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GREEN HOUSE GAS INVENTORY

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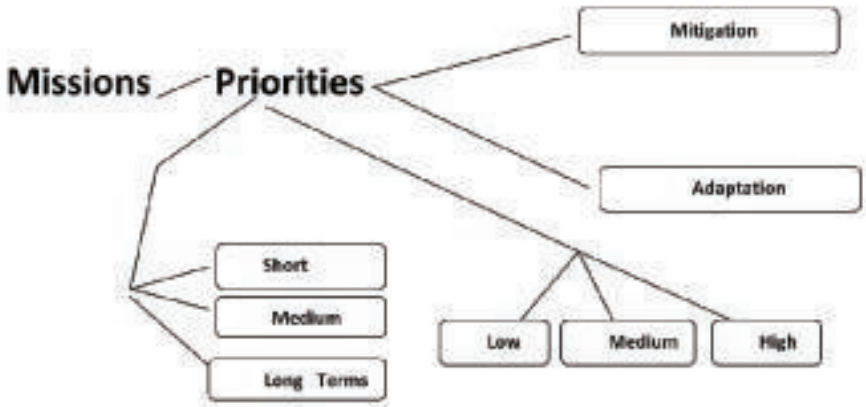
The Government of India, Ministry of Environment Forests & Climate Change has formulated a National Action Plan for combating Climate Change. The same can be accessed at http://dste.puducherry.gov.in/envisnew/envis1.htm. The MoEF &CC, Government of India had advised all the State Governments and UTs to prepare similar State Action Plan for Climate Change relevant to the particular State or UT. Accordingly, the Government of Puducherry carried out an exercise and formulated a State Action Plan for Climate Change in consultation with various stakeholders viz., different Government Departments NGOs, academic institutions and general public

Wide consultations were held with the respective line Departments. Different templates of data sheets were prepared and circulated to all the relevant Departments. Data collection, compilation and report preparation were done through World Bank appointed consultants in close coordination with the Department of Science, Technology & Environment, and Government of Puducherry.

The report includes six of out of eight relevant missions. Additionally, Coastal and Disaster Management Mission was added, as it was felt relevant considering the geographical location of the UT.

Vulnerability assessment and index were prepared for all the four regions. Under each mission, priorities of activities were identified in consultation with the respective implementing departments. The activities was further sub divided into mitigation and adaptation, short term, medium term and long term and low, medium and high priority activities. Budget estimates have been worked out only for the high priority activities identified under each mission.



GREEN HOUSE GAS INVENTORY

Introduction

The UT of Puducherry is having 480 Sq. Km. With 24 Km of coast in Puducherry, 18 km. of coast at Karaikal. The landmass is distributed in the erstwhile French colonies one in Puducherry, one in Karaikal within the state of Tamil Nadu, one in Mahe in the State of Kerala and one in Yanam in the State of Andhra Pradesh.

As a part of the state Climate Change Action Plan, it Dartity and baseline emission data is needed to identify and evaluate the interventions that are implemented. 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 viz 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 MOEF & CC, **Govt. of India** were 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 requires data in greater details and specific emission factors. The uncertainties in estimation, however, are reduced when it moves up the tier ladder.

Global-Warming Potential (GWP) is a relative measure of how much heat a **greenhouse gas** traps in the atmosphere. It compares the amount of heat trapped by a certain mass of the **gas** in question to the amount of heat trapped by a similar mass of **carbon dioxide.** A GWP is calculated over a specific time interval, commonly 20, 100 or 500 years, GWP is expressed as a factor of carbon dixide (whose GWP is standardized to 1). In the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Methane has a lifetime of 12.4 years and with climate-carbon feedbacks a global warming potential of 86 over 20 years and 34 over 100 years in response to emissions. The GWP depends on the following factors :

- the absorption of **infrared radiation** by a a given species
- the spectral location of its absorbing wavelengths
- the **atmospheric lifetime** of the species.

Due to non-availability 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 state Climate Change Action Plan.

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

Values

Carbon dioxide has a GWP of exactly 1 (since it is the baseline unit to which all other greenhouse gases are compared).

GWP values and lifetimes from 2013 IPCC AR5 p714 (with climate-carbon feedbacks)	Lifetimes (years)	GWP time horizon	
		20 year	100 year
Methane	12.4	86	34
HFC-134a (hydrofluorocarbon)	13.4	3790	1550
CFC-11 (chlorofluorocarbon)	45.0	7020	5350
Nitrous oxide (N2O)	121.0	268	298
Carbon tetrafluoride (CF4)	50000	4950	7350

GWP values and lifetimes from 2007 IPCC AR4 p212 (2001 IPCC TAR in parentheses)	Lifetime (years)	GWP time horizon		
		20 years	100 years	500 Year
Methane	12 (12)	72 (62)	25 (23)	7.6 (7)
Nitrous oxide	114 (114)	289 (275)	298 (296)	153 (156)
HFC-23 (hydrofluorocarbon)	270 (260)	12,000 (9400)	14,800 (12,000)	12,200 (10,000)
HFC-134a (hydrofluorocarbon)	14 (13.8)	3,830 (3,300)	1,430 (1,300)	435 (400)
Sulfur hexafluoride	3200 (3,200)	16,300 (15,100)	22,800 (22,200)	32,600 (32,400)

The values given in the table assume the same mass of compound is released.

Domestic Sector :

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

Industrial Sector :

For estimation GHG emission from industry sector fossil fuel and electricity consumption by all category and numbers of industries located in Puducherry were considered. The GHG estimation from fossil fuel consumption by the industries was done on the projected fuel consumption information provided by the industries to the PPCC relating to their production capacity. For industry sector, estimation of fossil fuel consumption was not done on the basis of actual production, but, on the basis of the projected production capacity and specific fossil fuel consumption.

GHG emission for electricity consumption by industries was calculated based on the cumulative amount of electrical energy consumed by the industries based on the information from the electrical utility.

Municipal Solid Waste :

The GHG source categorized for estimation in waste sector are as follows –

Municipal solid waste disposal

Domestic waste water disposal

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

Agricultural Sector:

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

Manure management

Rice cultivation

Enteric fermentation

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

Estimation of GHG from Individual Sector:

The product of activity data and corresponding emission factor were 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 CO2 equivalent (CO2-eq). The basic equation involved in estimating the emission is as follows;

Emission j = ?ADi * EFij

Where, AD is activity data of ith activity and EF is emission factors of ith activity for jth GHG emission.

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 CO2 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

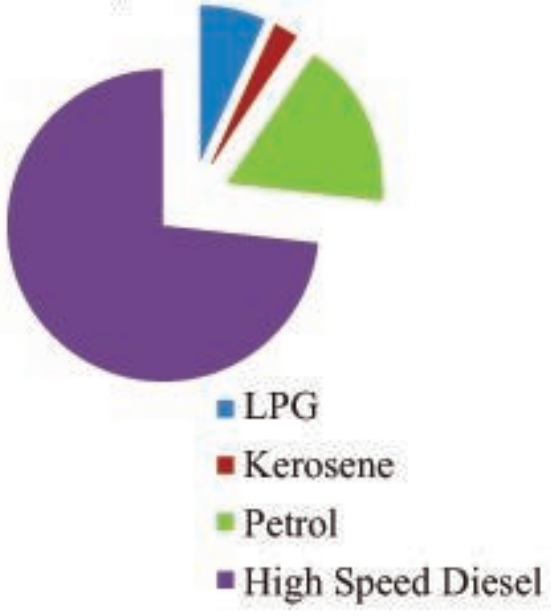
Energy Type	Consumption (Metric Tonne/ year)	Emission Factor (tonnes of CO2e/TJ)
LPG	33,074.00	63.10
Kerosene	12,276.00	71.90
Southern Regional Grid Emission Factor	578 (Million units)	0.91 (tCO2e/MWh)

For transport sector, the GHG emission was 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 CO2e/TJ)
Petrol	83,971.00	69.30
High Speed Diesel	3,54,002.00	74.10

Consumption vs Emission Factor



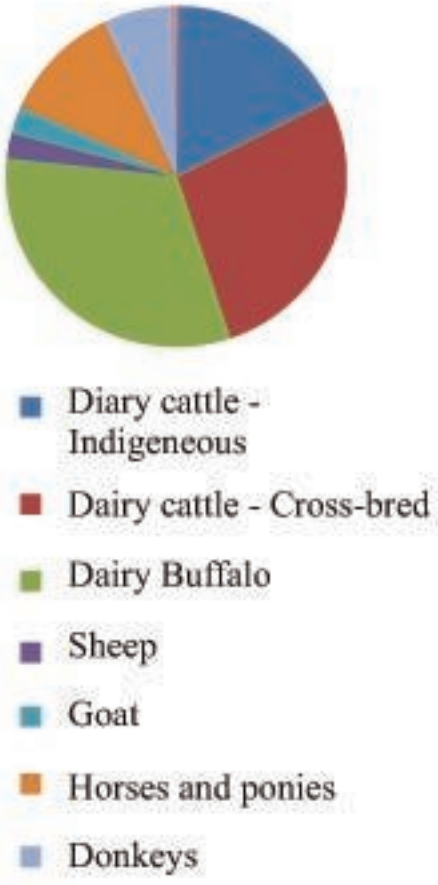
domestic wastewater handling are estimated for both urban and rural centres. Emission due to sewage is estimated considering the above mentioned population and waste water generation potential of 120 litre/capita/day the annual greenhouse gas emission is estimated at 92,779 tCO_{2e}.

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 micro-organisms 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 was used for calculation of UT specific sectoral emission:

Table 4: Specific emission factors for different livestock

Category of livestock	Emission Factor (kg CH4/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



Specific emission factors for different livestock

Since, the latest statistics present for the livestock population was based on 2007 census in UT the same was 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

However, it is noted that because of the low price of the Diesel/Petrol in the UT, vehicles from adjacent state get the fuel filled from the UT. Due to 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 was done to arrive at the emission figure (Case II).
As per the publication by MOEF & CC "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 CO2ein 2007. Considering the population of 1.15 billion the per capita GHG emission from transportation sector is estimated to be 0.107 tCO2e/capita/annum. Considering current population of Puducherry the total emission of GHG from transport sector is 0.134Million tonnes of CO2e.

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 type of fuel multiplied by respective GHG emission factors as available in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter I and CO2 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 CO2e/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:

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

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 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 of 0.00045 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 generation of both domestic and industrial wastewater. Further, emissions from

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 tCH4/year (84,768 tCO2e/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 was used for calculation of UT specific sectoral emission.

Table 6: Specific emission factors for different livestock

Category of livestock	Emission Factor (kg CH4/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 was calculated at 354 tCH4/year (or 7,452 tCO2e/year).

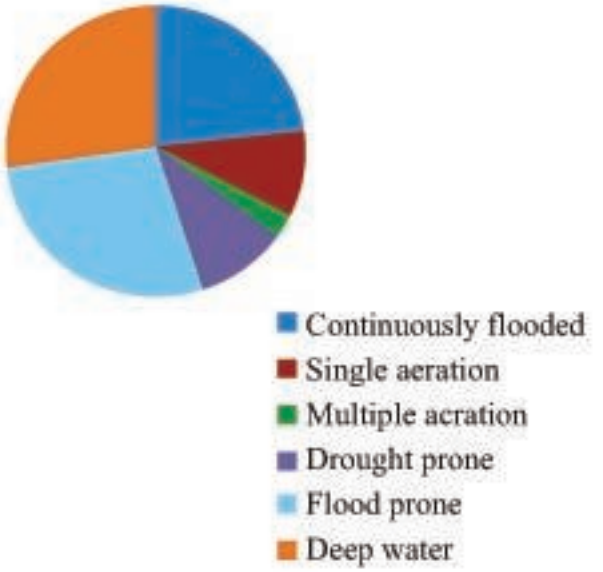
Rice Cultivation:

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 condition.

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 was 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



Specific methane emission from different water application

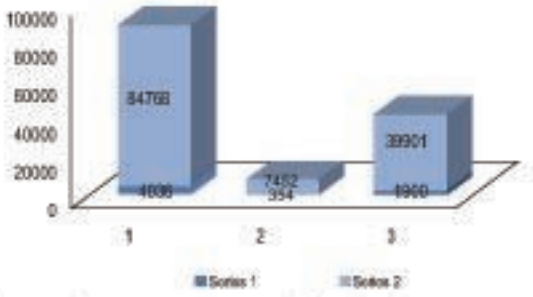
Based on the total 20,926 ha of land area under Paddy cultivation with 80 percent of land under irrigation and considering single aeration and 20 percent of the area under non irrigated flood prone area the total methane emission was calculated at 1,900 tCH_4/year (39,901tCO_{2e}/year). The inventory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

The inventory of GHG emission from agriculture sector is presented as follows:

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}**

2009-10



Series 1 = Total emission (t CH_4/year)
Series 2= Total emission (t $CO2_e$ /year)

Total GHG Estimation:

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 from industry sector 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.

In domestic sector, emission were 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	CO2e emission (Million Tonnes o f CO_2/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) Considering on the basis of population	**0.1337**
Industry	**2.3540**
Coal	0.8866
Diesel	0.0001
Furnace Oil	0.0817
Electricity	1.3859
Waste	**0.1810**
Municipal solid waste disposal	0.0887
Domestic Waste Water disposal	0.0927
Agriculture	**0.1321**
Enteric Fermentation	0.0848
Manure Management	0.0075
Rice Cultivation	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)

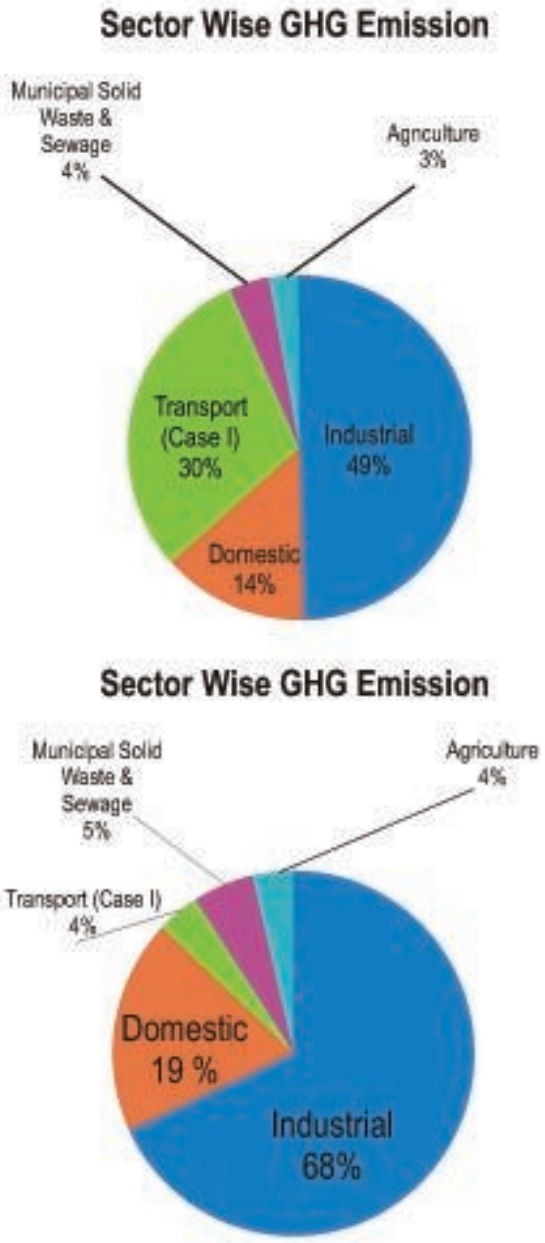


Figure 1: Sector Wise GHG emission across UT

2.1.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} & CH4 emission
Agriculture	0.1321	Million tonnes of CO_{2e}	Annualized CH, 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 CO2e emission
Domestic	0.6630	Million tonnes of CO_{2e}	Annualized CO2e emission for 2009-10
Transport (Case II)	0.1340	Million tonnes of CO_{2e}	Annualized adding the CO2e emission
Municipal Solid Waste & Sewage	0.1810	Million tonnes of CO_{2e}	Annualized adding the CO2e & CH4 emission
Agriculture	0.1320	Million tonnes of CO_{2e}	Annualized CH4 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 CO2e and population of 1.247 million the per-capita emission in Puducherry is estimated at 2.7 tCO2e in compared to national per capita emission of 1.7tCO2e (2007).

The national per capita emission has increased at a CAGR of 3.35% from 1994 to 2007.

The Government of Puducherry, has formulated the State Action Plan on Climate Change keeping the GHG inventorisation into consideration. Mission wise priority activities have been identified. The proposed activities have been categorized into Mitigation, Adaptation and as short, medium and long term activities. With full implementation of the Action plan it is envisaged that the GHG emissions will be reduced considerably.

EVNIS PROJECT Sponsored by
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Government of India, New Delhi.

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