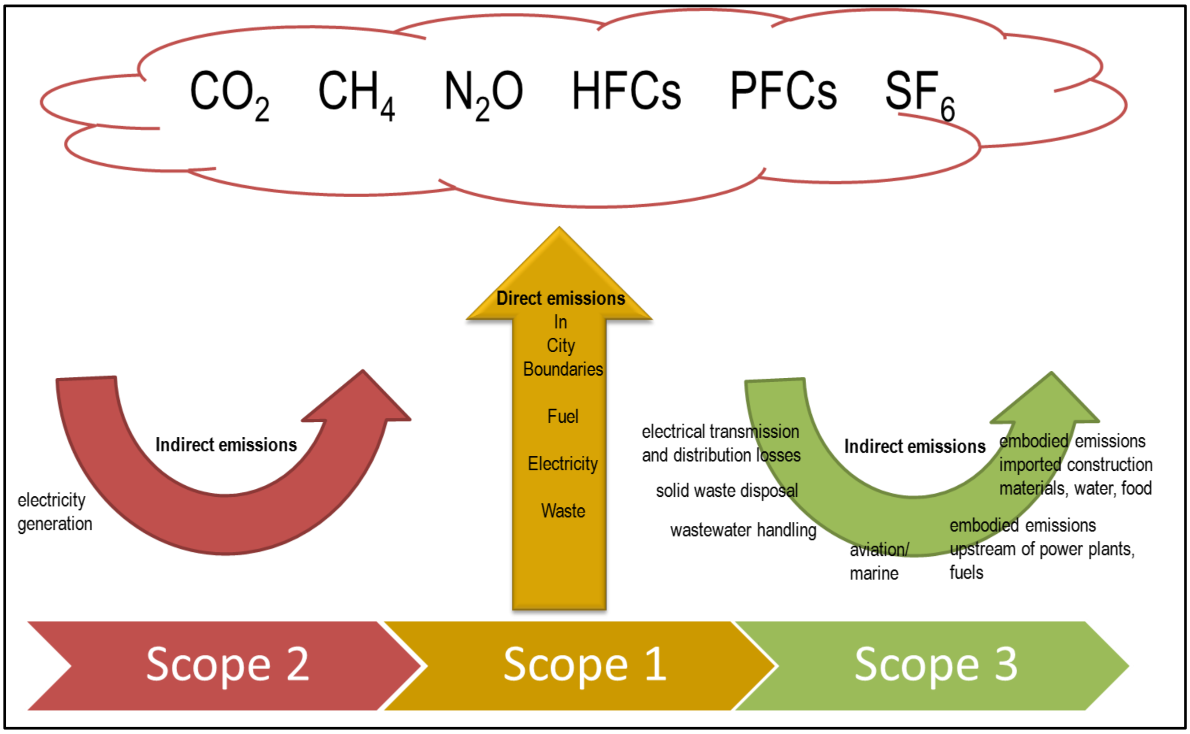

Figure 3: Scope for emission inventory as per ISDGGEC document

[21] http://www.unep.org/urban_environment/PDFs/InternationalStd-GHG.pdf

2.1.3 The method and extent of reporting

There are different ways to report carbon emissions of cities or any type of physical entity. Many GHGs may be insignificant and hard to monitor. Their reporting can be time consuming and of little added value to the study. The ISDGGEC document suggests that inventories may focus on gases representing 95% of emissions. Therefore, gases such as CO_2 and CH_4 are considered for reporting, and gases with minor overall impacts such as SF_6, CF_4, and so on, are left out for the sake of clarity and efficiency of the estimates.

Further, GHG emissions can be either reported by energy source (e.g., emissions from electricity, oil, heat, and so on) or by sector (e.g., emissions from residential sector, industrial sector, and so on). The ICLEI and IPCC recommend the use of sector analysis as it provides more information on increase/decrease in energy consumption of various categories of high/low emitters. The sector analysis proves more valuable for policy-makers.

2.1.4 Identification of the appropriate data sources

Residential, commercial, industrial

The main rule to follow is that emissions should be reported in common units (i.e., CO_2 equivalents). Emissions from residential, commercial, and industrial sectors are fairly straight forward to compute, given standard assumptions (i.e., efficiency of devices), carbon emission factors of fuels used, and data on fuel consumption of each sector. Such data can either be derived from fuel bills or directly from energy providers or surveys.

Waste

Emissions from waste can prove harder to obtain. On top of the quantity of waste generated by the city, knowledge of the average composition of waste and the way in which the waste is being processed is also required to be known. Composition of waste gives information on the carbon content of the waste material, which is generally highly variable in nature. The way in which the waste is actually processed determines the actual level of emissions. If the waste is recycled there are hypothetically zero-emissions; if it is burnt then it releases carbon dioxide and ashes; and if it is processed anaerobically, then it results in producing CH_4 and other solid by-products. Such information is available only at the regional level and assumptions have to be made for estimating the city-level information.

Transportation

Emissions from transportation can be obtained in two ways. The first method involves estimation of emissions by using the data on quantities of fuel sold at petrol stations within the city. The average emission factors are applied depending on the characteristics of the fleet (i.e., the share of cars, trucks, and two-wheelers) to obtain the level of emissions. The second method to estimate emission levels is to obtain data on average Vehicle-Kilometres-Travelled (VKT) within the city from transport municipal offices. Such data is generally measured and available in terms of peak VKT per day. A correction factor is applied to such VKT figures to convert the information into average VKT per year. Emissions are derived from these numbers by applying constant emission factors depending on the characteristics of the vehicle fleet.

2.1.5 Defining the time frame of analysis

Another challenge in reporting the carbon inventories of urban centres is in defining the proper time frame for analysis. Emissions should not only be estimated for the present situation but it is also important to understand the evolution of emissions over a given period of time. The problem mostly rises in the fact that, it is often hard to trace reliable historical data on energy consumption or CO_2 emissions.

2.1.6 Developing the right GHG model

GHG emissions can be estimated by using any spread sheet software (e.g., Microsoft Excel), provided users have the right information on emission factors. Spread sheet models can be developed (with country-specific emission factors) to estimate GHG emissions.

The above discussed guidelines have been considered while drawing up the methodology of carbon inventory for Pune. Some international and domestic initiatives of estimating city level inventories have also been reviewed to devise the methodology (Appendix 1).

3. Pune city greenhouse gas inventory

Pune is among the top seven cities in India, and after Mumbai, it is the second largest city in the State of Maharashtra. Spread across about 5 sq. km in 1818, Pune has now grown into a metropolitan city covering more than 243.84 sq. km. Pune city has a glorious past and a promising future. The city is a continuously growing centre of IT (Information Technology), automotive technology, and BT (Biotechnology). Over the years, the city has been acknowledged/recognized by many and also earned a reputation for being the 'Student Capital of India', the 'Oxford of India', the 'Queen of the Deccan', the 'Pensioner's Paradise', the 'Cyber City', and the 'Upcoming IT-BT Hub', and so on.

Situated to the west of the Deccan plateau, the city stands at the confluence of the rivers Mula and Mutha, which are tributaries of river Bhima. The Sinhagad–Katraj–Dive *ghat*s range forms the southern boundary of the urban area. Geographically, the city is surrounded by hills on three sides, which make the climatic conditions more pleasant. **Table 1** depicts a brief on geographical and general information about Pune city.

Table 1: Basic details of Pune city [22]

Longitude	18°25′ and 18° 37′ North
Latitude	73°44′ and 75° 57′ East
Mean sea level	560 m
Pune city (PMC limits)	
Total area	243.84 sq. km
Population[23]	31.15 lakh
Pune cantonment	
Total area	12.50 sq. km
Population[24]	~ 75,000
Average rainfall	722 mm
1979–2008 recorded maximum and minimum temperature	Max: 42.5°C (April 1983) Min: 2.8°C (January 1991)

This is the first among a list of steps for the city to take mitigation actions aiming at reducing the city's carbon emissions. Based on the results of this study, the city would have to set before itself an emissions reduction target for a particular forecast year and develop a climate action plan. Subsequently, the results of the action plan and policies have to be monitored and results need to be verified and compared versus this baseline carbon inventory exercise.

[22] PMC (2010) *Environmental Status Report 2009-10* Pune: Pune Municipal Corporation
[23] GoI (2011) Provisional data Census 2011: Census of India http://www.census2011.co.in/census/city/375-pune.html
[24] Census 2007, as conducted by Pune cantonment board; conveyed to TERI as per personal correspondence

3.1 Objectives

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

- To determine the baseline carbon inventory and estimate the carbon footprint of Pune city
- To map the sources of GHG emissions
- To develop a source apportionment of the GHG emissions

3.2 Study area

The carbon inventory has been undertaken for the PMC area. All key urban activities taking place within the administrative boundaries of PMC[25], have been considered while estimating the carbon emissions. Although cantonment area is out of the PMC's jurisdiction, the cantonment areas are an integral part of Pune city urban infrastructure. The urban services like sewage treatment and solid waste collection in cantonment area are provided by the PMC[26]. Also MSEDCL supplies electricity to households in cantonment area. Hence, the data collected and per-capita calculation for emissions includes population of cantonment area.

3.3 Methodology

The inventory methodology designed for the study draws from the carbon inventories and the general guidelines reviewed in Chapter 2 and the Appendix 1. The methodology developed also had to take into account specificities of Pune 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.

3.3.1 Time period

The time period chosen to document the inventory spans between 2006–07 and 2010–11. This is the largest time frame on which data could be retrieved and compared.

3.3.2 Study scope

Scope 2 is chosen for the inventory of Pune, 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, municipal waste disposal sites, and sewage treatment. It is acknowledged that there may be a few other activities within the city — apart from energy consumption, municipal waste disposal sites, and sewage transport by pipelines — 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[27] for tandoors in hotels, use of fire wood by population Below Poverty Line (BPL). Hence, it was decided to consider only sources of

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[25] Jurisdiction of Pune Municipal Corporation and cantonment area have been considered for the study

[26] http://www.punecantonmentboard.com/
Solid waste generated in cantonment 10-15 tons/day, Sewage generation in cantonment 7-8 MLD, Population around 75,000

[27] TERI conducted a cursory survey in 2011 for estimating the coal consumption in Pune city. It was noted that, total estimated sale of coal in city is around 340-400 tons / year. The coal is received mainly from Gujarat, Jharkhand, Bihar and other parts of Maharashtra

energy consumption, municipal waste disposal, and sewage treatment sites while estimating the carbon emissions from Pune city.

A schematic depicting the sources of carbon emissions mapped while developing the carbon inventory for Pune city is presented in **Figure 4**.

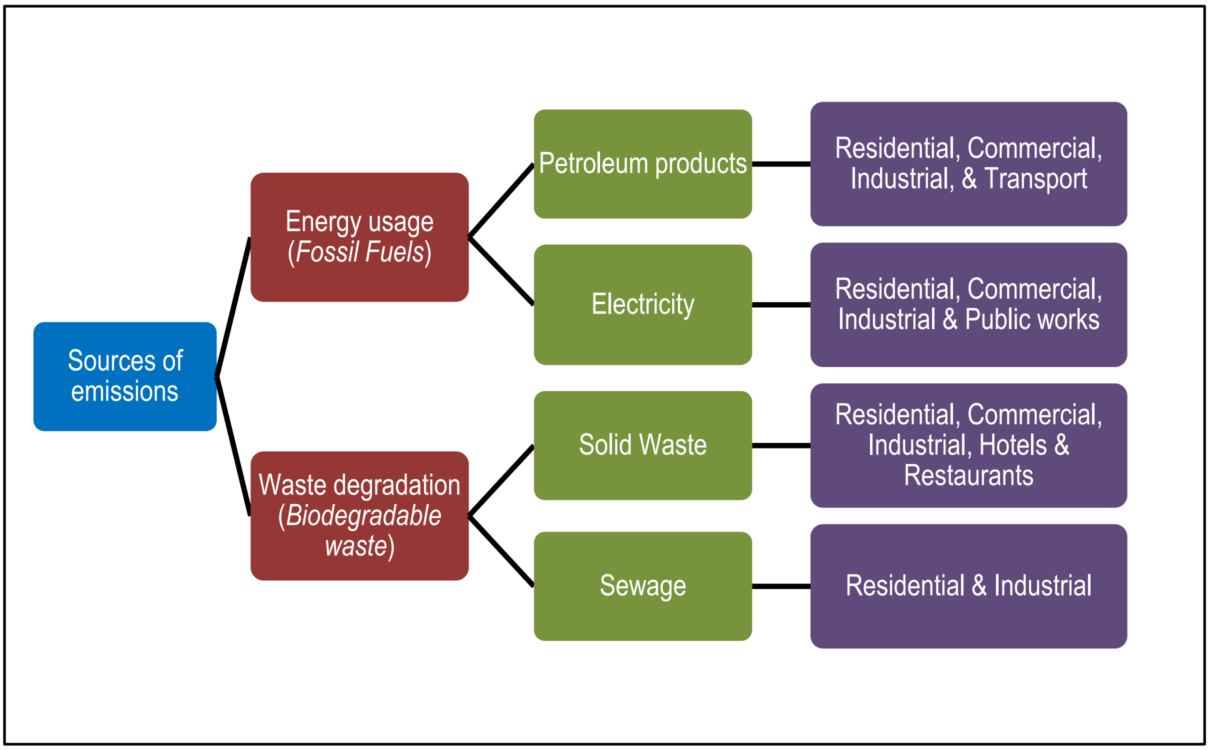

Figure 4: Sources of emissions for Pune city

As per IPCC and ICLEI's recommendations, emissions from aviation are reported for comparison purposes only. Since the uncertainty around these estimates is much higher than for emissions from other sources, i.e., residential, commercial sectors, they should be read separately.

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 Pune city inventory.

3.3.3 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	Fuels used
Residential	Electricity, LPG, Kerosene
Commercial	Electricity, LPG, Kerosene
Industrial	Electricity, LPG, Kerosene, Diesel, Furnace oil
Transportation	Petrol, Diesel, CNG, LPG
Utilities/Municipal services	Petrol, Diesel, Electricity

Note: Apart from the sectors listed above, electricity usage through High Tension consumption was not available with sector classification. Similarly, profiling of waste generated from various sectors was not available. Hence information regarding, HT consumption and waste, has been accounted separately.

3.3.4 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 (see **Figure 4**). 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[28] 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.

[28] 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

3.4 Tier 2 emission factors and Scope 2 approach

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.

3.5 Main assumptions

3.5.1 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. Also, it may happen 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.

3.5.2 Petrol, CNG, and Auto LPG sold at petrol pumps are used for transportation sector 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.

3.5.3 Diesel sold at petrol pumps is used in diesel engines (mobile and stationary) that 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.

4. Energy consumption and emissions

4.1 Electricity consumption

Pune is part of the Western region of the North-East-West-NorthEast (NEWNE) grid[29] along with other medium- sized cities in Maharashtra like Solapur, Kolhapur, and Aurangabad. It is one of the principal centres of electricity consumption in the region, drawing over 3,244.31 GWh in 2010–11 from the Western grid.

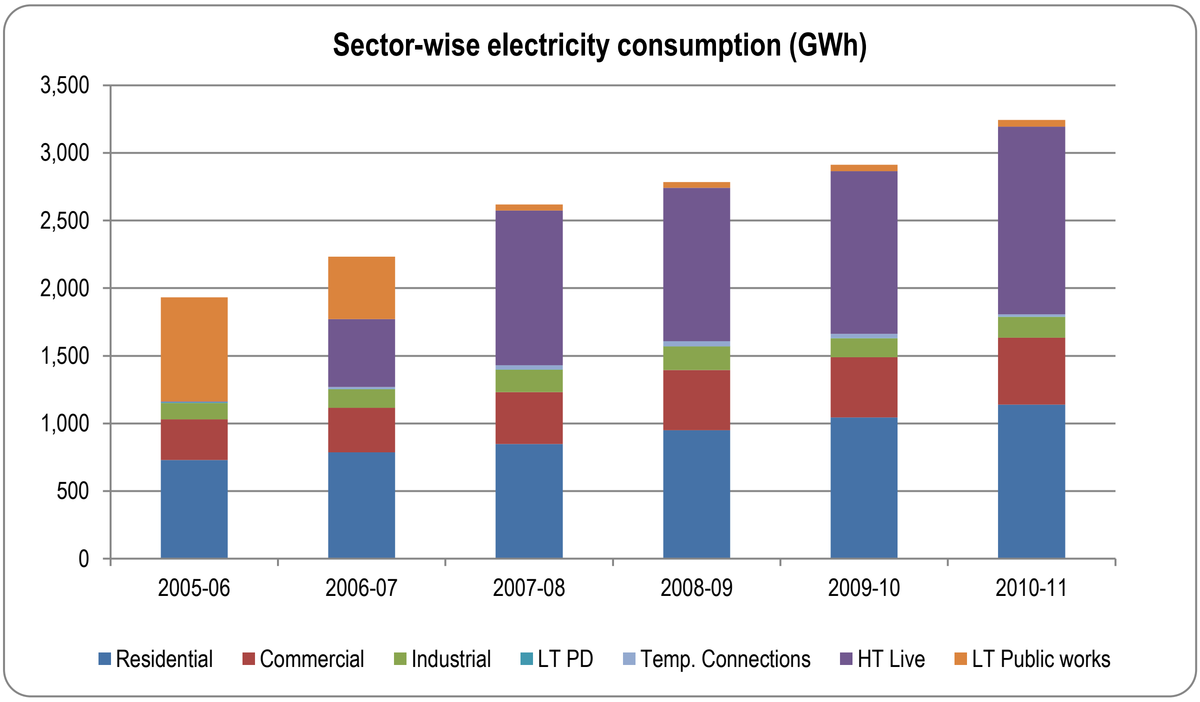

Figure 5: Sector-wise increase in electricity consumption (2005–11)[30]

Note:
Temp. Connections are temporary connections
LT. PD: Low tension consumers Permanent Disconnect

The pattern of electricity use within the city has undergone significant changes in the last few years; the consumption grew by over 1,300 GWh between 2005–11 (1,932.33 GWh in 2005-06 to 3,244.29 GWh in 2010–11), which accounts to an increase of about 68%. Owing to the higher demands, a significant amount of the load of electricity used by public utilities has been shifted to the high tension (HT) distribution network after 2005–06. As seen in **Figure 5**, the shift of electricity consumption from low to high tension electricity distribution has taken place between 2005–06 and 2007–08. As of 2010–11, about 43% of the electricity load of the city was on HT lines. The HT network primarily caters to the public utilities and commercial and industrial setups within the city limits. Most of the public utilities such as water works and sewage treatment plants are serviced by HT lines.

[29] http://www.cea.nic.in/reports/planning/cdm_co2/user_guide_ver6.pdf
[30] As per data procured from MSEDCL, Pune office in 2011

Further break-up of electricity utilization by the HT consumers is not available. This makes analysis of electricity end use from the HT consumption difficult. However, in most instances HT electricity is used for running high peak load energy setups like sewage treatment plants, water pumping stations, crematoriums, hospitals, theatres, heavy load commercial setups, and industrial units.

The principle sectors drawing electricity from the low tension (LT) lines are residential and commercial sectors; these sectors draw more than 50% of the total electricity from LT lines used in the city.

For electricity distribution, Pune is organized into two different circles called Rastapeth and Ganeshkhind. As shown in **Table 3**, as of 2010–11, these two circles were responsible for electricity consumption in the ratio of 66% to 34%, respectively. The Ganeshkhind circle is further segmented into two divisions called Shivajinagar and Kothrud while the Rastapeth Circle comprises Padmavati, Parvati, Bundgarden, and Rastapeth divisions. A flow chart depicting the same is provided in **Figure 6**.

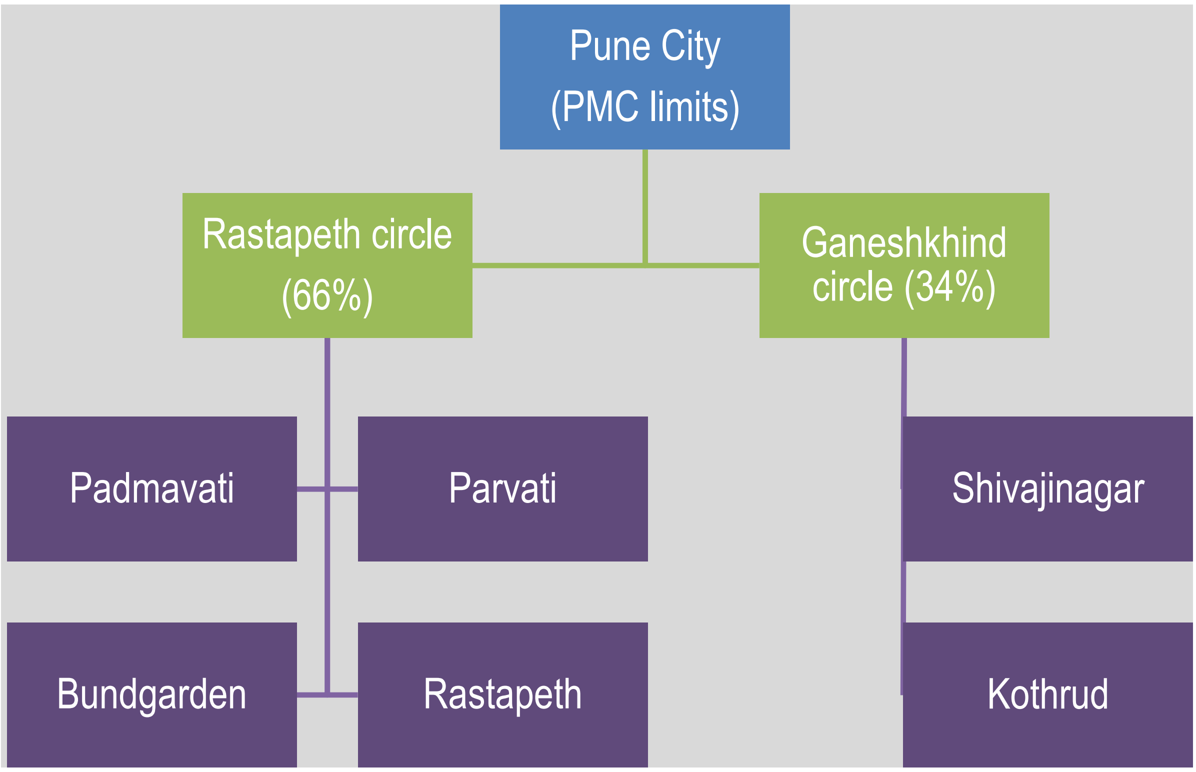

Figure 6: Electricity distribution network in Pune city[31]

The Rastapeth Circle is larger of the two circles and is responsible for consumption of almost 80% of the industrial and 70% of the HT electricity of the city. Although smaller in scale, the Ganeshkhind circle has higher concentration of commercial activity, given its larger share in commercial electricity consumption (43.2%).

[31] As per data procured from MSEDCL, Pune office in 2011, for the study

Table 3: Electricity consumption in Pune Municipal Corporation area (2010–11)[32]

Distribution Circle	Residential	Commercial	Industrial	HT	HT PD	LT PD	LT Public works	Temp. Conc.	Circle Total 2010–11
Ganeshkhind Circle	425.73	212.43	31.79	428.52	0.00	0.63	15.15	2.82	1,117.07
Rastapeth Circle	714.47	282.05	121.08	958.35	0.02	2.56	34.32	14.39	2,127.24
PMC Total	**1,140.20**	**494.48**	**152.87**	**1,386.87**	**0.02**	**3.19**	**49.47**	**17.21**	**3,244.31**

Note: Units in GWh

4.1.1 Electricity consumption in the residential sector

The National Housing Bank's Residex, an index that captures the city-wise housing prices, shows that the residential prices in Pune have increased more than 84% within a period of only three years between 2007 and 2011. However, this has not impacted the demand for housing in the city. As of 2011, there are 916,846[33] households in the city. Its young citizens, mainly in-migrants, now not only have the option of renting low end housing developments, but also have the option of renting or buying high end residential properties that have been rapidly coming up within the extended city limits.

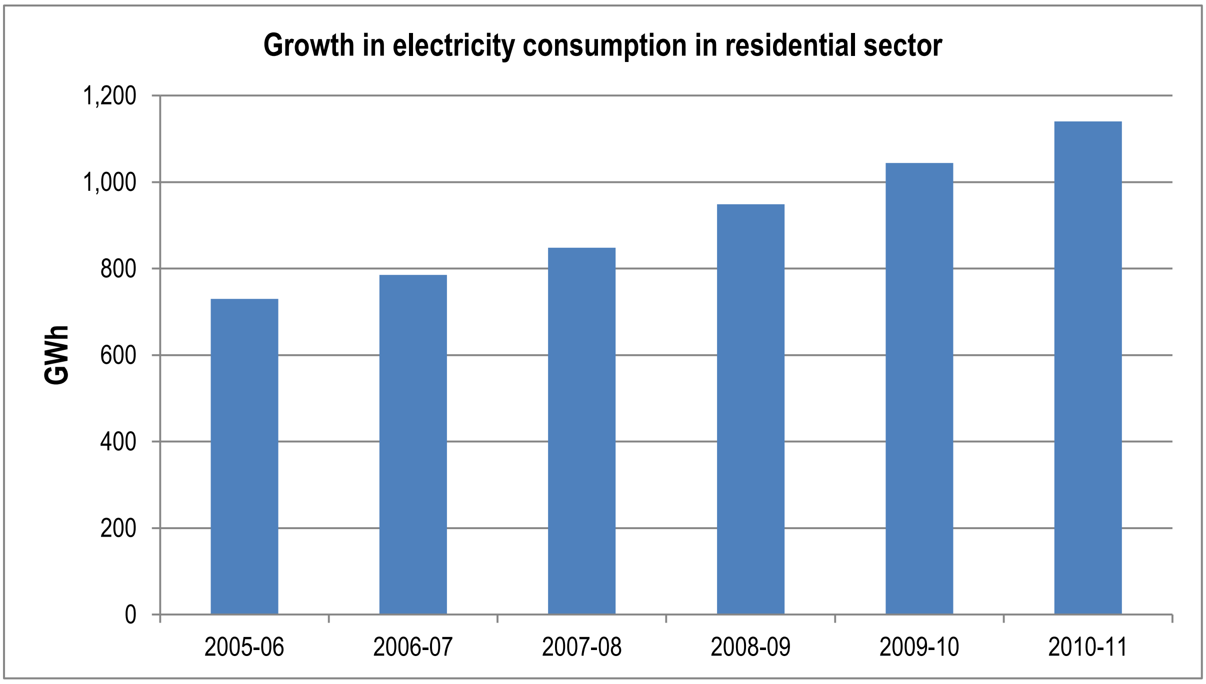

Figure 7: Growth in electricity consumption in residential sector[34]

[32] As per data procured from MSEDCL, Pune office in 2011
[33] PMC (2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation
[34] As per data procured from MSEDCL, Pune office in 2011

Of the total 3,244.31 GWh of electricity consumed by the city in 2010–11, the residential sector was responsible for over 35% of the electricity consumption. This translates to about 1,140.20 GWh of electricity consumption in 2010–11 for households/residences within the city limits (see **Figure 7**). Rapid increase in migratory population owing to business and employment opportunities could be directly attributed to increase in residential consumption levels. Given the city's large number of working couples, migrants, and Double Income and No Kids (DINK) couples with high disposable incomes, there has been an explosive increase in the penetration of organized retail in the city. Electronic appliance sales form a large share of all retail sales. Directly linked to the increasing urbanization and migratory populations, the domestic electricity consumption has increased by about 1.56 times in the last five years from 730.15 GWh to 1,140.20 GWh (between fiscal years 2005–06 and 2010–11) at a compound annual growth rate (CAGR)[35] of about 9.32% between those years.

4.1.2 Electricity use in the commercial and industrial sector

Electricity use in the commercial and industrial sectors is a good proxy for the level of economic activity in the city of Pune. The city, which has been rated as the eighth largest in the country in terms of its annual GDP of $30 billion by the McKinsey Global Institute, has seen an explosion of economic activity in the last decade. Of late, Pune's software industry has grown by leaps and bounds.

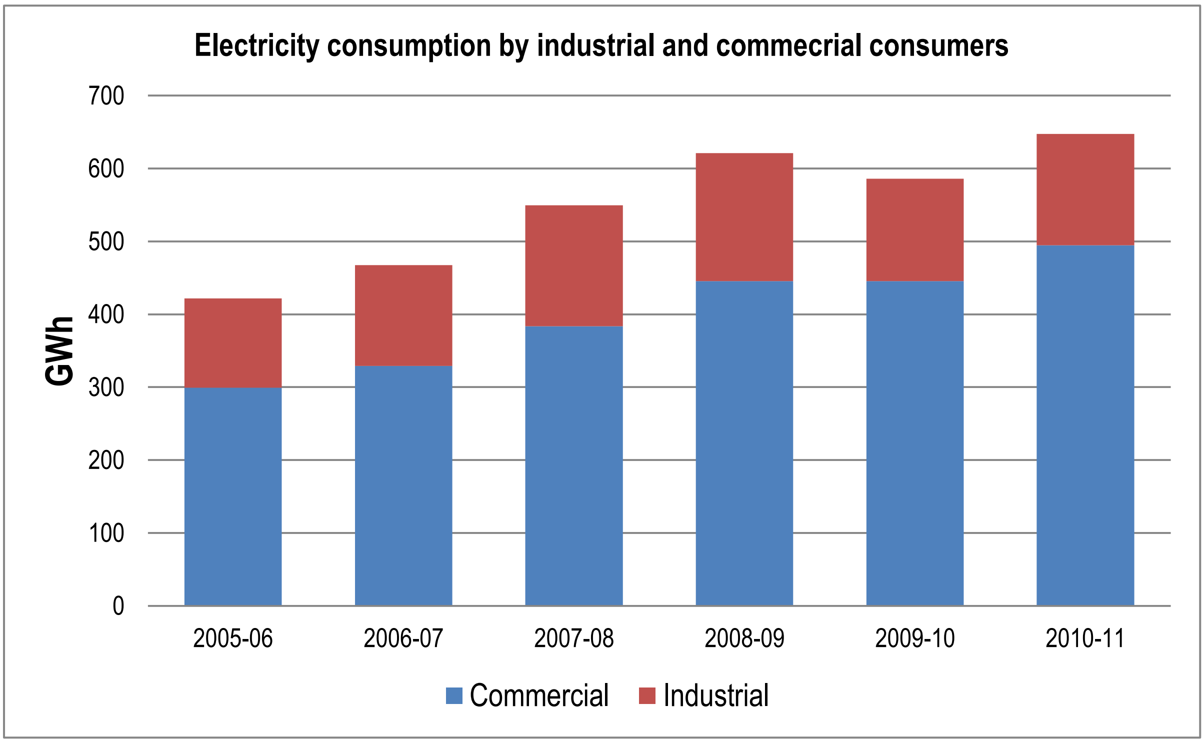

Figure 8: Growth in electricity consumption by commercial and industrial consumers[36]

[35] CAGR = [(tn/t0) ^(1/No of years)] – 1
= tn = Consumption in 2010-11, t0 = Consumption in 2005-06 , No of years = 5, ^ = raise to the power
= [(1140.20/730.15) ^ (1/5)] – 1
= 0.09323 = 9.32%

[36] As per data procured, from MSEDCL, Pune office in 2011

Although most of the heavy industrial developments have been happening outside the boundary of the city area, the old manufacturing units within the city limits are slowly getting transformed into retail and commercial spaces, aligned with the objectives of walk to shop and walk to work. New and more energy-intensive air conditioned malls and retail spaces have been growing in the city. Pune figures in the list of high retail growth cities across the country with the third-largest mall space distribution among all Indian cities at 4.1 million sq. ft[37].

Commercial and industrial activities consuming 494.48 GWh and 152.87 GWh of electricity, respectively, were jointly responsible for about 20% of the overall electricity use within the city in 2010–11. All of this electricity consumption was from the LT distribution network. The period between 2005–06 and 2010–11 saw the electricity consumption of commercial and industrial setups within the city grow from 422.01 GWh to 647.35 GWh at a CAGR of 8.94% including both for commercial usage and for industrial usage (**Figure 8**). The commercial electricity growth rate was particularly steep between the years 2007–08 and 2008–09.

4.1.3 Electricity use in public works and infrastructure

A portion of the electricity consumed in the city is used to support its public infrastructure projects. Amongst other things, it is used to provide street lighting, to operate the sewage and water treatment plants and to run the government offices. From the energy audit performed by the Bureau of Energy Efficiency (BEE) in 2010, it was calculated that of the total connected load for public works, water treatment plants (WTPs) and sewage treatment plants (STPs) formed about 83% of the connected load and street-lighting another 15%. Based on its connected load, the PMC was estimated to be able to consume approximately 236.75 GWh of electricity in a year[38].

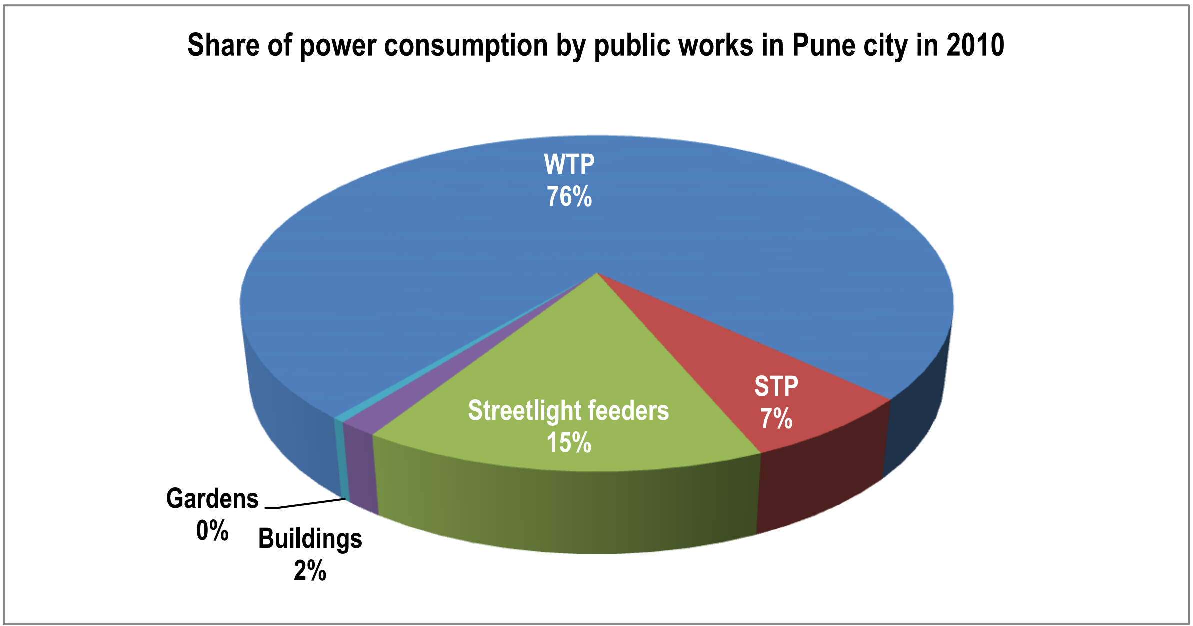

Figure 9: Share of power consumption by public works in Pune city (2010)[39]

[37] IBEF (2007). *Retail: Market and Opportunities*. New Delhi: IBEF

[38] BEE (2010). *Investment Grade Energy Audit*. New Delhi.

[39] BEE (2010). *Investment Grade Energy Audit*. New Delhi. Note: The values below 0.5% may be rounded off to 0% while representing the data in pie chart format

The pattern of electricity consumed by PMC has undergone a change in the last few years. Owing to the more modern and high capacity treatment plants with high peak load requirements, there has been a significant switch to the use of HT lines for meeting the public-work needs. The LT distribution component of electricity used by the public water works and other utilities has dropped from 737.24 GWh in 2005–06 to barely 6.45 GWh in 2010–11, owing to a large shift to HT lines.

The total electricity used by the PMC in 2010–11 for powering only its water pumping stations, STPs, and streetlights was 225.58 GWh.

Data for electricity consumption for street lighting was available from the PMC for the five years of analysis between 2005–06 and 2010–11 and it indicates increased efficiency in street lighting. This is because even though this time period has seen very rapid economic and public infrastructure growth like roads; the electricity used for providing street-lighting has increased only marginally from 33.04 GWh to 43.02 GWh. This can in part be explained by the initiatives that have been taken by the PMC to convert its lights to more efficient LEDs and fluorescent lamps.

In the year 2007, TERI, in collaboration with PMC implemented the "Energy Efficiency in Street Lighting" project in Pune[40]. The project was implemented with an objective to demonstrate and introduce energy-efficient city street lighting systems in Pune. The project demonstrated the technical and economic feasibility of tapping energy saving potential of 20% to 30% by retrofitting about 500 poles in Pune city.

Streetlights within PMC

Being a budding metropolis, with massive public infrastructure requirements, PMC has been focused not only towards providing the required infrastructure but with the objective of providing energy efficient systems. The same has been true for street lighting. Street-lights are responsible for about 15% of the electricity used by the municipality and results in significant costs.

PMC has started to introduce LED lamps for street lighting and is also increasing the share of florescent lights within its jurisdiction. This is reflected in the moderate growth of electricity consumption for street-lighting from 33 GWh in 2005–06 to 43 GWh in 2010–11.

In 2010–11, the connected load for all of PMCs lamps together amounted to 13,822 kW, which if used for 9 hours every day would have resulted in a utilization of about 45 GWh of electricity per annum

Lamp type	Load (kW)
HPSV	9,052
Fluorescent lamps (T5)	3,721
Metal halide	753
LED	296
Total connected load	**13,822**

The PMC has started the "Development of Energy-efficient Street Lighting through Performance Contracting in Pune Municipal Corporation under PPP Mode" to make a detailed evaluation of its present lighting infrastructure to make the system more efficient.

[40] http://www.wisions.net/files/seps_project_descriptions/SEPS_Summary_Lighting_India_SB037.pdf

The PMC has 11 STPs (including old and new) at Baner, Bopodi, Tanajiwadi, Erandwane, Dr. Naidu nagar (Pune Station area), Bhairoba (Kalyaninagar), Mundhwa, Vitthalwadi, and the Botanical Garden. Owing to the large peak demand for each of these plants, there is a large variance between the connected capacity and the actual use of the facilities.

Table 4: List of sewage treatment plants and pumping stations under PMC [41]

Name of STP / SPS	Capacity (MLD)	Connected Load (KW)	Actual Load (KWA)
Mundhwa STP	45	1900	730
Dr Naidu STP	115	500	438
Bairoba STP	130	2200	934
Mental Hospital Pumping Station		280	134
Tanajjwadi STP	17	515	220
Erandwana STP	50	1473	497
Bopodi STP	18	320	174
Botanical Pumping Station		171	89
Baner STP	30	1493	450
Tophkana Pumping Station		815	400
Vitthalwadi STP	32	1485	905

Note: Data from botanical garden STP was not available for further analysis

In 2010–11, the highest amount of electricity consumption was in the Bhairoba STP with a usage of 5.19 GWh followed by the Erandwana plant with 3.54 GWh. These two are the plants with the higher capacities. Some of the newly established plants at Vitthalwadi (2009), Mundhwa (2009), and Naidu (New) (2010) have helped in reducing loads on the other plants.

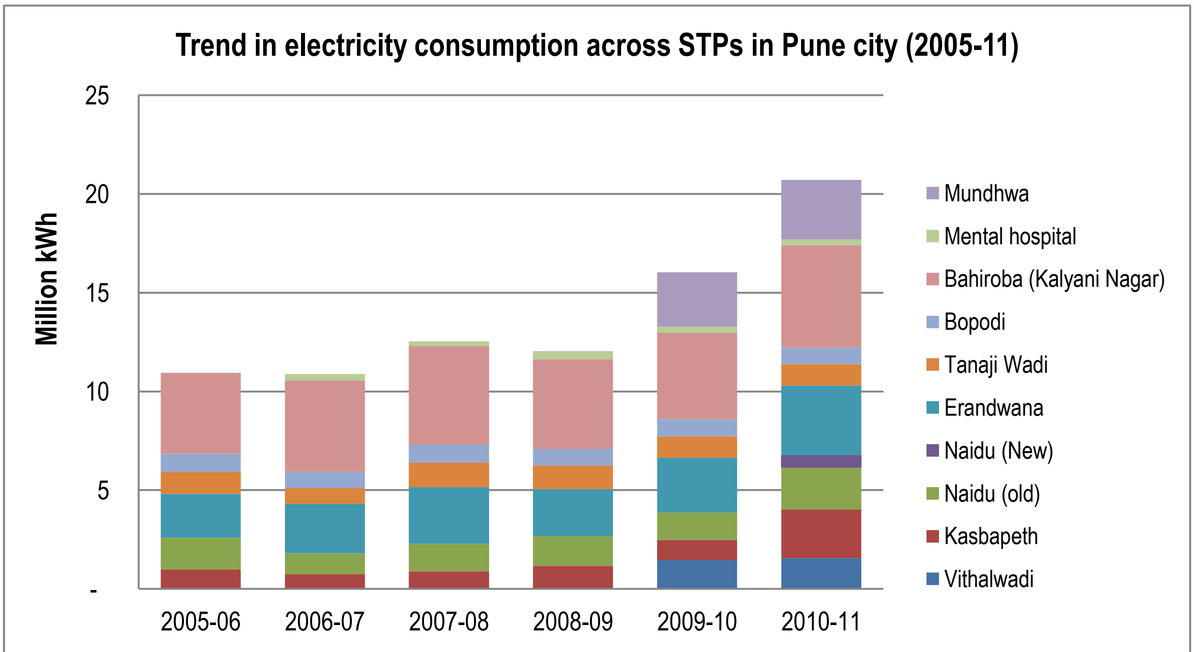

Figure 10: Trend in electricity consumption across STPs in Pune city (2005-11)[42]

[41] As per data procured from officials of water supply and sanitation department, PMC
[42] As per data procured from officials of water supply and sanitation department, PMC

Public Water Works consumes the highest amount of electricity within the public utilities comprising of over 70% of the actual electricity used by the PMC. The water works units are spread across three different divisions: Swargate, Cantonment, and SNDT. The greatest capacity is handled by the Swargate division (89.31 GWh). This division includes Parwati Water Works (38.12 GWh), the largest water works in Pune.

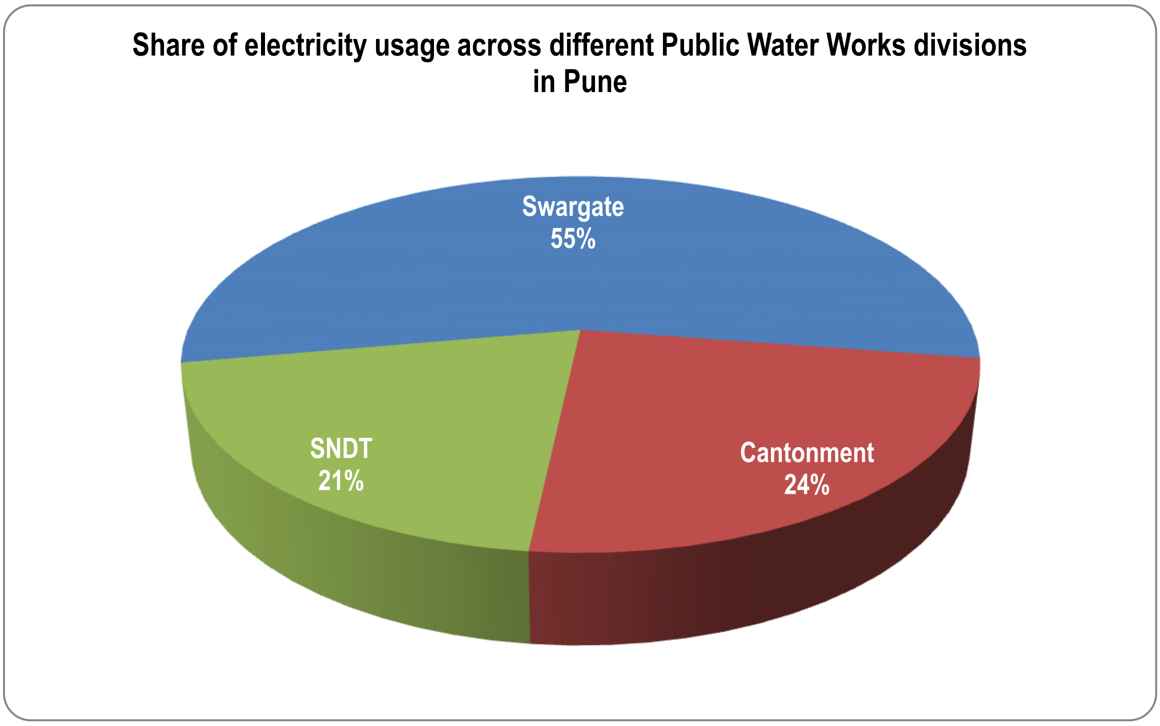

Figure 11: Share of electricity usage across different PWW divisions in Pune[43]

Note: PWW - Public Water Works

The municipality had an annual pay-out of Rs 39.11 Cr. in 2011–12 for running these water works units across the city at an average unit (i.e., kWh) cost of Rs 4.38.

Apart from the Public Water Works, STPs, and streetlights, electricity is also consumed by the municipality in maintaining its gardens and for meeting the needs of municipal buildings. The data for electricity used in gardens and municipal buildings were, however, not considered for this report. Their share comprises less than 2% of the electricity used in the municipality as per the data from the energy audit report for the public utilities[44].

[43] As per data procured from officials of water supply and sanitation department, PMC
[44] BEE (2010). *Investment Grade Energy Audit*. New Delhi: Bureau of Energy Efficiency

4.2 CO_2 emissions due to electricity consumption

4.2.1 Calculating CO_2 emissions from electricity consumption

The nature of CO_2 emissions from electricity consumption is directly dependent on the manner in which the electricity is generated. The Western Regional Grid, that Pune is a part of, derives electricity from thermal, hydro, gas-fired, nuclear and, wind-based power plants. Central Electricity Authority of India (CEAI) has calculated CO_2 emission factors for different electricity grids in the country. These emission factors based on the average mix of the generation from different sources are well-accepted nationally and internationally. This study makes use of the annual CO_2 emission factors generated by CEAI for the Western Electricity Grid to calculate CO_2 emissions from electricity consumed in Pune city.

Table 5: CO_2 emission factors for the Western Grid[45]

	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
CO_2 emission factor (tCO_2/MWh)	0.82	0.83	0.85	0.85	0.84	0.81	0.80	0.79	0.82	0.81

The CO_2 emission factors given in **Table 5** have been used to derive CO_2 emissions by multiplying with the overall electricity usage numbers. An example is provided to help understand the calculation process.

Actual Example

Electricity use in residential sector in Pune in 2010–11
1,140.20 GWh [A]

CO_2 emission factor from CEAI for Western Grid (2010)
0.81 tCO_2/MWh [B]

Unit Conversion
1 GWh = 1,000 MWh [C]

CO_2 emissions from residential sector in 2010–11
923,562.00 tCO_2 [A*B*C]

Equation 1: Calculation of CO_2 emissions from electricity use in Pune

[45] GoI (2011) *CO_2 Baseline Database for the Indian Power Sector*, CEAI, New Delhi, Ministry of Power, http://www.cea.nic.in/reports/planning/cdm_co2/user_guide_ver6.pdf

4.2.2 Emissions from electricity used in the city in 2010–11

Based on the method of calculation explained in **Equation 1**, the overall CO_2 emissions from the use of electricity in Pune city are estimated to be 2,627,874.90 tCO_2 in 2010–11. This includes emissions from electricity used in residential, commercial, industrial, and public works sectors. Given the overall population of Pune, 3,115,431 in 2011 as per the last census[46] the per capita[47] emissions from electricity use in Pune are 0.82 tCO_2.

The residential sector which was responsible for 35% of the electricity use within the city in 2010–11 was responsible for 923,562.00 tCO_2 (35%) emissions or 0.29 tCO_2 emissions per capita in the same year. The commercial and industrial setups generated emissions of 400,528.80 tCO_2 (15%) and 123,824.70 tCO_2 (5%), respectively, in 2010–11, which was equivalent to 0.13 and 0.04 tCO_2 per capita, respectively.

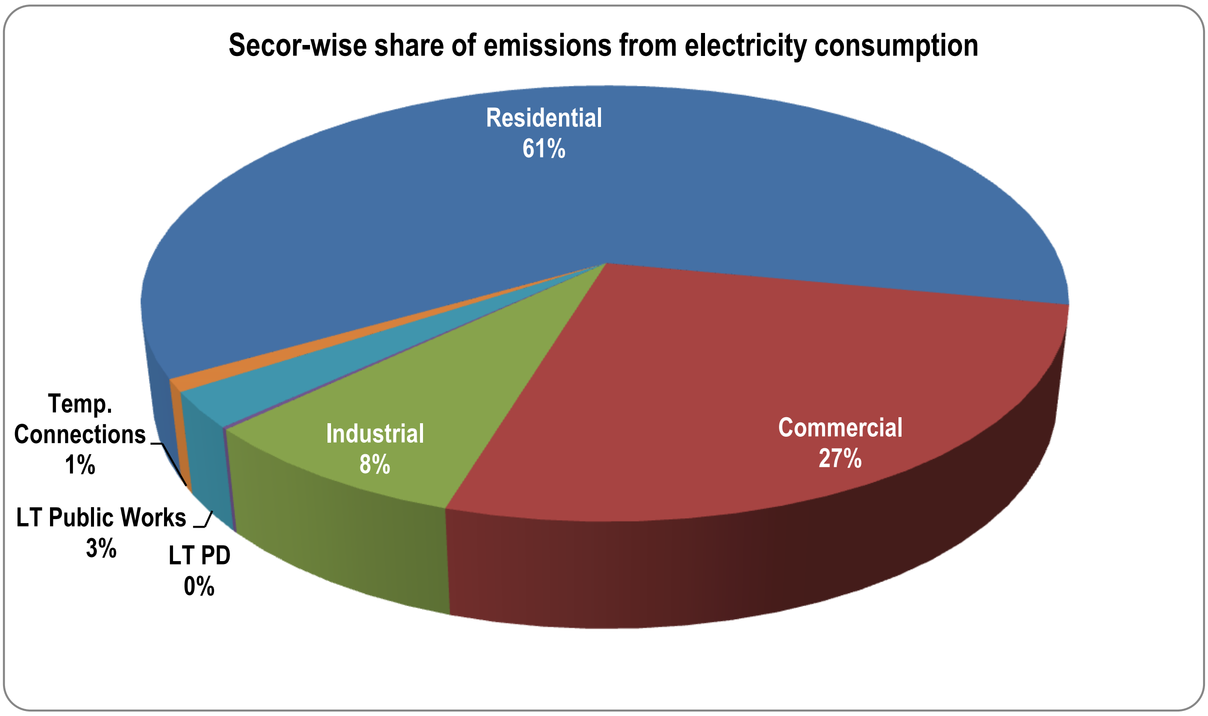

Figure 12: Sector-wise share of emissions from electricity consumption (2010–11)

Note: The percentages in the figures have been rounded off and fractional amounts less than 0.5 may be reflected as 0% in a pie chart

The largest independent source of emissions from electricity use was the HT consumers. A total of 43% of the electricity used in the city is by HT consumers generating a total of 1,123,364.70 tCO_2 (43%) or 0.35 tCO_2 per capita. Sectors like public works, commercial, and industrial could be the possible end use sectors for using this electricity. However, due to lack of end use information, it is not possible to identify the sectors which were exactly responsible for generating these emissions.

[46] GoI, (2011) *Census of India, 2011*. New Delhi: Ministry of Home Affairs, Government of India.

[47] Per-capita calculations includes population of Pune city + cantonment area

4.2.3 Trend of GHG emission from electricity usage

In the last six years, there has been an increase in the overall level of emissions generated in Pune. The CO_2 emissions from electricity rose from 1,565,187.30 tCO_2 in 2005–06 to 2,627,874.90 tCO_2 in 2010–11, at CAGR[48] of 10.92% between these years. One may observe from **Figure 13** that the increase in the annual growth rate in emission levels is not constant across the years and fluctuates in the range of 16% (2007–08) to 3% (2009–10).

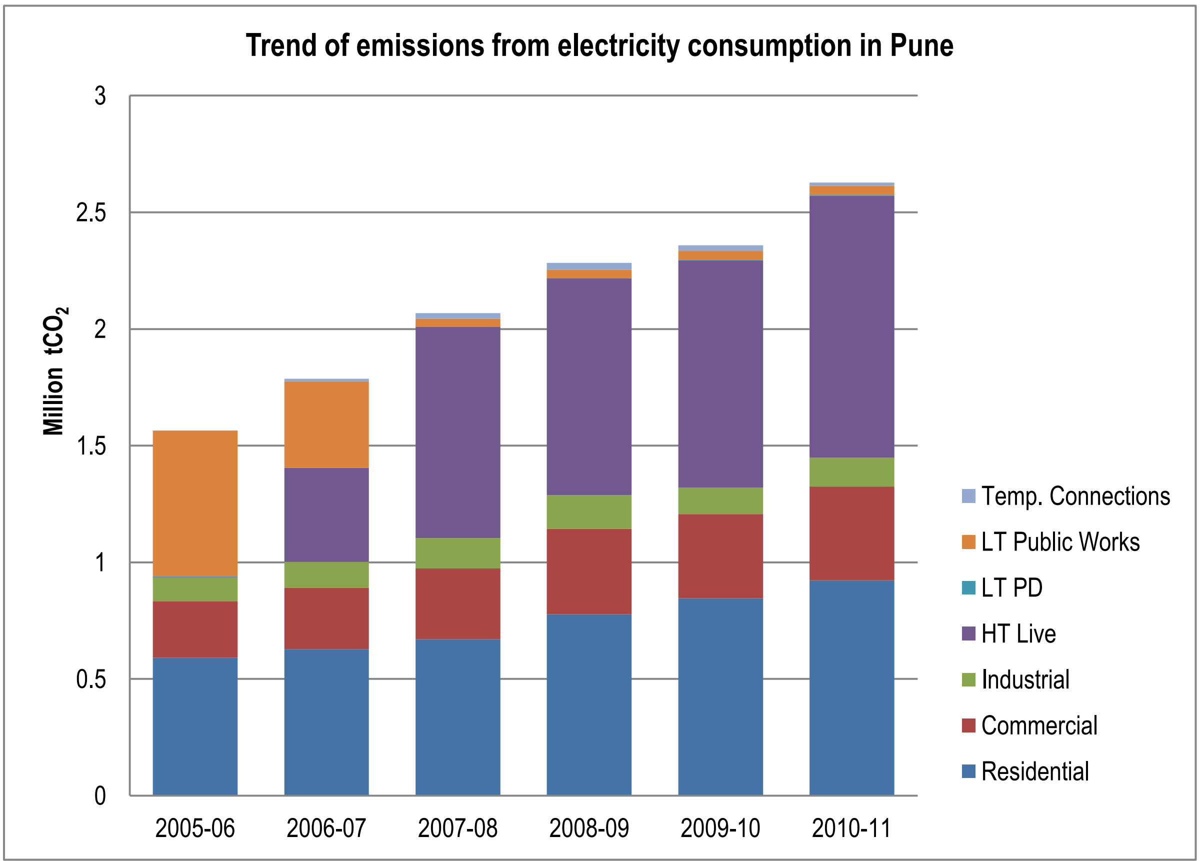

Figure 13: Trend of emissions from electricity consumption in Pune

[48] CAGR = [(t_n/t_0) ^(1/No of years)] – 1
= t_n = Emissions in 2010-11, t_0 = Emissions in 2005-06 , No of years = 5, ^ = raise to the power
= [(2627874.9/1565187.3) ^ (1/5)] – 1
= 0.10919
= 10.92%

4.3 Consumption of petroleum products

Petroleum use is directly related to the development of any country or region. The same is true for the city of Pune. The heavy use of personalized transport in the form of two and four wheelers has caused a rapid growth in the overall demand for petroleum products within the city. In addition, the demand for domestic and industrial LPG has also grown given the increasing residential and industrial usage of the fuel. There has been increase in the sales[49] for almost all petroleum products.[50]

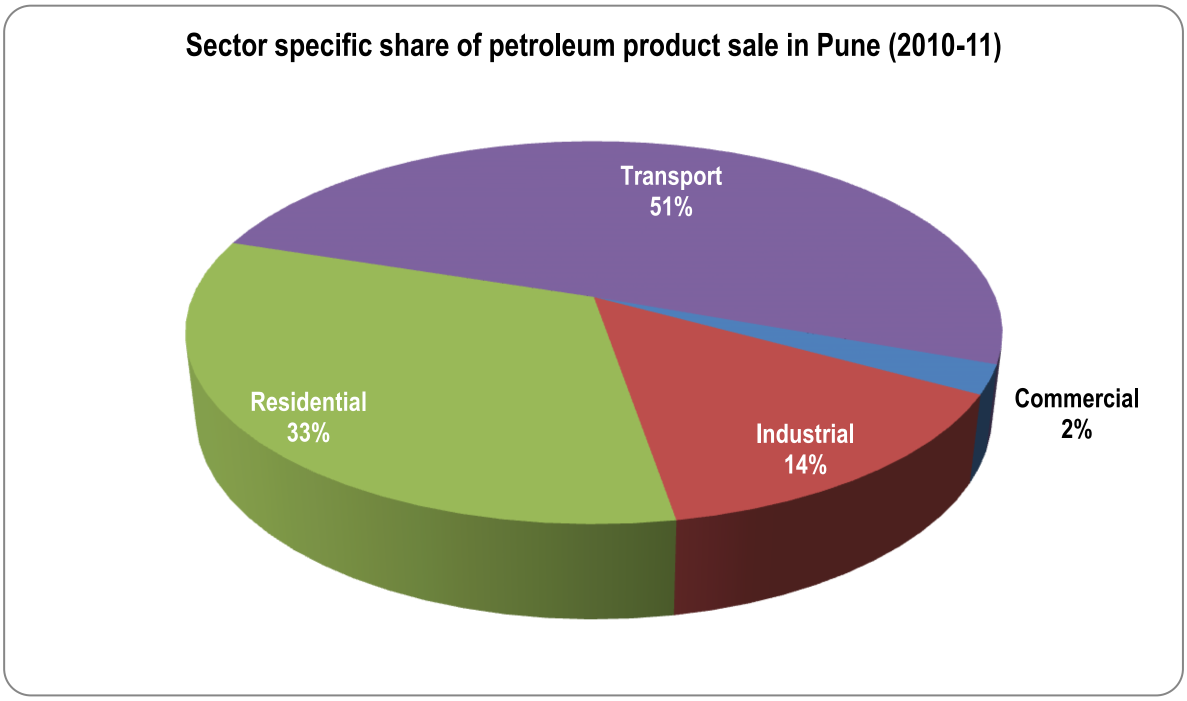

Figure 14: Sector-specific share of petroleum product sale in Pune (2010–11)[51]

The data for the petroleum usage from the city was collated using information provided by the three oil majors in the city, Bharat Petroleum Corporation Limited (BPCL), Hindustan Petroleum Corporation Limited (HPCL), and Indian Oil Corporation Limited (IOCL) for five years between 2006–07 and 2010–11. The fuels that were considered were Compressed Natural Gas (CNG), Furnace Oil (FO), High Speed Diesel (HSD), Kerosene, Light Diesel Oil (LDO), Liquefied Petroleum Gas (LPG), and Motor Spirit or Petrol, all of which are retailed at different end points such as petrol pumps and door to door deliveries. Aviation Turbine Fuel (ATF) consumption numbers were available, but have been reported separately given the Scope 2 methodology adopted for the study.

Barring the sales of kerosene and Auto LPG, which have either stayed the same or dropped in some years, the sales of all kinds of petroleum products have been on the rise in

[49] Information about sales of petroleum products within the city of Pune was collated from information received from three petroleum majors, BPCL, HPCL and IOCL. Consistent petroleum sales data was available only from 2006-07 to 2010-11.

[50] Petroleum products comprise of CNG, Furnace Oil, HSD, Kerosene, LDO, LPG and Motor Spirit. However, ATF consumption and emissions numbers are reported separately.

[51] As per data collected from IOCL, BPCL, HPCL, and MNGL for the study

the last few years. Sales of fuels like ATF and CNG, particularly, have shot up in the last couple of years given the large increase in the number of flights in and out of the Pune Lohgaon Airport and the government directive for switching auto rickshaws to CNG.

As shown in **Figure 14** the transport sector is the highest consumer of petroleum products in the city with 51% share of the total sales [compared in metric tonnes (MT)], followed by domestic or residential consumption of petroleum products at 33%.

4.3.1 Use of petroleum products in the transport sector

The transport sector is the largest consumer of energy in the form of petroleum products. Petrol or Motor Spirit, Diesel, Auto LPG, and CNG are the principle forms for energy used to drive mobility within the city.

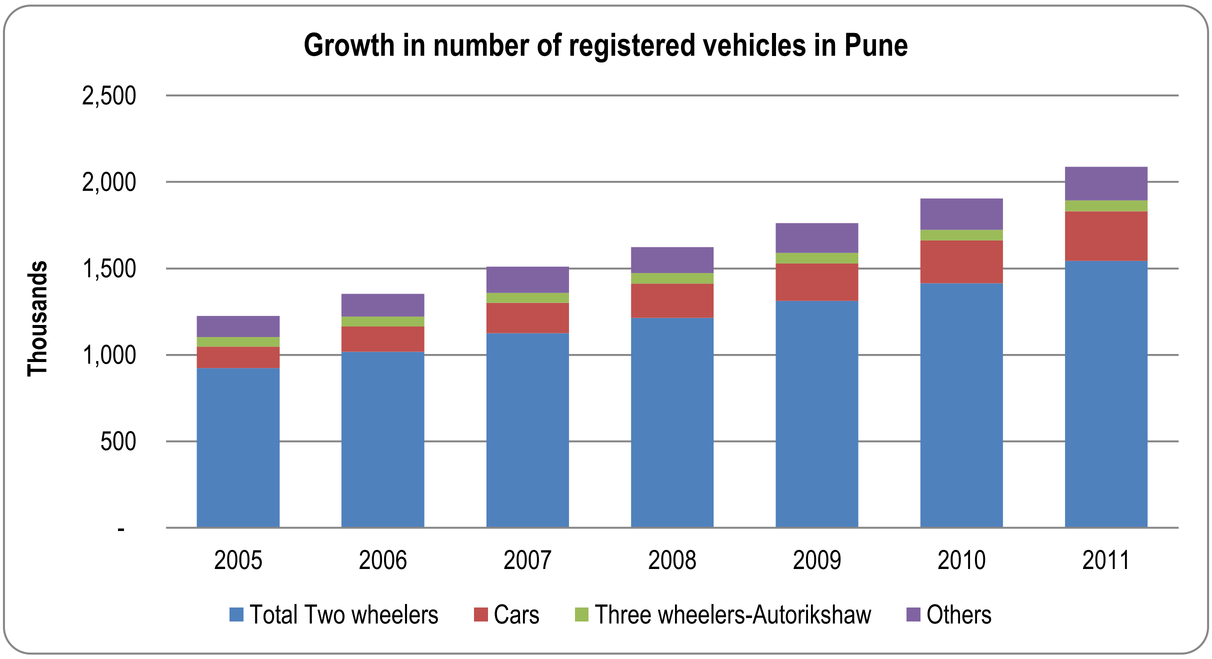

Figure 15: Growth in the number of registered vehicles in Pune[52]

The increasing number of two and four wheelers on the roads, which primarily use petrol, has sparked of a high-growth trajectory for the demand of fuel in Pune. The fuel sales of petrol have been growing in proportion with the total number of registered petrol vehicles in the city. The similar is true for diesel and diesel vehicles such as buses, taxis, heavy, and light commercial vehicles.

Petrol (Motor Spirit) and diesel (HSD) sales figures have gone up by 39% and 73.30%, respectively, between 2006–07 and 2010–11. These two fuels jointly contributed about 96% of the total fuel consumed in MT by the transportation sector in the year 2010–11. There is a steady growth rate of sales of petroleum products used in the transport sector between the years 2007–08 and 2009–10.

[52] As per data procured from RTO Pune in 2011

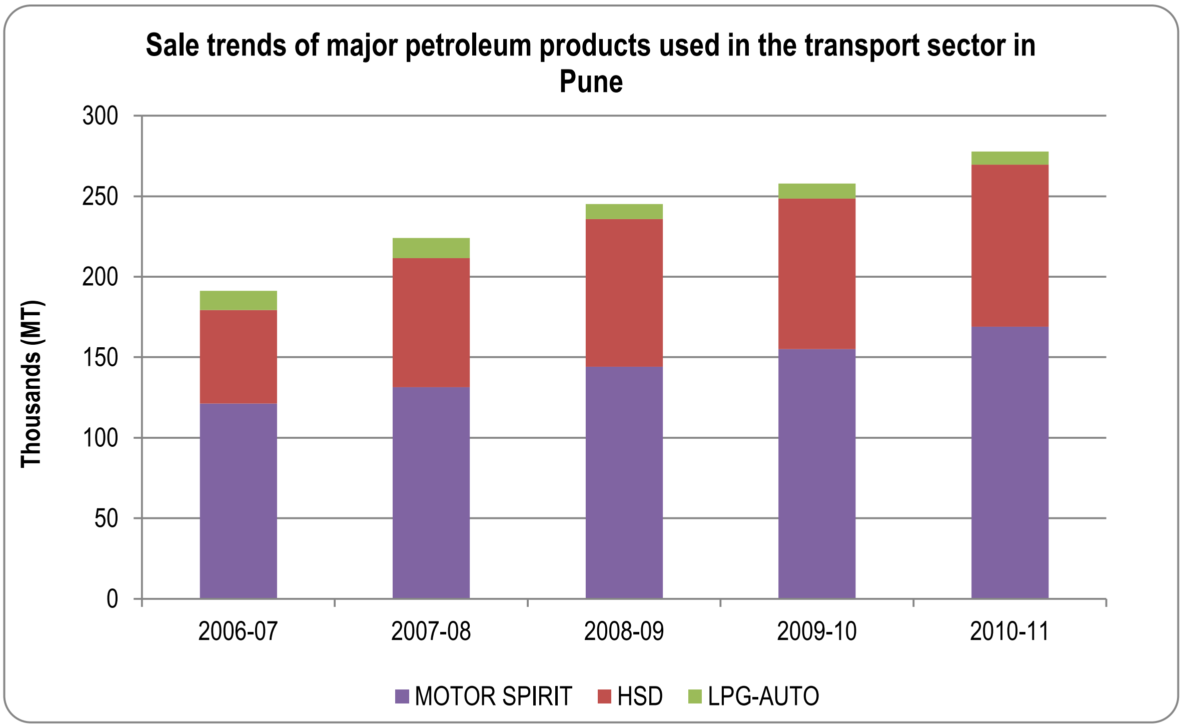

Figure 16: Sale trends of major petroleum products used in transport sector in Pune[53]

Auto LPG has seen some fluctuation in sales volumes with some year sales values going lower than the previous years. The sales volumes of Auto LPG have dropped from 9,503 MT to 8,167 MT between 2009–10 and 2010–11. One possible reason for the same might be the introduction of CNG in Pune since 2009–10. CNG sales volumes have gone up from 660 MT in 2009–10 to 2,166 MT in 2010–11, an increase by 3.28 times.

[53] As per data procured from IOCL, BPCL, and HPCL for the study

4.3.2 Domestic use of petroleum products

Petroleum products for domestic use comprise of LPG (domestic) and kerosene.

In Pune, kerosene is sold through select channels of the Public Distribution System (PDS) whereas LPG (domestic) is retailed directly to homes by the fuel companies. The rising incomes and increasing standards of living have led to a drop in the overall sale of kerosene across the city and more households switching to LPG (domestic). Kerosene's share in domestic consumption of petroleum products has declined; the fuel is primarily used by low-income households.

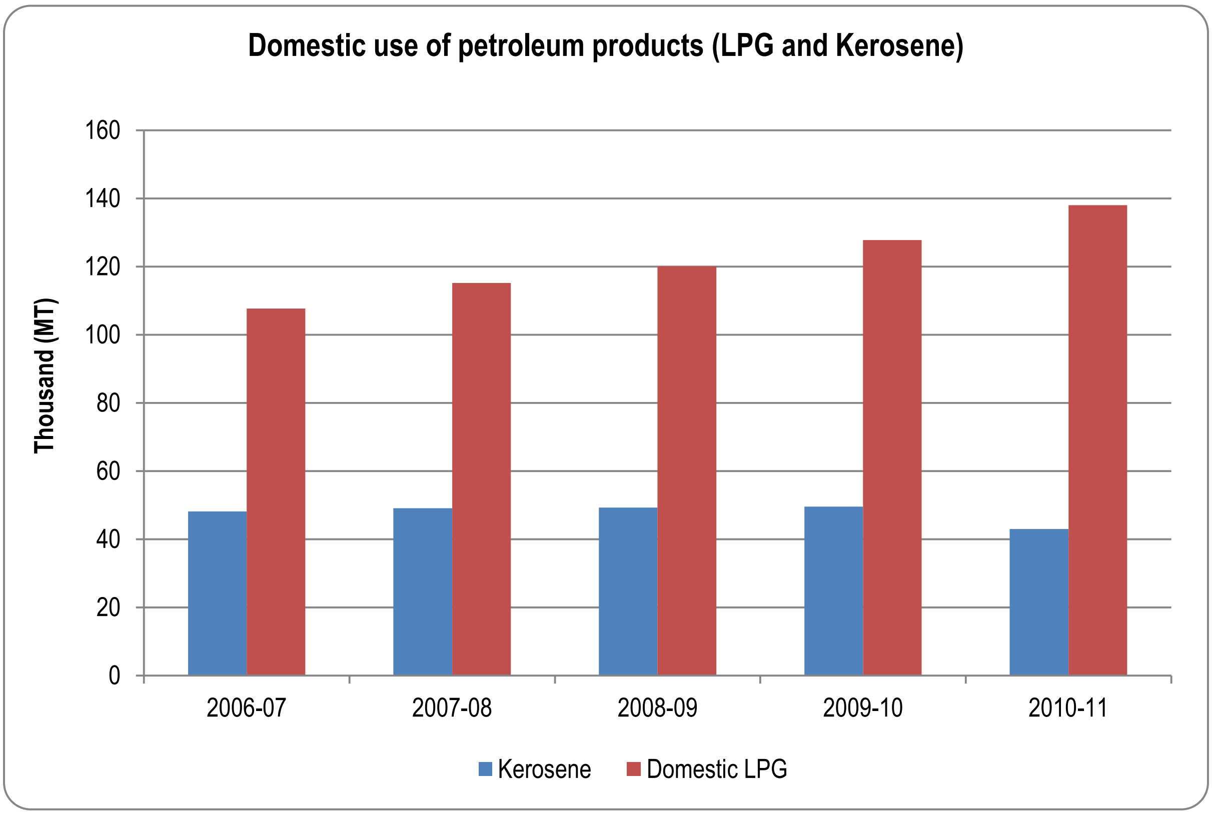

Figure 17: Domestic use of petroleum products (LPG and Kerosene)[54]

On the other hand, LPG is a much better and convenient fuel with lesser negative impacts to human health. Hence, the use of domestic LPG has grown from 107,701.96 MT to 138,004.50 MT between 2006–07 and 2010–11 at a CAGR of 5.08%.

Residential consumption of petroleum products (in the form of domestic LPG and kerosene) formed 33% of the overall consumption of petroleum products (in MT) in the city in 2010–11.

[54] As per data procured from IOCL, BPCL, HPCL & PDS (rationing office) for the study

4.3.3 Consumption of petroleum products in the commercial and industrial setups

Commercial and industrial setups have a demand for petroleum products to run their machinery, boilers, chillers, and so on. Furnace oil, LDO, and LPG for commercial purposes are the primary fuels used in these sectors.

Keeping in line with the industrial growth in Pune, the requirement for furnace oil and commercial LPG has been growing in the last few years. Furnace oil sales have increased from 29,593 MT to 45,558.96 MT between 2006-07 and 2010-11 at a growth rate of 8.99% per annum. Likewise, the sales for commercial LPG have increased from 10,728.14 MT to 13,516.63 MT during the same period at a CAGR of 4.72%.

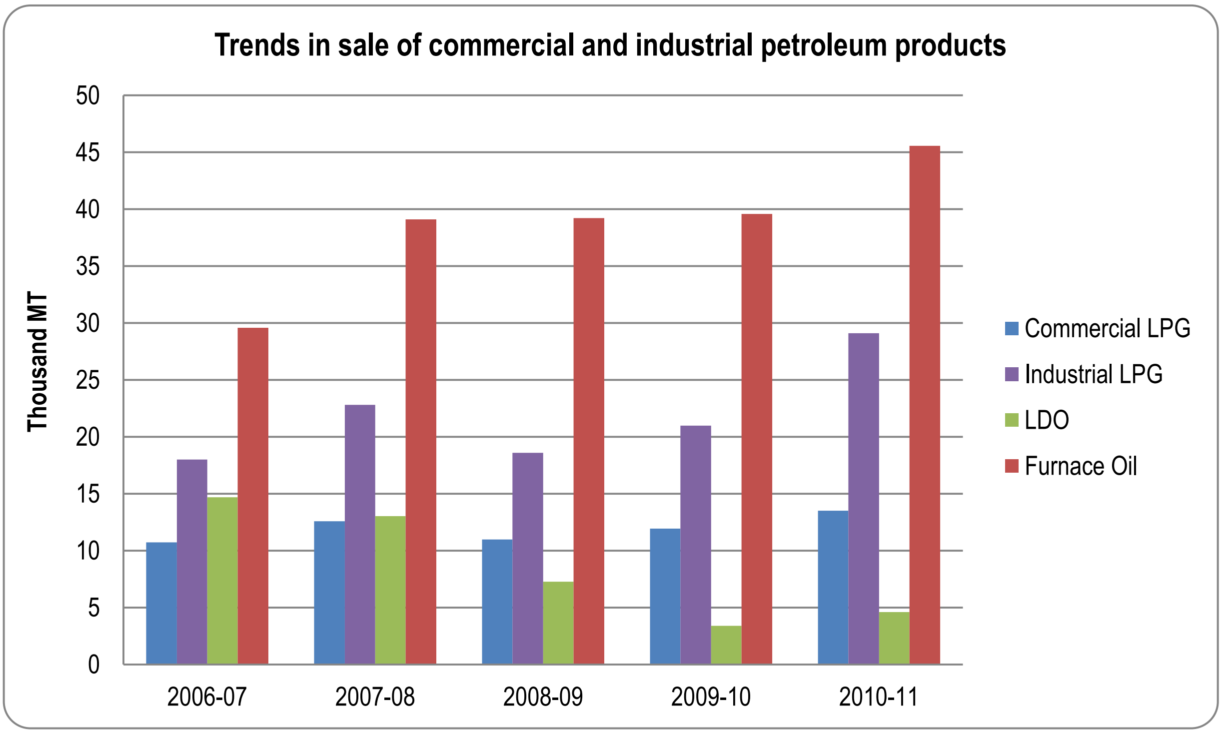

Figure 18: Trends in sale of commercial and industrial petroleum products[55]

[55] As per data procured from IOCL, BPCL, and HPCL for the study

4.4 Emissions from petroleum products

The heavy use of petroleum products in Pune 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.

4.4.1 Emissions calculations from 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 in Pune were first converted into a uniform unit of metric tonnes (MT) for ease of calculations as presented in **Table 6**.

Table 6: Conversion factors for KL to MT of particular petroleum products[56]

Conversion Factor	LPG	Petrol	Kerosene	Diesel	Fuel oil	CNG
KL to MT	0.542	0.74	0.806	0.839	0.939	0.185

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 7**.

Table 7: Derivation of petroleum emission factors from energy content

Petroleum Product	Emissions by energy content ($T\ CO_2/MJ$)	Calorific value (MJ/kg)	Emissions by weight ($T\ CO_2/kg$)	Emissions per tonne ($T\ CO_2/MT$)
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
ATF	71.50	44.10	3,153	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 given in **Table 7**. One complete example of the conversion is given in **Equation 2.**

[56] Source: British Petroleum http://www.bp.com/conversionfactors.jsp

Actual Example:

Petrol Sales
168,948.92 MT [A]

Emissions factors using fuel calorific values for Petrol
3.06999 tCO_2 /MT [B]

Emissions from Petrol sales in 2010-11
518,671.49 tCO_2 [A*B]

Equation 2: Calculation of emissions from petroleum products

4.4.2 Emissions generated from the use of petroleum products

The increase in consumption of petroleum products has led to increased CO_2 emissions. In 2010–11, the emissions from the use of petroleum products resulted in a total of 1,967,299 tCO_2 being generated from Pune. Of this, 51% emissions were generated by the transport sector, 32% by the residential sector and about 17% by the industrial and commercial sectors put together.

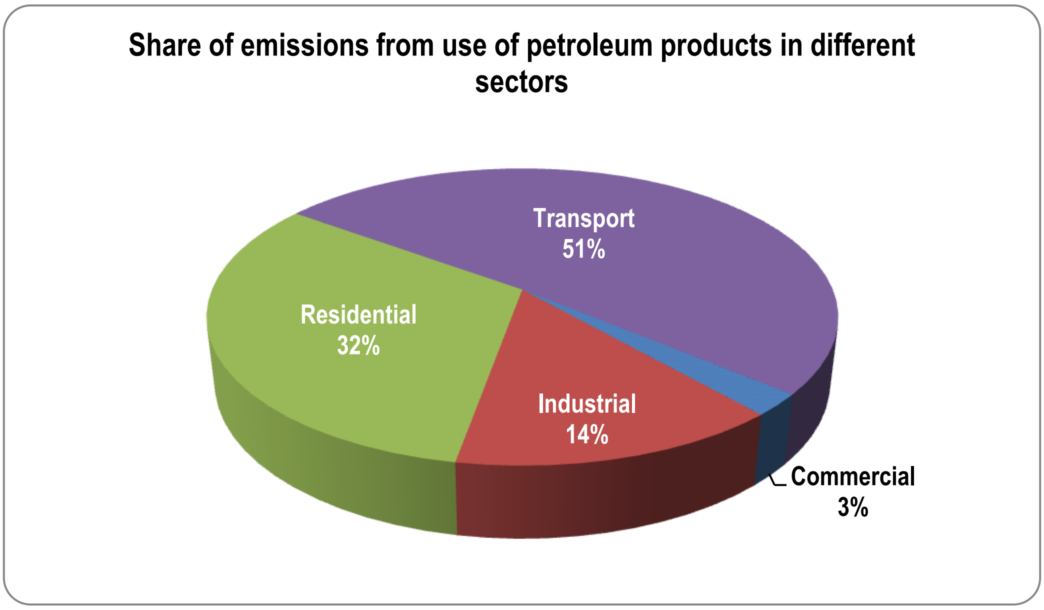

Figure 19: Share of emissions from use of petroleum products in different sectors

Driven by the heavy use of two and four wheelers in the city, petrol has become the largest emitter of CO_2 emissions amongst all fuels occupying a 60% share in the transport CO_2 emissions mix. This amounted to 518,671.49 tCO_2 of emissions from petrol use for transport in 2010–11. Diesel, which is the second-most intensively used petroleum product, occupies a share of about 37% in the CO_2 emissions from the transport sector. The fuel generated about 320,684.37 tCO_2 emissions in the year 2010–11, up from 185,050.00 tCO_2 in 2006–07.The other two fuels used for road transport — CNG and auto LPG — were responsible for 30,209.38 tCO_2 emissions in the city.

A recent development in Pune has been a high growth in the number of flights to and from the city. This has led to the increase in the overall demand for ATF from the airport bunkers. ATF, which was earlier retailed only by IOCL, is now also sold by the other majors, BPCL and HPCL. This has resulted in substantial growth in the overall emissions resulting from the fuel that is distributed from bunkers at the Pune airport (266,144.51 tCO_2 in Pune in 2010–11). However, these CO_2 emissions are not treated to be part of the city's emissions footprint in the Scope 2 methodology that has been chosen for this study.

Second to transport, the residential or domestic sector is also a large consumer of petroleum fuels sold in Pune, generating about 547,226.96 tCO_2 in 2010–11. The principle fuels, kerosene and LPG share about 25% and 75% of the overall demand of the households and generate emissions in the same proportions. Domestic LPG generated 411,892.38 tCO_2 and kerosene 135,334.58 tCO_2 in 2010–11. The two fuels had a share of 24% of the overall CO_2 emissions from all kinds of petroleum product use in the city.

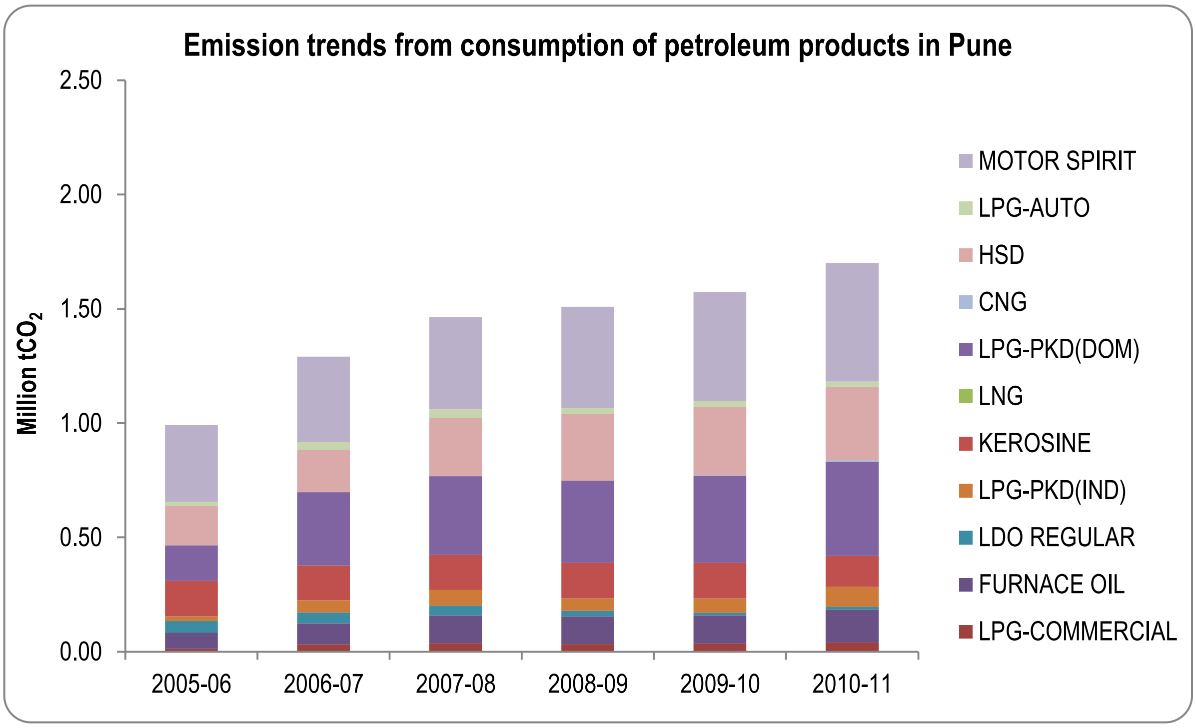

Figure 20: Emission trends from consumption of petroleum products in Pune

Petroleum products used in the industrial and commercial sectors were responsible for 17% of the total CO_2 emissions generated from the use of petroleum products in the city. Of this, LPG used in these sectors is responsible for 45% of the emissions, whereas furnace oil is responsible for 50%. The remaining 5% of the emissions from the sectors are generated from the use of light diesel oil in industry.

5. Solid Waste and Sewage

One of the major challenges faced by any urban centre revolves around the disposal of its waste, both solid-wastes as well as sewage. Pune is no exception. With a rapidly increasing population with higher per capita incomes and changing lifestyles, the magnitude of the challenge has also been increasing. This has resulted in the creation of larger quantities of waste at the residential units, restaurants, shops, and commercial units.

To meet this challenge of treating the rapidly growing waste volumes, Pune has aligned itself to the National Urban Sanitation Policy (NUSP). It is much ahead of other cities of similar size in India in terms of the actions it has taken towards waste management. With incentives such as vermi-composting at the source of waste generation, the Pune municipality has been in the forefront in taking positive action towards management of the solid waste and installed 11 bio-methanation plants to treat biodegradable waste. At present Pune has the capacity to treat all the waste that it generates. However, the sector remains largely unorganized and segmented to address the issue of increasing waste in the future.

Unavailability of adequate toilet facilities for the entire population in the city of Pune still results in discharge of large volumes of untreated sewage. Sewage treatment facilities in the city of Pune are not adequate for all the sewage and wastewater that is collected. Only about 70% of the amount collected is treated. There is a lot of scope to improve the collection rate and treatment facilities of sewage in the city of Pune.

5.1 Solid Waste Disposal

5.1.1 Generation and collection[57]

Pune generated approximately 1,360 tonnes of solid waste everyday, which translated to about 496,400 tonnes of waste in 2010–11. This equates to an average of about 0.44 kg of waste per person per day, or about 0.16 metric tonnes per annum in 2010–11. However, given the rapid rate of urbanization and in-migration, the problem of solid waste management has increased manifold in the last few years and is expected to grow further.

At present, an informal group of rag pickers and *ghanta*-trucks owned by the PMC collect garbage from the waste generating units at various times of the day. Further, the PMC has also authorized over 4,000 rag pickers for the purpose of segregation of the waste collected by its *ghanta*-trucks. Although no formal method of waste collection is followed from the residences within the municipal corporation limits, households pay an average of about Rs 10 per month for collection of their domestic waste by these garbage collectors. This informal setup, though socially relevant, does not allow for a centralized method of collection and segregation of waste making the process inefficient.

Better planning in collection, transportation, segregation, storage, and processing of solid waste is required to increase efficiencies of the system and minimize environmental degradation. Solid waste has the potential to create increased incidence of disease and health hazards if not disposed with proper care. Methane, a green-house gas with a Global Warming Potential of about 21 times[58] that of CO_2, is one of the principle emissions from the SWD (dumping) sites. Planned disposal of solid waste is required for an improved local environment and for mitigating the global challenge of a warming environment.

[57] PMC (2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation

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

5.1.2 Solid waste treatment and management

Pune is one of the few cities in the country that has the capacity to treat all the waste that it generates and since 2010, the city has stopped all forms of open dumping of solid waste. The PMC is responsible for this scientific collection, segregation, processing, and disposal of solid waste generated within its limited jurisdictional area.

Table 8: Details of solid waste treatment facilities in Pune[59]

Plant Details	Treatment Capacity	Type of Waste
Hanjer Biotech projects I & II	1000 TPD	Inert and biodegradable
Organic Waste Composting	300 TPD (100 TPD X 3 Units)	Biodegradable
Biogas plants	50 TPD (5 TPD X 10 Units)	Biodegradable
Micro-OWC	1 TPD	Biodegradable
Micro-Biogas plant	3 TPD	Biodegradable
Total Treatment Capacity	**1354 TPD**	

The largest portion, about 1,000 MT of the waste collected every day, is transported for treatment at the Hanjer Biotech Plant which currently operates at 100 per cent capacity. The remaining waste is sent to the organic waste composting facilities such as the three organic waste composting facilities of 100 TPD each and other bio-gas and micro-biogas plants across the city (**Figure 21**). As seen in **Table 8**, the combined daily treatment capacity of 1,354 TPD is almost equal to the volume of waste generated in the city every day.

The PMC has also been making a sustained effort to address the issue of solid waste management at source. PMC incentivizes its citizens to take measures at the point of waste generation itself. Some of the initiatives that have been taken are as follows:

1. ***Tax discounts for property owners undertaking vermi-composting at source:***

   The PMC has been encouraging the practice of vermi-composting at the source by giving discounts on the property tax paid by the residential or commercial units. The number of properties that have been availing this discount has been growing manifold since 2007–08. Although there are property units that claim multiple discounts, the ones that exclusively claim it for vermi-culture have grown from 29 in 2007–08 to 4,584 in 2010–11. The total discounts offered to such properties was Rs 10,83,175.00 in 2010–11. Apart from these property units that exclusively claim discounts for vermi-culture, there are some others that claim discounts for jointly undertaking vermi-culture and solar heating or vermi-culture and rain-water harvesting.

   Initiatives like these by the municipality help in reducing some portion of the load on the infrastructure required to treat waste at the municipality plant level.

[59] PMC(2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation

Further, the aerobic composting process reduces the possible CH_4 emissions from the waste.

2. ***Incorporating the 'Garbage Free Katraj' model across the PMC*:**

   This was a trial project based on people's participation initiated by the municipality in the Katraj ward with 6,000 households. The PMC identified and gave requisite training to two voluntary social workers — one senior citizen and one youth — from the ward to disseminate awareness amongst the residents of the ward about the importance of waste segregation at source. The organic waste collected in this fashion was effectively transported to the nearest bio gas plant, while the inert waste was sent for recycling where possible. After the success of this trial project the PMC aims to replicate the same model across its different wards.

   Using such local knowledge and resources to segregate and effectively treat waste not only reduces the pressures on the solid waste treatment infrastructure, but it also helps in reduction in the overall emissions from the treatment process.

3. ***Organic waste treatment in Kothrud area to generate electricity*:**

   The PMC has initiated this trial initiative to collect all organic and wet waste from the hotels in the Kothrud area for generating electricity from the same. The waste is treated in a biogas plant at Bavdhan and is able to generate 14 kW of electricity, enough to operate 112 streetlights daily. The PMC has the objective to replicate this waste to energy project across other areas under its jurisdiction and thereby reducing the harmful effects of solid waste including the generation of CH_4.

Figure 21: Bio-methanation plant at Model colony installed by PMC

5.2 Sewage treatment

5.2.1 Generation and collection

Like solid waste, waste water, and sewage are other serious urban challenges that require to be looked into. Rapid urbanization leading to increased construction and road works in Pune have led to reduced space for managing sewerage lines and narrowing of the natural drainage networks within the city. The lack of segregation of the different forms of waste and unplanned disposal of the same had historically led to a persistent problem of blockages in drains and sewerage lines in Pune. This resulted in increased incidences of flooding and urban distress. A large portion of the sewage generated is also left untreated due to the lack of treatment facilities in the city. **Table 9** presents the status of sewage and treatment in Pune city.

Table 9: Sewage generated in the city and the treatment capacity[60]

Description	Amount (MLD)
Sewage generation and collected **(A)**	629 MLD
Other un-channelized sewage **(B)**	115 MLD
Total Sewage **(A)+(B)**	744 MLD
Rated capacity of all STP	527 MLD
Treatment plant capacity in per cent	**70.83 %**

The lack of treatment facilities is further aggravated by toilet facilities not connected to the sewage network. A recent estimate by the Pune City Sanitation Plan 2012 suggests that there are approximately 24,000 properties in the city without access to a toilet facility within walking distance. These households will however very soon be added to the sewage network, thereby increasing the load on the present capacity. It is, therefore, important to plan the network and build sufficient treatment facilities catering for the future.

[60] PMC (2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation

5.2.2 Treatment and management of sewage

The city generates about 744 MLD of sewage of which only 71 percent is treated. This means about 215 MLD of sewage is left untreated and leaks into open water bodies or underground drains. At present about 98 percent of the 995,578 households in the sewerage network area are connected to the city network[61].

Table 10: Sewage treatment plants in Pune city and their methods of treatment[62]

Name of treatment plant	Capacity (MLD)	Method of treatment
Bhairoba	130	Activated Sludge Process
Erandawane	50	Modified Activated Sludge Process
Tanajiwadi	17	Biotech with extended Aeration
Bopodi	18	Extend Aeration Process
Naidu (Old)	90	Activated Sludge Process
Mundhwa	45	Sequential Batch Reactor Process
Vitthalwadi	32	Activated Sludge Process
Naidu (New)	115	Activated Sludge Process
Baner	30	Sequential Batch Reactor Process
Total treated	**527**	

Other than the sanitation and health hazards of untreated sewage, it is also a source of CH_4 emissions. However, with controlled treatment, the emissions can be significantly reduced for increased environmental benefits. The PMC is heading in the right direction by increasing the number of treatment plants for the city from its present listed nine with a capacity of 527 MLD **Table 10** by another 177 MLD within the next couple of years.

[61] PMC (2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation
[62] PMC (2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation

5.3 Emissions from Solid Waste Disposal and Sewage Treatment

Greenhouse gas emissions in the form of methane (CH_4) are generated from the fermentation of bio-degradable matter present in solid-waste and sewage. The emission volumes generated are a direct function of the amount of waste (both in terms of solid-waste and sewage) generated in the city. Linked to the rapid explosion in the population, these emissions numbers have also grown manifold. Although the city has already put in place a scientific method to treat almost all the solid waste that it generates, its present capacity to treat fermentable matter is just about adequate and fluctuation could affect the efficiency. For sewage, of the 916,846 households within the city, about 733,668 have individual toilet facilities, implying that the remaining 20% households have to rely on either public toilets or open defecation, resulting in a large amount of untreated sewage flowing back into the water systems and higher emissions than if it were to be treated. The following section examines the emissions on account of the solid and sewage waste generated within the city of Pune, based on the ways in which they are currently treated.

5.3.1 Solid waste disposal

As per the PMC estimates, majority of the total amount of about 1,360 MT of solid waste that is generated by the city every day is scientifically treated at its Hanjer Biotech plant (1000 TPD) and three other organic wastes composting sites (each with a 100 TPD capacity). In the course of the last three years between 2008 and 2011, Pune has turned around its waste disposal situation from that of crisis to a situation of advantage. The waste management facilities are now in a position of converting the waste that they are treating to Refuse Derived Fuel (RDF), a greener energy source.

The proportion of fermentable matter in the solid waste mix of Pune is about 65 per cent[63], resulting in approximately 850 MT of bio-degradable waste generation in the city in 2010–11. The remaining constituent of the waste (35%) is made up of either inert or recyclable materials like metal, glass, paper, plastic, rubber, and leather that go back into the system or to dumping sites. The biodegradable portion of the waste is segregated and taken to the various treatment centres, which are at present working at full capacity to meet these requirements.

Although at present most of the waste is treated scientifically, there is still some amount of emissions generated in the process. The following calculative methodology presented in **Equation 3**, as prescribed in the IPCC 2006 guidelines for GHG emissions inventory for estimating the emissions from SWD is used to calculate the emissions in Pune.

[63] PMC (2006). *City Development Program.* Pune: Pune Municipal Corporation

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 CH4 in landfill gas (default is 0.5)

R = recovered CH4 (MT/yr)

OX = oxidation factor (fraction - default is 0)

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

Table 11: Variable values and calculated emissions from Solid Waste Disposal in 2010–11

Variable	Value
Total MSW generated[64]	496,400.00 MT/year
% of MSW disposed to landfill sites	18%
Methane correction factor*	0.6
Degradable organic carbon	56%
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	10,131 MT/year
Total CO_2 equivalent emissions	**212,760 MT/year**

Note: * These are IPCC default correction factors.

[64] As per data obtained from Solid waste department, PMC

The default methane correction factors have been used for calculating the emissions based on the methodology suggested in the IPCC guidelines. As per the PMC's Sanitation Plan 2012, 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. Although this is a figure which is not typical in other urban centres across the country, Pune has been a front runner in the development of planned waste disposal. If all of this would have been completely processed and converted into a different state, then the impact on GHG emissions would have been very negligible. However, about 18% of the waste generated is sent to scientifically monitored landfill sites, and that is the only portion of waste responsible for generating emissions from solid waste.

This translates to about 10,131 MT/year of CH_4 emissions from Pune's SWD in the year 2010–11. To make the emissions from solid waste comparable with emissions from other sources, the Global Warming Potential of 21[65] that is assigned with CH_4 is multiplied to the CH_4 emissions figures to generate the CO_2e numbers[66]. This results in 212,760 MT of CO_2 equivalent emissions from Pune. In per capita terms this translates into 0.07 tCO_2e emissions for the year 2010–11 on account of solid waste disposal.

By treating the waste, PMC helps in significantly reducing the methane emissions to 1/5th of the emissions as against a scenario where the total MSW generated in the city were disposed of at the dumping sites. The total CO_2 equivalent emissions could have been 5.58 times (1,182,000 MT CO_2e) the current emissions in case PMC had not installed the scientific technologies to process MSW in Pune city.

[65] Please refer Appendix 3 for more information on Global Warming Potential
[66] This is the lifetime global warming potential of CH_4 as compared to CO_2 over a period of hundred years

5.3.2 Sewage treatment

With a population of 3,115,431 in the year 2011[67], Pune generates about 744 MLD of sewage discharge. About 527 MLD of the city's total wastewater reaches the treatment plants with a collection efficiency of 69.63 per cent[68]. The emissions from the sewage generated from the city are calculated based on the revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories methodology for methane emission calculations from wastewater.

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 waste generated is divided into two parts for emission calculations, a) the untreated portion and b) sludge generated from the treatment plants which are 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 Pune.

An important variable in the whole calculation is the assumption for the default number for per capita BOD contribution for the city of Pune. The BOD contribution for urban centres in the State of Maharashtra, i.e., 13.87 kg BOD/year has been assumed for Pune[69].

The CH_4 emissions from wastewater in Pune are estimated to be 5,678.98 MT of CH_4 for the year 2010–11. This is equivalent to about 119,258.62 MT of CO_2e for the same year or 0.04 MT of CO_2e per capita.

The combined emissions from both solid waste disposal and sewage wastewater are about 332,018.73 MT of CO_2e for the year 2010–11. Of this 36% is generated from wastewater and the remaining 64% from solid waste. This translates to approximately 5% of the total CO_2e emissions generated within the city.

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[67] GoI (2011) *Census of India, 2011.* New Delhi: Ministry of Home Affairs

[68] PMC (2012) *Pune City Sanitation Plan*. Pune: Pune Municipal Corporation

[69] MoEF (2007). *Ministry of Environment and Forests.* Retrieved 12 March 2012, from http://moef.nic.in/downloads/others/M%20Karthik.pdf

6. Conclusion

The overall emissions generated from the city of Pune in the year 2010–11 were 4,661,064.20 tonnes of CO_2e. This translates to about 1.46 tonnes of CO_2e per capita in the same year.

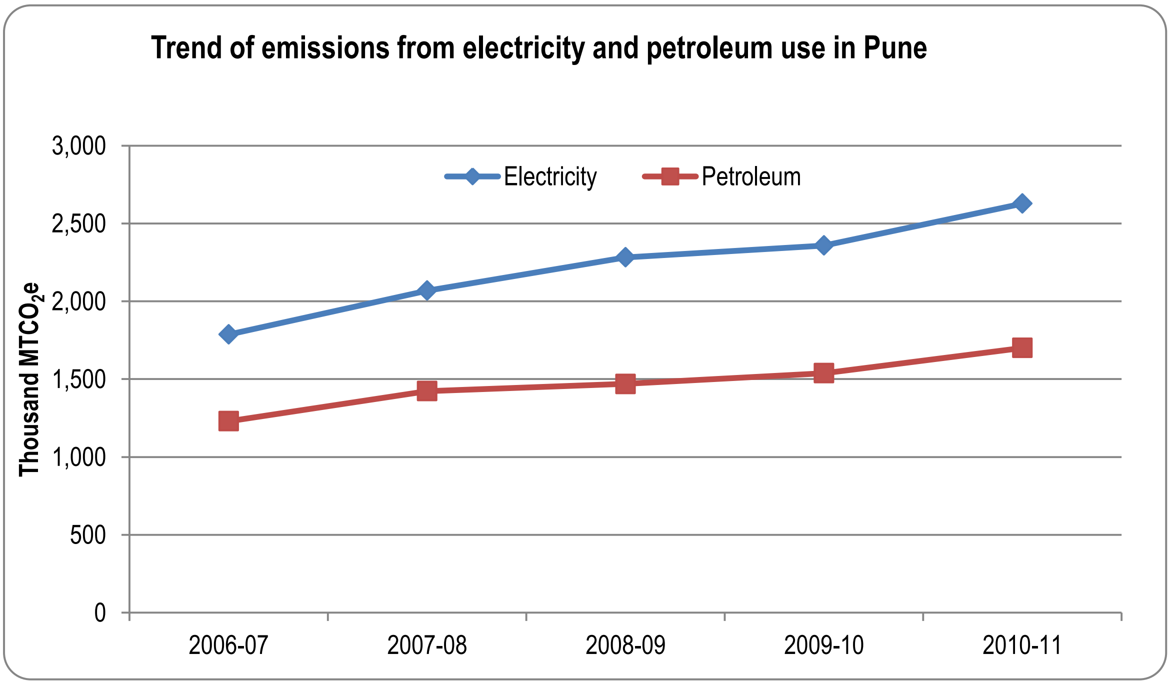

Figure 22: Trend of emissions from electricity and petroleum use in Pune

Of the total emissions generated in the city in 2010–11, over 56% of the emissions were from the use of electricity. A total of 36% of the remaining emissions were due to petroleum products used and about 8% from waste (solid waste and sewage) generation.

Of the emissions due to electricity, the HT consumers in the city were responsible for the highest fraction (43%) of the emissions generating 0.35 tonnes of CO_2e per capita in 2010–11. This was followed by the residential sector which was responsible for 0.29 tonnes of CO_2e per capita (35% of the emissions from electricity). Data was not available to further split the share of HT distributed electricity usage into various sectors of end use and hence this electricity use information has been treated separately.

The transport sector generated about 51% of the emissions from the use of petroleum products within the city. The transport sector is also the fastest growing in terms of CO_2 emissions; about 13% per annum between 2006–07 and 2010–11. The per capita emissions from the transport sector were 0.27 tonnes of CO_2e per capita.

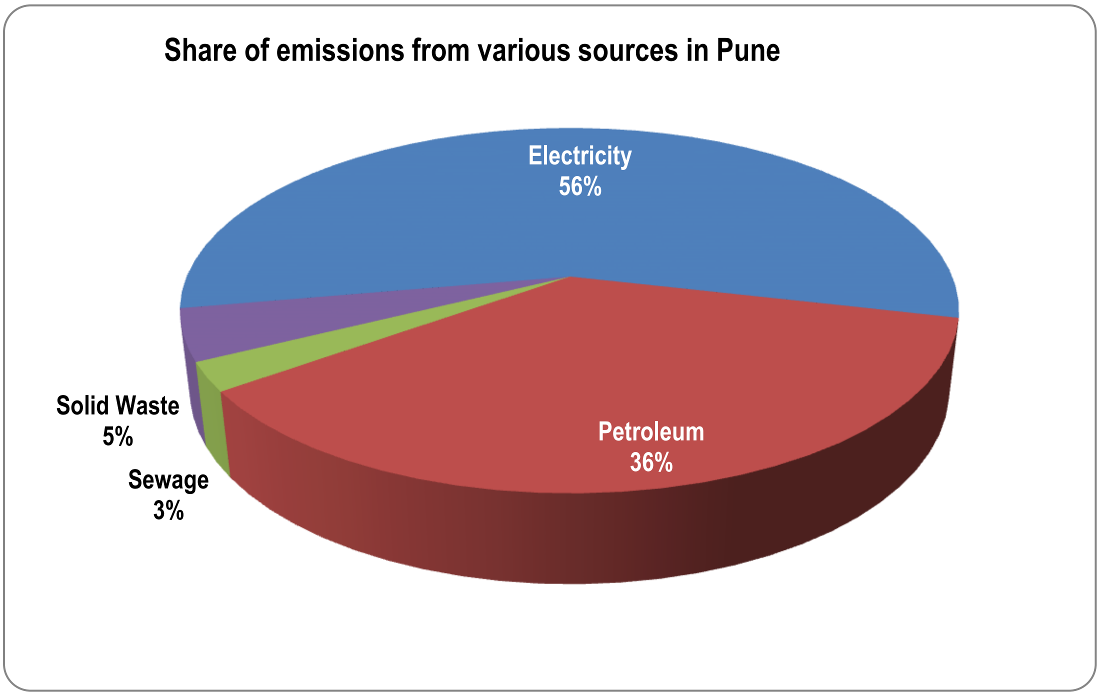

Figure 23: Share of emission from various sources in Pune

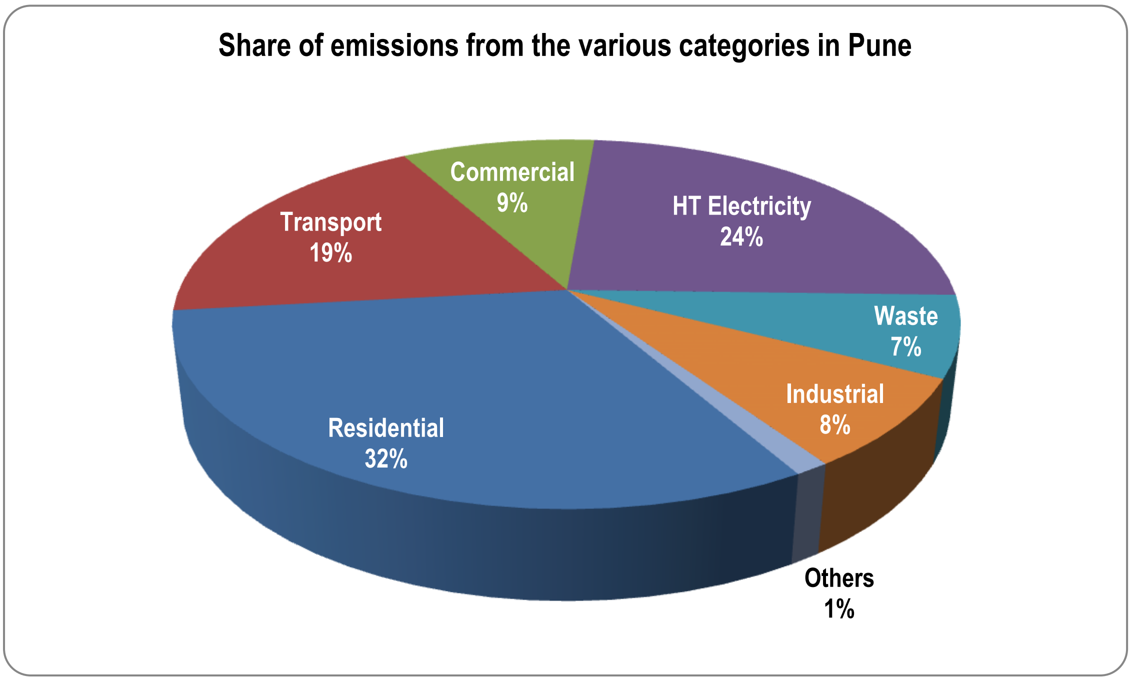

Figure 24: Share of emissions from the various categories in Pune[70]

[70] High Tension distribution lines were available without sectoral classification and hence that information has been accounted for separately. Although there could be some overlap in industrial and commercial consumers through HT consumption

In 2010–11, the residential sector generated the highest amount of emissions in Pune, responsible for 32% of the overall emissions.[71] Emissions from sectors that used electricity at HT connections generated about 24% of the emissions from the city. This was followed by emissions from the transport sector which was the third-largest contributor to CO_2 emissions with 19% share. Untreated waste and sludge from sewage and solid waste generated 332,018.73 tCO_2 resulting in 7% of the city's emissions. Commercial and industrial activities that use both electricity and petroleum products jointly generated 0.26 tCO_2 emissions per capita with a share of 17% in total emissions.

Pune's per capita emissions of 1.46 tCO_2e can be reasonably be assumed to be much lower than in other Indian urban centres given the positive initiatives taken by the PMC to reduce its emissions. Further steps taken in the similar direction would only help in Pune becoming a greener city.

Table 12: CO_2 emissions generated in Pune in 2010–11

Categories	tCO_2e emissions (2010–11)	Per capita tCO_2e emissions[72]	Share
Residential	**1,470,788.96**	**0.46**	**31.6%**
Electricity	923,562.00	0.29	19.8%
Petroleum products	547,226.96	0.17	11.7%
Transport	**869,565.25**	**0.27**	**18.7%**
Commercial	**440,870.94**	**0.14**	**9.5%**
Electricity	400,528.80	0.13	8.6%
Petroleum products	40,342.14	0.01	0.9%
HT Electricity	**1,123,364.70**	**0.35**	**24.1%**
Waste	**332,018.73**	**0.10**	**7.1%**
Solid Waste	212,760.11	0.07	4.6%
Sewage	119,258.62	0.04	2.6%
Industrial	**367,844.71**	**0.12**	**7.9%**
Petroleum products	244,020.01	0.08	5.2%
Electricity	123,824.70	0.04	2.7%
Others[73]	**56,610.90**	**0.02**	**1.2%**
Grand Total	**4,661,064.20**	**1.46**	

MEDA was consulted to get the values for share of Renewable Energy (RE) power supply. It was revealed that although grid connections for RE were established in the year 2004, electricity generation from RE is mere 4% of the total generation for the state in the year 2010-11. It was further informed that power from RE is supplied to the western grid and not directly to Pune grid. Although off grid data was negligible, the use of solar PV in the streetlights and solar water heaters is on the rise in the city. Due to lack of comprehensive information, role of RE in offsetting carbon footprint of Pune city could not be determined.

[71] The residential sector is also responsible for a large portion of the waste generation; however segregation of information about source of waste generation was unavailable and cannot be apportioned to the residential sector. Waste is therefore reported as a composite sector.

[72] The population considered includes cantonment area population

[73] "Others" consists of the following heads - HT PD Tot. Consumption, LT Permanent disconnects, LT Public Utilities and Temp Connections

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[74]

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[75]: (*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 close contact 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 clarity purposes. It uses the CACP software to process the data. The main difference with 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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[74] MCNY (2010). *Inventory of New York City Greenhouse Gas Emissions*. New York:

[75] 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 to 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)[76]

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.

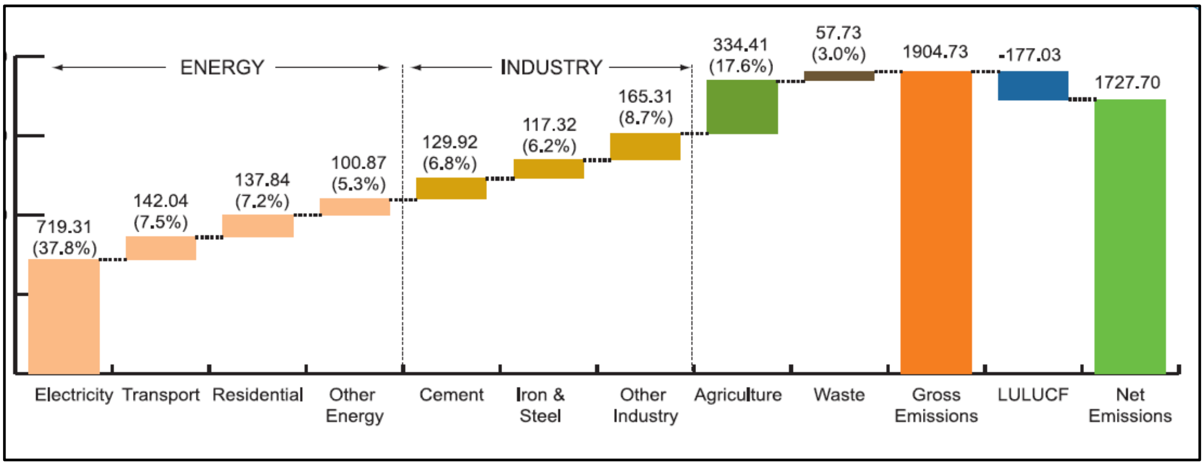


Figure A.2.1 Emissions from various sectors in India

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.

[76] GoI (2010) *India: Greenhouse Gas Emissions 2007*, New Delhi, MoEF
http://moef.nic.in/downloads/public-information/Report_INCCA.pdf

A.2.2 Estimation of Tamil Nadu's carbon footprint (state level)[77]

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 as 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

[77] 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)[78]

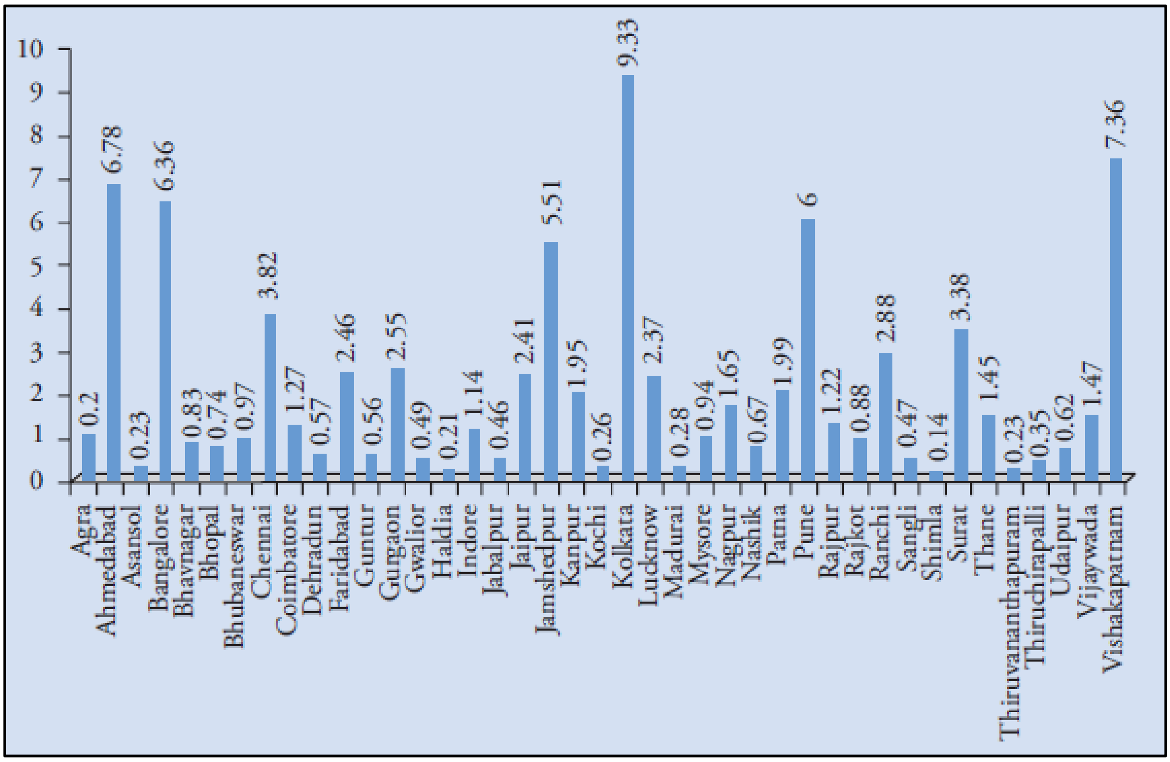
This report is an output of the 'Roadmap of South Asian Cities and Local Governments for the Post 2012 Global Climate Agreement and Actions' project and is prepared by ICLEI-South Asia with support from the British High Commission. This report provides a brief inventory of energy status and carbon emissions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



[78] ICLEI (2009) *Energy and Carbon Emissions Profiles of 54 South Asian Cities* New Delhi: British High Commission http://www.iclei.org/fileadmin/user_upload/documents/Global/Progams/CCP/CCP_Reports/ICLEI_Indian_Cities_2009.pdf

A.2.4 Ahmedabad's low carbon vision study[79]

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.

[79] IIM (2009) *Low Carbon Society Vision 2035:*AHMEDABAD, http://2050.nies.go.jp/report/file/lcs_asialocal/ahmedabad_2009.pdf

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[80]

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

[80] 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[81].

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.[82]

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[83].

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.

[81] http://www.biogas-renewable-energy.info/anaerobic_digestion_definition.html
[82] http://www.epa.sa.gov.au/xstd_files/Waste/Guideline/guide_waste_definitions.pdf
[83] 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[84].

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.

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

Scope 1 inventory: Organization's direct GHG emissions.

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).