GREEN HOUSE GASES INVENTORY FOR PUDUCHERRY

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Green House Gas Inventory

Introduction

While finalizing the Climate Change Action Plan, it was felt that knowledge of baseline emission is needed to monitor the progress. The exercise was taken up to estimate the emission from various activities across the UT.

For the purpose of computing GHG emission from various sectors like domestic, transport, waste, industry, agriculture, etc.; approach outlined in **IPCC 2006 Guidelines** and **India Second National Communication to the United Nations Framework Convention on Climate Change** published in **2012** by **Ministry of Environment & Forests**, **Govt. of India** is followed.

Methodology

The IPCC 2006 Guideline suggests a three tier approach for estimation of GHG emission, while Tier - 1 approach needs less complex data and depends mostly on default emission factors; the higher tier approaches will require data in greater details and specific emission factors. The uncertainties in estimation however, are reduced when it moves up the tier ladder. For the purpose of GHG emission estimation; the following six Green House Gases were considered:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Per fluorocarbon (PFC)
- Hydro fluorocarbon (HFC)
- Sulphur Hexafluoride (SF_6)

Due to unavailability of detailed baseline data and information during estimation process; it was decided to follow the quick estimation process using Tier 1 methodology and in most cases with default emission factors. The estimation under Tier 1 is considered to be adequate for the Climate Change Action Plan as of now.

The key sectors relevant to Puducherry were selected and the extent of these activities in the UT was determined. The sectors are –

- Domestic
- Transport
- Waste
- Industrial process
- Agriculture

This estimation in the domestic sector includes electricity, kerosene and LPG[1] consumption by domestic users whereas the transport sector emission includes UT wide emission from road transport.

For estimation GHG emission from industry sector fossil fuel and electricity consumption by all category and numbers of industries located in Puducherry are considered. The GHG estimation from fossil fuel consumption by the industries is done on the projected fuel consumption information provided by the industries to the SPCB relating to their production capacity. For industry sector, estimation of fossil fuel consumption is not done on the basis of actual production, but on the basis of the projected production capacity and specific fossil fuel consumption since collection of actual data would require more time. GHG emission for electricity consumption by industries is calculated based on the cumulative amount of electrical energy consumed by the industries based on the information from the electrical utility.

The GHG sources categorized for estimation in waste sector is as follows –

- Municipal solid waste disposal
- Domestic waste water disposal

The main greenhouse gases emitted from waste management sector is methane which is produced and released into the atmosphere as a by-product of the anaerobic decomposition of solid waste, whereby methaneo-genic bacteria break down organic matter in the waste. Similarly, wastewater becomes another source of methane emission when treated or disposed anaerobically.

Inventory of GHG emission from agricultural sector is carried out considering the following source categories:

1. Enteric fermentation
2. Manure management
3. Rice cultivation

Though soil carbon and field burning of agricultural residues are sources of agricultural emission, they are however eliminated from calculations. Specific emission factor used for national GHG inventory is considered for the estimation of inventory for the agriculture sector.

The product of activity data and corresponding emission factor is used to determine the emission of GHG. The emissions of the GHGs were then multiplied with the corresponding Global Warming Potential (GWP) to express the emission in terms of CO_2 equivalent (CO_2-eq). The basic equation involved in estimating the emission is thus;

Emission j = $\sum AD_i * EF_{ij}$

Where AD is activity data of i^{th} activity and

EF is emission factors of i^{th} activity for j^{th} GHG emission.

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[1]*Liquefied Petroleum Gas*

The GHG emission from domestic sector was estimated by multiplying the total amount of electricity, kerosene and LPG consumed by the domestic users with respective emission factors (as per 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter I for kerosene and LPG and CO_2 Baseline Database, Version 8.0 published by CEA for electricity).

Table 1: Energy consumption and Specific GHG emission factors for different energy source in Domestic sector

Energy Type	Consumption (Metric Tonne/ year)	Emission Factor (tonnes of CO_2e/TJ)
LPG	33,074.00	63.10
Kerosene	12,276.00	71.90
Southern Regional Grid Emission Factor	578 (Million units)	0.91 (tCO_2e/MWh)

Similarly for transport sector, the GHG emission is estimated based on the total diesel and petrol sold in the UT multiplied by emission factor. (Case I)

Table 2: Energy consumption and Specific GHG emission factors for different energy source used in Transport sector

Energy Type	Consumption (Metric Tonne/ year)	Emission Factor (tonnes of CO_2e/TJ)
Petrol	83,971.00	69.30
High Speed Diesel	3,54,002.00	74.10

It is worthwhile to note that because of the low price of the Diesel/Petrol in the UT, vehicle from adjacent state get the fuel from the UT. However due to the lack of information with regard to the distances travelled by the vehicle across all the four regions of UT, the national per capita emission from the transportation sector multiplied to the population of union territory is done to arrive at the emission figure (Case II).

As per the publication by MOEF "India: Greenhouse Gas Emissions 2007" INCCA: Indian Network for Climate Change Assessment the total emission from Road transportation sector is 1,23,554.00 (thousand tons) of CO_2ein 2007. Considering the population of 1.15 billion the per capita GHG emission from transportation sector is estimated to be 0.107tCO_2e/capita/annum. Considering current population of Puducherry the total emission of GHG from transport sector is 0.134 Million tonnes of CO_2e.

The emission from industry sectors includes emission due to energy consumption only. Electricity, coal, diesel, furnace oil, etc. are being used in the industries and the GHG emission is based on the total quantum of each fuel type multiplied by respective GHG emission factors as available in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter I and CO_2 Baseline Database, Version 8.0 published by CEA.

Table 3: Energy consumption and Specific GHG emission factors for different energy source used in Industry sector

Energy Type	Consumption (Metric Tonne/ year)	Emission Factor (tonnes of CO_2e/TJ)
Coal	4,89,600.00	95.81
Diesel	31.688	74.10
Furnace Oil	26,127.69	77.40
Electricity	1,523 (million units)	0.91

For waste sector (Municipal Solid waste and Sewage), the equation as per UNFCCC ***"Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" Version 5*** is as below:

$$BE_{CH4,SWDS,y} = \varphi \cdot (1-f) \cdot GWP_{CH4} \cdot (1-OX) \cdot \frac{16}{12} \cdot F \cdot DOC_f \cdot MCF \cdot \sum_{x=1}^{y} \sum_{j} W_{j,x} \cdot DOC_j \cdot e^{-k_j(y-x)} \cdot (1-e^{-k_j})$$

Where:

$BE_{CH4, SWDS, y}$ Methane emissions avoided during the year y from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year y (tCO_2e)

Emission from Municipal Solid waste and Sewage waste whether industrial or domestic contributes considerably to the GHG emission in a geographic region. Basically the waste comprising organic components result in emission of methane which has a global warming potential of 21 times that of carbon-dioxide. For the purpose of estimation of net GHG emission the waste generated from the domestic sector is only considered.

Emission due to Municipal Solid Waste Disposal: Based on the total population of the Union Territory as 12,47,953 nos. and solid waste generation at the rate of0.00045 tonne/capita/day; average greenhouse gas emission is estimated at 88,725 Tonnes of CO_2e per annum.

Emission due to Sewage: Methane is emitted from waste water due to anaerobic treatment or disposal of it. Wastewater originating from a variety of domestic, commercial and industrial sources has significant contribution in GHG emissions of the UT. The GHG emission from sewage for the UT is considered for both domestic and industrial wastewater generated. Further, emissions from domestic wastewater handling are estimated for both urban and rural centres. Emission due to sewage is estimated considering the above mentioned population and waste water generation potential of120 litre/capita/day; the annual greenhouse gas emission is estimated at 92,779 tCO_2e.

The method of emission due to enteric fermentation, manure management and rice cultivation is detailed below-

Enteric Fermentation: Methane is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by microorganisms into simple molecules for absorption into the bloodstream. The amount of methane that is released depends on the type of digestive tract, age, weight of the animal and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet.

The specific emission factor was calculated by NATCOM as a part of preparing the GHG inventory towards national submission is used for calculation of UT specific sectoral emission:

Table 4: Specific emission factors for different livestock

Category of livestock	Emission Factor (kg CH_4/head/year) – Enteric Fermentation
Dairy cattle - Indigenous	28±5
Dairy cattle - Cross-bred	43±5
Dairy buffalo	50±17
Sheep	4±1
Goat	4±1
Horses and ponies	18
Donkeys	10
Pigs	1

Since, the latest statistics present for the livestock population was based on 2007 census in UT; the same is used for calculation.

Table 5: Livestock population

Category of livestock	Number of livestock
Dairy cattle - Indigenous	6,134
Dairy cattle - Cross-bred	79,062
Dairy buffalo	3,325
Sheep	4,694
Goat	69,567
Horses and ponies	32
Donkeys	60
Pigs	728

Based on the total population of livestock in each category and the specific emission factor pertaining to enteric fermentation, the total methane emission is calculated at 4,036 tCH_4/year (84,768 tCO_2e/year).

Manure management: Methane is emitted from anaerobic decomposition of animal waste. The emission of methane however depends on the rate of waste production per animal, the number of animals, and on how the manure is managed. When manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobically produce significant quantity of methane. The temperature and the retention time of the storage unit greatly affect the amount of methane produced. When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions, hence less methane is produced.

The specific emission factor was calculated by NATCOM as a part of preparing the GHG inventory towards national submission is used for calculation of UT specific sectoral emission:

Table 6: Specific emission factors for different livestock

Category of livestock	Emission Factor (kg CH_4/head/year) – Manure Management
Dairy cattle - Indigenous	3.50±0.20
Dairy cattle - Cross-bred	3.80±0.80
Dairy buffalo	4.40±0.60
Sheep	0.30
Goat	0.20
Horses and ponies	1.60
Donkeys	0.90
Pigs	4.00

Based on the total population of livestock in each category and the specific emission factor pertaining to manure management the total methane emission is calculated at 354 tCH_4/year (or 7,452 tCO_2e/year).

Rice Cultivation: Methane is emitted from cultivation of rice mainly due to anaerobic decomposition of the organic matter, as rice cultivation in India is majorly done through water logging. The emission of methane pertaining to rice cultivation however depends upon the type of irrigation and also the type of application of water.

The specific emission factor was calculated by NATCOM as a part of preparing the GHG inventory towards national submission is used for calculation of UT specific sectoral emission:

Table 7: Specific Methane emission from different water application

Type of irrigation	Type of water application	Specific Methane emission (kgCH_4/ha)
Irrigated	Continuously flooded	162.00
	Single aeration	66.00
	Multiple aeration	18.00
Rain-fed	Drought prone	66.00
	Flood prone	190.00
Deep water	Deep water	190.00

Based on the total 20,926 ha[2] of land area under Paddy cultivation with 80% of land under irrigation and considering single aeration and 20% of the area under non irrigated flood prone area the total methane emission is calculated at 1,900 tCH_4/year (39,901tCO_2e/year). The inventory of GHG emission from agriculture sector is presented as follows:

[2] *2009-10*

Table 8: GHG emission from Agriculture sector

Category	Total Emission (tCH_4/year)	Total Emission (tCO_2e/year)
Enteric Fermentation	4,036.00	84,768.00
Manure Management	354.00	7,452.00
Rice Cultivation	1,900.00	39,901.00
Total	**6,290.00**	**1,32,121.00**
Total Equivalent GHG emission		**0.132 million tCO_2e**

Result

The estimation of major industrial, domestic, agriculture, transport and waste management sectors are made using Tier 1 methodology as per IPCC 2006 Guidelines and available data. The emissions of industry sector were calculated on the basis of installed capacity of the industry sector, as credible data on plant availability, plant utilisation, and production efficiency were not available. These assumptions might have resulted in slight over-estimation than the actual. It is thus necessary that this estimation process may be carried forward along the IPCC tier ladder for a more accurate GHG estimation. For completeness estimation of emissions from other sectors may also be considered to be incorporated.

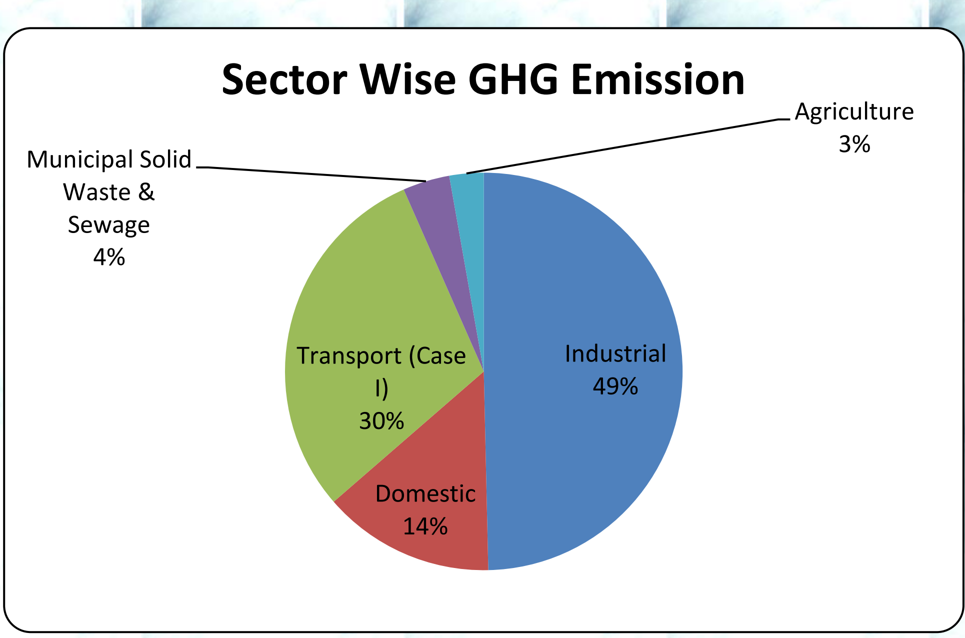
In domestic sector, emission calculated on the basis of total kerosene, LPG and electricity consumed whereas in case of the transport sector; it was calculated on the basis of actual fuel sold through retail selling of petroleum products. The emission estimation from municipal solid waste and sewage was done on basis of total population and not on actual generation due to unavailability of data during estimation time.
The summarized emission details are presented in Table below.

Table 9: Details of CO_2e emission

Sector	CO_2e emission(Million Tonnes of CO_2e/year)
Domestic	**0.6630**
LPG Consumption	0.0987
Kerosene Consumption	0.0386
Electricity Consumption	0.5260
Transport (Case I)	**1.4120**
Petrol Consumption	0.2647
High Speed Diesel Consumption	1.1476
Transport (Case II)	**0.1337**
Considering on the basis of population	
Industry	**2.3540**
Coal	0.8866
Diesel	0.0001
Furnace Oil	0.0817
Electricity	1.3859

Waste Municipal solid waste disposal Domestic Waste Water disposal	**0.1810** 0.0887 0.0927
Agriculture Enteric Fermentation Manure Management Rice Cultivation	**0.1321** 0.0848 0.0075 0.0399
Total Considering(Considering Case I)	**4.7435**
Total Considering(Considering Case II)	**3.4641**

The sector wise GHG emission is represented below with two cases of emission from transportation sector (Case I: GHG emission estimated for the transportation sector based on actual fuel oil being sold net of the consumption from industry and Case II: GHG emission from transportation sector is estimated based on per capita GHG emission from transportation sector in 2007 across India. However for case II estimation emission from road transportation is considered)



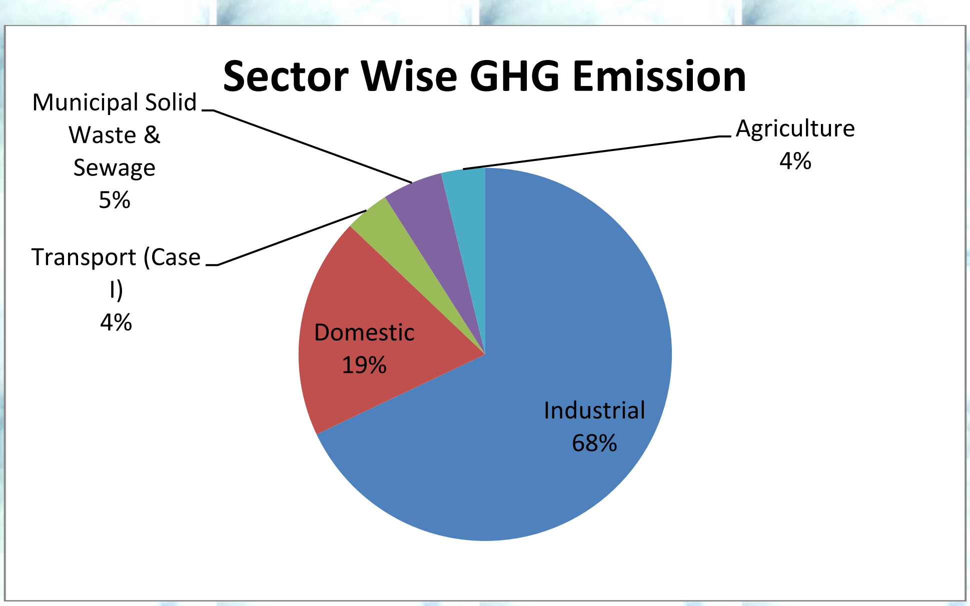


Figure 1: Sector Wise GHG emission across UT

Summary of GHG Emission

The following is the summary of the GHG emission across the UT.

Table 10: Summary of the GHG emission

Sectoral Emission	Amount	Unit	Remark
Industrial	2.3540	Million tonnes of CO_2e	Annualized adding the CO_2e emission
Domestic	0.6630	Million tonnes of CO_2e	Annualized CO_2e emission for 2009-10
Transport (Case I)	1.4120	Million tonnes of CO_2e	Annualized adding the CO_2e emission
Municipal Solid Waste & Sewage	0.1810	Million tonnes of CO_2e	Annualized adding the CO_2e & CH_4 emission
Agriculture	0.1321	Million tonnes of CO_2e	Annualized CH_4 emission
Net Emission	**4.7435**	**Million tonnes of CO_2e**	

Table 11: Summary of the GHG emission

Sectoral Emission	Amount	Unit	Remark
Industrial	2.3540	Million tonnes of CO_2e	Annualized adding the CO_2e emission
Domestic	0.6630	Million tonnes of CO_2e	Annualized CO_2e emission for 2009-10
Transport (Case II)	0.1340	Million tonnes of CO_2e	Annualized adding the CO_2e emission
Municipal Solid Waste & Sewage	0.1810	Million tonnes of CO_2e	Annualized adding the CO_2e & CH_4 emission
Agriculture	0.1320	Million tonnes of CO_2e	Annualized CH_4 emission
Net Emission	**3.4641**	**Million tonnes of CO_2e**	

The results have been obtained using the Tier I approach of IPCC and approved methodology of UNFCCC which can serve as a crude estimate of GHG profile of the UT.

Comparison of per-capita GHG emission

Considering the total emission of 3.46 million tonnes of CO_2e and population of 1.247 million the per-capita emission in Puducherry is estimated at 2.7 tCO_2e in compared to national per capita emission of 1.7tCO_2e (2007)[3].

[3]The national per capita emission has increased at a CAGR of 3.3% from 1994 to 2007