State Level Greenhouse Gas Estimates for the Waste Sector

2005-2013

Credits and Acknowledgements

This methodology note includes an estimation and analysis of India's state-level Greenhouse Gas (GHG) emissions for the Waste Sector, prepared by ICLEI South Asia under the GHG Platform India initiative. The GHG Platform India is a collective civil society initiative providing an independent estimation and analysis of India's GHG emissions across key sectors, namely, Energy, Industry, Agriculture, Livestock, Forestry, and Land-use and Land-use Change, and Waste. The platform seeks to add value to the various ongoing GHG estimation efforts by helping address existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and by increasing the volume of analytics and policy dialogue on India's GHG emission sources, profile, and related policies. The state-level estimates presented for the time period of 2005-2013 in this note have been prepared under the Phase II of the GHG Platform India initiative. This is the first instance of preparation of state-level estimates under the initiative.

The project team would like to thank the Ministry of Environment, Forest and Climate Change for its efforts towards preparation and submission of India's National Communication Reports and the Biennial Update Report, which were invaluable resources that helped in initiating this exercise. We acknowledge the inputs of the Ministry of Urban Development for information on waste management in states as reported to the Swacch Bharat Mission. We would also like to extend our appreciation towards the efforts undertaken by the Central Pollution Control Board (CPCB), various State Pollution Control Boards, and the National Environmental Engineering Research Institute (NEERI) to collate and publish technical information on the Waste sector in India.

We thank the Ministry of Food Processing Industries, Ministry of Statistics and Programme Implementation, Department of Industrial Policy and Promotion, Ministry of Commerce & Industry, Central Board of Excise and Customs - Central Excise, the Coffee Board of India, the Specialty Coffee Association of India, the Central Pulp & Paper Research Institute (CPPRI), the Indian Paper Manufacturers Association, All India Brewers Association (AIBA), the Rubber Board, and the Indiastat team for inputs on industrial datasets. We deeply appreciate the expert guidance provided by Mr. Mandtu Chowdhary (Scientist-E, CPCB), Mr. Sunil Kumar (Sr. Scientist, NEERI), Dr. D.R. Babu Reddy (Dy. Director, Coffee Board of India) and Ms. Lizy M. (Deputy Director(S&P)) Rubber Board).

We extend our sincere thanks to the Office of the Registrar General & Census Commissioner and the National Sample Survey Office for providing key information on population and domestic wastewater. We appreciate the inputs on state-level datasets from the Climate Change Department of Govt. of Gujarat, the Department of Environment of Govt. of Maharashtra, and the Department of Environment of Govt. of Tamil Nadu. We are thankful to several prominent cities in various states such as Andhra Pradesh, Bihar, Chhattisgarh, Delhi, Gujarat, Himachal Pradesh, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Karnataka ,Kerala, Uttarakhand, Uttar Pradesh, Telangana, Tamil Nadu, and West Bengal among others for providing information on the status of domestic wastewater treatment, We are also grateful to all the participants and sector experts who were a part of the regional roundtables organized in Kolkata, Bangalore, Mumbai, and New Delhi, for their useful comments which helped to shape up the estimates in phase-II of this project.

We express our gratitude to Shakti Sustainable Energy Foundation for their continuous support through phase-I and phase-II of the GHG Platform India initiative. We sincerely appreciate the invaluable contributions of our partners Council on Energy, Environment and Water (CEEW), Center for Study of Science, Technology and Policy (CSTEP), the International Maze and Wheat Improvement Center (CIMMYT), Vasudha Foundation, and the World Resources Institute India (WRI India), towards this exercise and the GHG Platform – India. We also thank the SEEG (System for Estimation of Greenhouse Gases Emissions) for their enriching inputs and support extended to this platform based on experiences from Brazil and Peru.

Abbreviations

ASI	Annual Survey of Industries
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
CPCB	Central Pollution Control Board
CPHEEO	Central Public Health and Environmental Engineering Organisation
CSE	Centre for Science and Environment
CAGR	Compound annual growth rate
CH_4	Methane
DOC	Degradable organic carbon
FOD	First Order Decay
GDP	Gross Domestic Product
GHG	Greenhouse gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
MCF	Methane Correction Factor
MOSPI	Ministry of Statistics & Programme Implementation
Mil. tonnes	Million tonnes
NEERI	National Environmental Engineering Research Institute
NSSO	National Sample Survey Office
N_2O	Nitrous oxide
QA	Quality Assurance
QC	Quality Control
SAIL	Steel Authority of India Limited
STP	Sewage Treatment Plant
SPCB	State Pollution Control Board
UNFCCC	United Nations Framework Convention on Climate Change

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Document Information

Version	Date	Description
2.0	April 1, 2018	The methodology note has been updated based on the peer review process. The revision includes • Improving the document in general for better readability, understanding and to avoid duplication of messages. • Improving the consistency of citation and referencing throughout the report. • Revising the 'Introduction' section to make it more concise. • Adding additional details for clarity on aspects of qualitative assessment of data and emission factors, recommended improvements for sub-sectors, quality assurance and quality control. • Inclusion of sample calculation for the 3 sub-sectors (solid waste disposal, domestic wastewater treatment and discharge, and industrial wastewater treatment and discharge) in the Annexures to enable readers to better understand computation of emissions. It should be noted that the revision has not led to any changes in the emission estimates.
1.0	September 28, 2017	This draft methodology note includes an estimation and analysis of India's annual state-level GHG emissions for the period 2005-2013 for the Waste Sector, prepared by ICLEI South Asia under the GHG Platform India initiative (www.ghgplatform-india.org). This document is undergoing a peer review process, however, any changes that may be made further will not have an impact on the figures and estimates. Once the review process is completed, the final document will be uploaded and the same shall be updated in this section.

Executive Summary

Brief Information on GHG estimates:

The Waste Sector contributes to 3.8% of India's aggregated economy-wide state-level GHG emission (including land use, land use change and forestry) in 2013 as per estimates prepared by the GHG Platform India[1]. The key sources of GHG emission included in the state-level Waste sector emission estimates from 2005 to 2013 are solid waste disposal, domestic wastewater treatment and discharge, and industrial wastewater treatment and discharge. Methane (CH_4) is produced and released into the atmosphere as a by-product of the anaerobic decomposition of solid waste and when domestic and industrial wastewater is treated or disposed anaerobically. Nitrous oxide (N_2O) emissions occur due to the protein content in domestic wastewater.

India's greenhouse gas (GHG) emissions from the Waste sector are estimated to amount to 93.78 million tonnes (Mil. tonnes) of carbon dioxide equivalent (CO_2e) in the year 2013[2]. This represents an increase of 1.29 Mil. tonnes CO_2e, or 1.4%, on the emissions recorded in 2012, and a cumulative increase of 26% (i.e. 19.16 Mil. tonnes CO_2e) above 2005 levels.

Table 1: GHG emission for Waste sector in India in 2005 and 2013

Sector/ sub-sector	Emission in Mil. Tonnes of CO_2e based on Global Warming Potential values from IPCC Second Assessment Report[3]		Emission in Mil. Tonnes of CO_2e based on Global Warming Potential values from IPCC Fifth Assessment Report[4]		Percent change (2005-2013)	
	2005	2013	2005	2013	Emission based on IPCC Second Assessment Report	Emission based on IPCC Fifth Assessment Report
4. Waste	**74.62**	**93.78**	**92.00**	**116.28**	**25.7%**	**26.4%**
4A. Solid Waste Disposal	**7.05**	**10.85**	**9.39**	**14.47**	**54.0%**	**54.0%**
4A2. Unmanaged Waste Disposal Sites	7.05	10.85	9.39	14.47	54.0%	54.0%
4D. Wastewater Treatment and Discharge	**67.57**	**82.93**	**82.61**	**101.81**	**22.7%**	**23.2%**
4D1. Domestic Wastewater Treatment and Discharge	43.82	58.94	50.94	69.83	34.5%	37.1%
4D2. Industrial Wastewater Treatment and Discharge	23.75	23.99	31.67	31.98	1.0%	1.0%

Major Inventory developments and Calculations:

Subnational emission estimates at the state-level have been prepared for the first time under the GHG Platform India.

[1] Available at http://www.ghgplatform-india.org/economy-wide-emission-estimates
[2] India's Second National Communication Report, 2012 and the Biennial Update Report, 2015 both use 100 year GWP values from the IPCC Second Assessment Report, 1996. To ensure consistency with the official GHG inventory submissions, the estimates indicated in terms of CO_2e throughout this note, (with the exception of Table 1 and Table 18) are based on the GWP values from the IPCC Second Assessment Report, 1996
[3] 100-year GWP values specified for the 3 GHGs considered for the Waste Sector are CO2: 1, CH4: 21, N2O: 310 as per the IPCC Second Assessment Report, 1996, Technical Summary, Table 4.
Available at https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf
[4] 100-year GWP values specified for the 3 GHGs considered for the Waste Sector are CO2: 1, CH4: 28, N2O: 265 as per the IPCC Fifth Assessment Report, 2014, Climate Change 2014: Synthesis Report, Box 3.2, Table.
Available at https://www.ipcc.ch/pdf/assessment-report/ar5/syr/SYR_AR5_FINAL_full.pdf

- Estimates for solid waste disposal cover disposal of municipal solid waste generated in urban areas and consider parameters such as solid waste generation rates, composition, and the proportion of solid waste undergoing treatment specific to each state.
- The estimates for domestic wastewater treatment and discharge cover urban areas as well as rural areas across the states in India. CH_4 emission estimates for domestic wastewater factor in state-specific conditions including the availability of several types of wastewater disposal facilities in urban and rural households, the extent of wastewater treatment, and the technologies that are used for treatment. State specific values of per capita protein intake have been used to estimate N_2O emissions from domestic wastewater.
- Emission estimates from treatment and discharge of industrial wastewater cover 10 industry sectors including Iron and Steel, Fertilizers, Meat, Sugar, Coffee, Pulp and Paper, Petroleum, Rubber, Dairy, and Tannery, which generate significant organic wastewater and lead to GHG emissions. CH_4 emissions from industrial wastewater are estimated based on available data on the prevalent industrial activity by state.

Summary of GHG emission trends:

GHG emissions from the Waste sector have increased at a compound annual growth rate (CAGR) of 2.9% for the reporting period of 2005-2013.

- Emissions from solid waste disposal have registered the highest CAGR of 5.5% among the 3 sub-sectors.
- GHG emissions from the domestic and industrial wastewater have grown at CAGR of 3.8% and 0.12% respectively on average from 2005 to 2013.

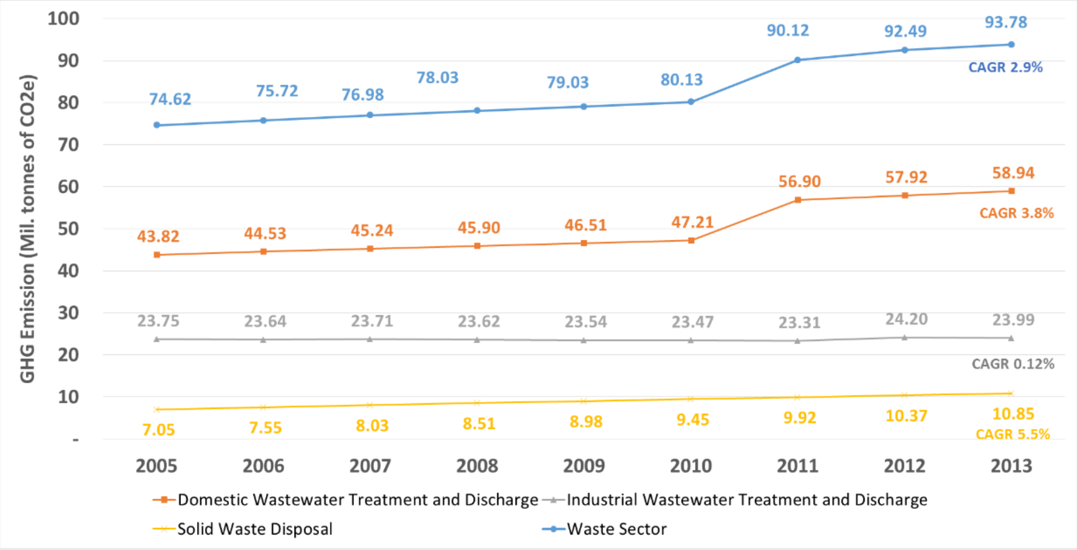
The trend of the aggregate state-level emission is observed to be quite steady with a relatively higher rise seen between the year 2010 and 2011 (see Figure 1) largely due to the corresponding increase in the estimated domestic wastewater emissions.

The Waste sector related GHG emission intensity of India's gross domestic product (GDP), based on aggregated state emissions, is observed to have decreased by 29% in 2013 as compared to the base year of 2005, falling at a CAGR of -4.2% per year in the period from 2005 to 2013. Per capita emissions from the Waste sector, based on state aggregates, were seen to rise at a CAGR of 1.2% per annum from 2005 to 2013.

Highlights on major emitting source categories:

- GHG emissions from domestic wastewater treatment and discharge (4D1) have accounted for the highest share in the sector over the reporting period, contributing to nearly 62.9% of the total aggregated state-level Waste sector emission in 2013. Average per capita state GHG emissions related to domestic wastewater for the urban population were higher by 32% as compared to that for the rural population in 2013.
- Industrial wastewater treatment and discharge (4D2) had the 2^{nd} largest contribution (25.6%) to the aggregate state-level Waste sector GHG emissions in 2013, with Pulp and paper, Coffee, Meat and Tannery observed to be critical industries having high specific GHG emission.
- Disposal of solid waste (4A) contributed to 11.6% of the aggregated state-level emissions from the Waste sector in 2013, with increased generation and changing waste composition driving the rise in emissions across states.

Figure 1: Aggregate State-level GHG Emission for the Waste Sector, 2005-2013



Introduction

1.1 Background Information on GHG estimates

GHG Estimates Reporting:

The GHG Platform-India is an Indian Civil Society initiative that aims to provide estimation and analysis of India's GHG emissions across different sectors such as energy, industry, waste and agriculture, livestock, forestry, and land-use and land-use change sectors. The platform's overall objectives are to complement existing efforts of the Indian government, such as the National Communication and Biennial Update Report process of the UNFCCC, by helping address existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and to drive an informed policy dialogue within the country on the GHG emissions inventory and the possibility to reduce emissions in the decades ahead.

The entire exercise of reporting GHG emission estimates from the Waste sector aims to contribute towards analysing and putting together all the existing activity data and emission factors that could be used for Waste sector GHG emission estimations under the GHG Platform India. The various sources used for gathering activity data for estimation, gaps identified in the datasets, and recommendations to improve reliability and accuracy of emission estimation processes have been put forward to the Government of India for further actions.

Greenhouse Gases:

The emission estimation scope covers three GHGs currently: Carbon Dioxide (CO_2), Methane (CH_4), Nitrous Oxide (N_2O). Activities in the Waste sector lead to emission of two GHGs, namely CH_4 and N_2O, both of which are accounted under the estimates. CH_4 is produced and released into the atmosphere as a by-product of the anaerobic decomposition of solid waste and when domestic and industrial wastewater is treated or disposed anaerobically. A smaller amount of N_2O emissions occur from the disposal of domestic wastewater into waterways, lakes or seas due to the protein content present in domestic wastewater.

Key Source Categories/ Sub-categories:
As per the Intergovernmental Panel on Climate Change (IPCC) reporting structure, the following source categories and sub-categories under the Waste sector have been considered in the state-level emission estimation. The relevant gases considered under each sub –category is also indicated

- 4A Solid Waste Disposal
  - 4A2 Unmanaged Waste Disposal Sites: CH_4
- 4D Wastewater treatment and discharge
  - 4D1 Domestic Wastewater Treatment and Discharge: CH_4 & N_2O
  - 4D2 Industrial Wastewater Treatment and Discharge: CH_4

The source categories and sub-categories considered for the state-level estimates are in line with India's Second National Communication and the Biennial Update Report 2010.

GHG estimation period:

The time period for State level estimations is from 2005 – 2013, in consonance with the estimation period considered in the National level estimates prepared under the phase-II of the GHG India Platform. India's Nationally Determined Contribution under the Paris Agreement, 2016 targets reducing the emission intensity of its economy by 33–35% by the year 2030 as compared to that in the base year of 2005. Therefore, this emission estimation exercise for the Waste sector has selected the same base year of 2005,

To ensure consistency with India's National Communication Reports and the Biennial Update Report 2010, the state emission inventory for all sub-sectors has been prepared on a calendar year basis.

- Activity datasets for industrial production for industrial wastewater emission estimations available on financial year basis have been converted to calendar year datasets for a given calendar year by considering 3/4th of the value from the previous financial year (corresponding to 9 months from April to December out of 12 months in a year) and 1/4th from the next financial year (corresponding to 3 months from January to March out of 12 months in a year). Industrial production data on monthly basis is not available in the datasets used for the industry sectors in this assessment and thereby the above approach is adopted to convert the activity data to calendar year basis.

- For instance, most of the production data for the industry sectors under consideration is available on a financial year basis. 3/4th of the production data from the financial year 2004-05 and 1/4th of the production data from the financial year 2005-06 has been considered and added together to estimate the production data for the calendar year 2005, and so on.

1.2 Institutional Arrangement and Capacity

The GHG India Platform is a collaborative effort of various civil society organizations. The institutional arrangement is given in the figure below.

- The project is funded by Shakti Sustainable Energy Foundation.
- Vasudha Foundation holds the secretariat for the platform and is responsible for the GHG emission estimates for AFOLU sector.
- ICLEI – Local Governments for Sustainability, South Asia (ICLEI South Asia) is responsible for GHG emissions estimates for waste sector.
- Center for Study of Science, Technology and Policy (CSTEP) is responsible for GHG emission estimates for energy sector.
- Council on Energy, Environment and Water (CEEW) is responsible for GHG emission estimates for industrial processes and product use sector.
- World Resources Institute India (WRI India) is responsible for peer review of estimations done by all partners previously mentioned.

Figure 2: Institutional Arrangement for GHG Platform - India

ICLEI South Asia works with national and state level governments in different capacities. ICLEI South Asia staff is and has been part of advisory/expert committees for informing policy and decision making at the national and state level (solid waste management, national mission on sustainable habitat, etc.). ICLEI South Asia is nominated as a preferred consultant in delivering services to local authorities by the national government under various schemes such as the SMART CITIES programme (empaneled consultants in 5 states), the Swachh Bharat Mission (national government empaneled consultants and state level committee members and facilitators in Rajasthan), HRIDAY scheme (empanelled city anchors in 3 cities in India), preferred consultants in the Solar City programme of the Ministry of New & Renewable Energy (out of 55 participating cities, ICLEI South Asia has supported the preparation of solar city master plans in 16 cities). ICLEI South Asia has also partnered with various national ministries in rolling out flagship programmes related to waste and sanitation sector such as the Service Level Benchmark programme in Urban Areas (Ministry of Urban Development), the National Urban Sanitation Policy (Ministry of Urban Development), the Swachh Bharat Mission (co-funding in 5 cities in Rajasthan and Maharashtra states).

ICLEI- Local Governments for Sustainability also seeks to build an international policy environment that strengthens local governments and supports local sustainability and climate mitigation. To facilitate this, ICLEI coordinates local government representation in several UN organizations. ICLEI's contributions in the form of side events, publications, verbal interventions and official background papers have been a consistent, major source of international attention to local initiatives and opportunities to enhance sustainability and mitigate GHG emissions.

The following staff members from ICLEI South Asia's Energy & Climate team, which is engaged in ICLEI's portfolio of energy and climate mitigation projects, have been involved in this assignment:

- Emani Kumar, Deputy Secretary General of ICLEI Global and Executive Director, ICLEI South Asia: Provided strategic inputs towards methodological approach for emission estimation and finalization of the methodology note.
- Soumya Chaturvedula, Deputy Director: Provided expert inputs to steer the process to help prepare and finalize this document including methodological approach, identification of datasets, assumptions to close data gaps, verification and review of datasets and emission estimates for all sub-sectors to help in finalization of this document.
- Nikhil Kolsepatil, Manager- Energy & Climate: Led overall preparation and finalization of this methodology document. Coordinated and led tasks towards methodology preparation and finalization, data identification, collection and estimate preparation, review and finalization of data and inventory estimates.
- Anandhan Subramaniyam, Manager- Energy & Climate: Undertook data collection, research, developing methodology for rural and urban domestic wastewater estimates, data validation and estimate preparation for the domestic wastewater sub-sector and drafted related sections in this note.
- Keshav Jha, Sr. Project Officer - Energy & Climate: Undertook data collection, research, data validation and estimate preparation for the industrial wastewater sub-sector and drafted related sections in this document.
- Sonali Malik, Project Officer - Energy & Climate: Undertook data collection, research, data validation and estimate preparation for the municipal solid waste sub-sector and drafted related sections in this document.

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1.3 GHG Estimation Preparation, Data Collection, Process and Storage

GHG Estimates preparation:

ICLEI South Asia has estimated the state-level GHG emissions for the Waste Sector based on the 2006 IPCC Guidelines for National GHG Inventories[5] with all relevant calculation approaches and default values of activity data and emission factors drawn from the guidelines as applicable. The overall methodology and approach adopted for the state-level estimates for the Waste Sector is similar to that followed in the phase-II national level estimates of the GHG Platform India and in line with India's Second National Communication[6] and the

[5] Available at https://www.ipcc-nggip.iges.or.jp/public/2006gl/
[6] Ministry of Environment and Forests, Government of India (2012): India - Second National Communication Report, 2012 to the UNFCCC, Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf

First Biennial Update Report[7] submitted to the United Nations Framework Convention on Climate Change (UNFCCC). As indicated previously, specific source sub-categories included in the emission estimates are:

- 4A2 Unmanaged Waste Disposal Sites
- 4D1 Domestic Wastewater Treatment and Discharge
- 4D2 Industrial Wastewater Treatment and Discharge.

The overall emissions reported for the Waste sector and related trend analysis included in this note is limited to the period 2005-2013. Given that state-level emission estimation is possible over the time period from 2005-2014 for the two source sub-categories of '4A2 Unmanaged Waste Disposal Sites' and '4D1 Domestic Wastewater Treatment and Discharge' due to availability of relevant datasets for year 2014, the corresponding estimates for year 2014 have been included as well in the relevant methodological sections 3.4 and 3.5 for these two source sub-categories in this document.

The emission estimates are based primarily on aggregated secondary data collected by ICLEI South Asia from published documents and reports of relevant government departments, nodal agencies and research institutions working at the state as well as national level in the Waste sector. Interactions were held with experts and representatives from some of these organizations to seek inputs on data availability and the emission estimation approach where required. The methodological approach adopted and the emission estimation results have been finalized post a peer-review by the WRI India team.

Planning and methodology improvement:

With regard to emission estimation, the phase-II of the GHG Platform India project involved

- expanding the national time series of emissions estimation prepared in phase- I (covering the years 2007-2012) for all sectors and 3 gases (CO_2, CH_4, N_2O) to the years 2005 to 2013 (or up to year 2014 subject to data availability)
- preparation of a time series of emission estimates for all sectors and sub-sectors for each Indian state for the same period as the expanded national estimates

The inventory planning commenced with the project partners jointly identifying the activities and developing a broad work plan to meet these objectives. Specific work plans and approaches were drawn up by each of the sector leads to undertake the exercise for the respective sectors, including ICLEI South Asia for the Waste sector. Detailed methodologies for preparation of the expanded national-level estimates and the state-level estimates were developed for each of the key source categories and sub-categories.

A series of round tables were organized in different regions of the country under the GHG Platform India to reach out to potential users of the Platform's outputs such as policymakers, research institutions, experts and the media. The round tables also aimed to capture feedback on the methodology, suitability of data sets, analyses undertaken and conclusions based on phase-I national –level emission estimates and to contribute to ongoing work under phase-II. ICLEI South Asia organized a sector roundtable in Kolkata and participated in the regional roundtables organised by the Platform partners in Bangalore, Mumbai and Delhi. Based on feedback received from the roundtables, it was decided to expand the scope of assessment to cover rural areas as well in the phase-II domestic wastewater emission estimation at both the national-level and the state-level.

To prepare the state-level emission estimates, secondary data research for state level information was undertaken across the years 2005 to 2014 for all sub-sectors with regard to parameters such as industrial production, domestic and industrial wastewater generation rates, treatment and discharge pathways, municipal solid waste generation rates, waste composition etc. Interactions have been held with relevant departments and institutions as needed. Updated information on activity data and related parameters that has been used in the expanded phase-II national-level estimates has been incorporated in the state-level estimates as well. The inventory development process involved regular discussions and reporting of progress between the project partners. Reporting formats were also developed for clear and transparent documentation and reporting of the methodology and results of the emission estimation.

[7] Ministry of Environment, Forest and Climate Change, Government of India (2015): India - First Biennial Update Report to the UNFCCC. Available at http://unfccc.int/resource/docs/natc/indbur1.pdf

Internal quality control (QC) procedures applied to the emission estimates include generic quality checks in terms of the calculations, processing, consistency, and clear recording and documentation as follows:

- The input activity data for each emission source sub-category has been selected from that available in different datasets by duly factoring in its relative time-series consistency and temporal and spatial applicability.
- The input data in the calculation sheets has been checked internally for transcription errors on a sample basis for all the 3 sub-sectors.
- The calculation spreadsheets have been checked for correct application of formulae, activity and factors and to ensure that calculations are correct. Manual calculations have been carried out for a part of the state emission estimates in all 3 sub-sectors to verify the spreadsheets results.
- Appropriate recording, conversions, processing and consistency of measurement units for parameters and emission has been checked across the reporting period.
- The state-wise emission estimates of each year of the reporting period have been compared to check for consistency in trends and detect any major deviations which cannot be correlated with corresponding changes in activity data and/or emission factors.
- A sheet providing an overview of sector, level of aggregation, reporting period, authors, reporting entity, version and usage policy has been included in the source category emission calculation spreadsheets that are linked to the main emission reporting spreadsheet. The state emission calculation equations, relevant data and parameter values used, intermediate formulae and cells wherein these are linked, and emission results are clearly depicted in the calculation spreadsheets for all 3 sub-categories.
- The reporting document has been checked to confirm all relevant references and secondary sources for activity data and emission factors have been included and documented.
- Emission source categories and sub-categories included and excluded in the emission estimates have been transparently reported in sections 1.7 and 3.3 of this note. Any known gaps in the state emission estimates along with rationale of assumptions used to address data gaps have been clearly indicated for each of the sub-sectors in sections 3.4, 3.5 and 3.6.

Once the draft state-level emission estimates have been prepared, these have been peer reviewed by the WRI team and feedback from the peer review process has been incorporated before finalization.

Data collection, processing and storage

To ensure that the estimates from the emission source categories represent the existing condition of waste management across the states in India, it has been sought to use country-specific and state-level data in the assessment to the extent possible. The data has been primarily collected through an extensive secondary research. The data collection exercise focused on gathering reliable information from published documents and reports of relevant government departments, nodal agencies and research institutions including Central Pollution Control Board (CPCB) and corresponding State Pollution Control Boards (SPCB), the National Environmental Engineering Research Institute (NEERI), various industry departments and associations, and the Ministry of Urban Development among others. Discussions on methodology, activity data available and emission factors being used, were held with relevant organizations such as the CPCB, NEERI, industry associations, and SPCB in-person and over telephone. The data collected was in various forms and units and has been assessed to ensure its applicability within the emission estimation boundaries and subsequently processed for further use.

The emission estimation method, reporting period, boundaries, year-wise activity data, emission factors and relevant parameters along with data sources and any assumptions to address gaps, and state-level emission results have been transparently recorded in this reporting document and in excel spreadsheets to provide clear understanding and to enable reconstruction of the emission estimations as required. All information collected and compiled for the emission estimates has been archived electronically in separate folders for future use as needed along with copies of relevant references or data sources. The final emission estimates and reporting documents are published and available on the GHG Platform India website (www.ghgplatform-india.org).

1.4 General description of methodology and data sources

Estimation methods:

The emission estimates for the Waste sector are based on the 2006 IPCC Guidelines for National GHG Inventories (hereafter referred as 2006 IPCC Guidelines). The emission factors and activity data used in the emission estimates are a mix of specific state-level data (where available) or national-level data and default values specified by the 2006 IPCC Guidelines. While use of state-level activity data has been prioritized, national-level and IPCC default values are used where requisite reliable state-level activity data is not available. State specific values of emission factors are used for the degradable organic carbon (DOC) content to estimate CH_4 emissions from solid waste disposal.

The tier method selected for each of the 3-emission source sub-categories included in this assessment is guided by the decision trees provided in the 2006 IPCC Guidelines and is based on data availability. The estimation approach uses a combination of Tier 1 and Tier 2 methods, with limitations in availability of disaggregated state or country specific data and emission factors restricting use of Tier 2 and Tier 3 methods. Further details on the Tiers used for the 3-emission source sub-categories in the Waste sector are provided in the 3.4.2, 3.5.2 and 3.6.2 of this note for each of the sub-sectors.

Activity data collected and relevant emission factors selected have been used to calculate emission estimates using the following basic principle given in the 2006 IPCC Guidelines:

GHG emission= activity data x emission factor

Complex calculations and models based on this basic principle are outlined for the Waste sector in the 2006 IPCC Guidelines and used in the emission estimates for the 3 sub-categories included in this assessment. The emissions estimates have been reported in Table 1 and Table 18 in this note in terms of CO_2 equivalent (CO_2e) for CH_4 and N_2O gases using the respective Global Warming Potential (GWP) values over a 100-year time horizon, as provided by the IPCC in its Second Assessment Report, 1996[3] and the latest updated GWP values in the Fifth Assessment Report, 2014[4]. India's Second National Communication Report[6] and the First Biennial Update Report[7] both use 100-year GWP values from the IPCC Second Assessment Report, 1996. To ensure consistency with the official GHG inventory submissions, the estimates reported in terms of CO_2e throughout this note, except for Table 1 and Table 18, use the GWP values from the IPCC Second Assessment Report, 1996.

1. Solid waste disposal

Solid waste disposal includes CH_4 emissions from solid waste collected and disposed at specific waste disposal sites. This assessment considers disposal of municipal solid waste, which typically includes waste from households, gardens and parks, and commercial and institutional areas in urban areas across the states of India. Given that solid waste in rural areas does not decompose under anaerobic conditions due to lack of waste management and disposal facilities, emissions from rural solid waste in the states are considered not to be significant, in-line with India's Second National Communication[6] and the First Biennial Update Report[7].

The First Order of Decay (FOD) method has been used to estimate the CH_4 emission from MSW disposal over the years. The method assumes that the degradable organic component in waste decays slowly over a few decades, during which CH_4 is released. Based on the 2006 IPCC guidance[8] on the FOD model and India's Second National Communication[6], a period of 50 years is considered appropriate for CH_4 emissions from a given quantum of waste to come down to significant level. Therefore, the historical waste disposal and resultant emissions have been estimated for each state for a period of 50 years prior to 2005 i.e. 1954-2004 along with emissions for the reporting period from 2005 to 2014. A combination of Tier 1 and Tier 2 approaches is used in the state emission estimation. Prevalent waste management practices such as open dumping/unmanaged landfill, waste characteristics and composition, and per capita waste generation rates in cities across Indian states have been factored in the methodology and emission estimation.

2. Domestic wastewater treatment and discharge

[8] As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

Domestic wastewater emissions have been estimated for CH_4 and N_2O gases for the states over the period 2005-2014. The characteristics of the domestic wastewater and consequently the associated GHG emissions vary from place to place depending on factors such as economic status, community food intake, water supply status, treatment systems and climatic conditions of the area. To account for these variations, the population generating domestic wastewater has been categorized into that residing in urban and rural areas. Domestic wastewater treatment systems and pathways considered include centralized treatment plants, septic tanks, pit latrines, open/closed sewers, and anaerobic digesters. N_2O emissions occurring as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea have also been considered. A Tier 1 approach has been used to estimate CH_4 and N_2O emissions for this source category.

3. Industrial wastewater treatment and discharge

The 10 industrial sectors considered in the assessment include Iron and Steel, Fertilizers, Meat, Sugar, Coffee, Pulp and Paper, Petroleum, Rubber, Dairy, and Tannery -sectors which have relatively high organic wastewater generation and thereby lead to significant CH_4 emissions on its treatment and discharge. The emission estimation has been conducted for years 2005-2013 due to unavailability of activity data on state-level industrial production for the year 2014. A Tier 1 approach has been used to estimate state-wise CH_4 emissions due to industrial wastewater treatment and discharge.

To ensure consistency across the sectors, overall state emissions reported for the Waste sector in this document are limited to the years 2005-2013. However, given that the relevant data for year 2014 is available for the source sub-categories of '4A2 Unmanaged Waste Disposal Sites' and '4D1 Domestic Wastewater Treatment and Discharge', the corresponding state estimates for year 2014 have been included in the relevant methodology sections of this note for these two source sub-categories.

Data Sources:

As indicated previously, it has been sought to use state and country-specific data in the emission estimates. Activity data has been primarily sourced from official data reported in publicly available web-based publications and statistical documents of relevant central/state government departments, nodal agencies, industrial departments and research institutions including NEERI, CPCB, SPCB, Census of India, industry associations, Ministry of Urban Development and others as indicated in the Table 5.

The CPCB is a statutory government organization responsible for collecting information on generation and treatment of solid waste and wastewater from all states and send requisite directives for necessary measures and therefore is a key source of activity data relating to solid waste disposal and domestic wastewater. Information on total volume of wastewater generated from industrial sectors is not available either with the CPCB, the SPCB or the relevant government departments and thus a Tier 1 approach which uses industrial production to estimate volume of wastewater generation is used in the case of industrial wastewater. Therefore, data sources for state-wise industrial production data for the 10 sectors under consideration include corresponding nodal industry departments and bodies, industry associations, and research/studies conducted in these sectors.

NEERI is a government research institute working on solid waste and wastewater[9] in the country and has also been involved in GHG emission estimation for the Waste sector in India's National Communication. Given the experience of NEERI in waste management, peer-reviewed literature from NEERI have been preferred as a data source for activity data, emission factors and related parameters related to solid waste disposal as well as domestic and industrial wastewater across the states. Data on historical per capita solid waste generation rates have been taken from a report published by The Energy Resources Institute (TERI)[10]. Data on the population and availability of different types of wastewater disposal facilities in households from the Census of India has been used in the solid waste and domestic wastewater emission estimates.

[9] NEERI's focus areas on solid waste include technical and scientific research on solid waste quantification, solid waste characterization, development of better and scientific solid waste management practices and treatment technologies, climate change related issues such as methane emissions from solid waste disposal etc. With regard to wastewater, NEERI works on research towards wastewater generation and management, physio-chemical characteristics, recycling and recovery for both domestic and industrial wastewater along with technology development and design of wastewater treatment systems. Available at www.neeri.res.in

[10] TERI (1998): Looking Back to Think Ahead: Green India 2047'

As mentioned earlier, discussions were conducted with experts from CPCB and NEERI over the methodology and datasets available for solid waste and wastewater. Inputs were also received on prevalent wastewater treatment technologies for industry sectors such as Iron & Steel, Rubber, Petroleum, Dairy, Coffee, Meat that are considered in this assessment. Discussions were also held with representatives from industrial departments and associations including the Ministry of Statistics and Programme Implementation, Central Board of Excise and Customs - Central Excise, the Central Pulp & Paper Research Institute, the Indian Paper Manufacturers Association, the Coffee Board of India, All India Brewers Association, the Rubber Board on industrial production datasets. Inputs received helped to ascertain the status of available state-level industrial production data and gaps therein and identify potential data sources for Beer, Soft drinks, Pulp & Paper, Coffee and Rubber sectors in particular.

Since state-specific emission factors are not available, national-level emission factors are sourced primarily from India's national communication documents to the UNFCCC, research documents and publications of NEERI, and the 2006 IPCC Guidelines on national GHG inventories, in this order of preference. While the importance of using of country-specific emission factors is well understood, the limited availability of data and specific emission factors for India has necessitated the use of the IPCC default values to some degree in the emission estimates. Further details of specific data sourced from each of the entities mentioned above are given in the corresponding detailed sections on methodology for the 3-emission source sub-categories.

Table 2: Principal Sources of Data for Source Categories and Sub-Categories

IPCC ID	Name of Sector	Principal Activity data source	Principal collection mechanism
4A2	Unmanaged Waste Disposal Sites	CPCB; NEERI; Central Public Health and Environmental Engineering Organization (CPHEEO), Ministry of Urban Development; TERI; 2006 IPCC Guidelines on national emission inventories	Published data from reports, manuals and studies from the web
4D1	Domestic Wastewater Treatment and Discharge	CPCB; NEERI; Census of India; NSSO, Ministry of Statistics & Programme Implementation (MOSPI); 2006 IPCC Guidelines on national emission inventories	Published data from reports, studies and statistical publications from the web
4D2	Industrial Wastewater Treatment and Discharge	• Ministry of Steel • Indian Bureau of Mines • Department of Fertilizers, Ministry of Chemicals and Fertilizers • Directorate of Sugarcane Development, Ministry of Agriculture • Coffee Board, Ministry of Commerce and Industry • Petroleum Planning and Analysis Cell, Ministry of Petroleum & Natural Gas • Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture • Central Pulp & Paper Research Institute • Rubber Board, Ministry of Commerce and Industry • Food and Agriculture Organization (FAO) • Department of Industrial Policy and Promotion, Ministry of Commerce & Industry • NEERI • Centre for Science and Environment (CSE) • 2006 IPCC Guidelines on national emission inventories	Published data from reports, studies and statistical publications from the web

Note: Related web-links for the data sources are given in the corresponding detailed methodology sections for the emission source categories.

1.5 Brief description of key source categories

It is observed that the 3 source categories - Unmanaged waste disposal sites (4A2), Domestic wastewater treatment and discharge (4D1), and Industrial wastewater treatment and discharge (4D2) – considered in the emission estimates each contribute to more than 5% of the cumulative state-level Waste sector emissions across the reporting period from 2005-2013. Domestic wastewater treatment and discharge (4D1) contributes to 60% of the overall emissions between the years 2005-2013. This is followed by Industrial wastewater treatment and discharge (4D2) which accounts for 29% and Unmanaged waste disposal sites (4A2) which has a share of 11% in the total state emissions from 2005-2013.

Therefore, in line with the 2006 IPCC Guidelines for National GHG Inventories all the 3 source categories are identified as key source categories within the Waste sector.

1.6 Uncertainty Evaluation

Since the state-level emission estimation for the Waste sector uses complex calculations and models involving compilation and processing of several input parameters (i.e. activity data and emission factors), the availability and quality of the input data or lack thereof is bound to bring in uncertainty in the estimation. Comprehensive quantitative and qualitative reporting of uncertainties requires a detailed understanding of the processes of compilation and reporting of input parameters used in the estimates. The lack of reliable and updated state-specific data is a key challenge encountered for all the 3 Waste sub-sectors considered in the state-level emission estimation. Due to the lack of disaggregated data, an aggregation based top-down approach has been used in the state emission estimation, which contributes to propagation of inherent errors in the input data into the estimates. Given the absence of quantitative and qualitative information to help identify inaccuracies in the input datasets, it is difficult to make an overall statement of uncertainty for the state-level Waste sector estimates.

A qualitative assessment of the potential sources of inaccuracy for each of the source categories considered in the Waste sector estimates has been undertaken at present, to the extent possible, with reference to the IPCC guidance and default uncertainty values. Assumptions made in the emission estimation for the states have been clearly reported and a sensitivity analysis has been conducted for key parameters and assumptions for all the 3 sub-sectors. The emission estimate uncertainties are assessed to be relatively higher for the state-level CH_4 emission estimates from 'Industrial wastewater treatment and discharge' as compared to 'domestic wastewater treatment and discharge' and 'solid waste disposal'. Recommendations relating to data gathering and disaggregation suggested at the end of this report will help in refining the inventory and reducing uncertainties.

Going forward, it is sought to undertake a more comprehensive uncertainty analysis, with partner organizations under the GHG Platform India attempting to better identify data gaps and quantify related uncertainties across sectors while proposing adequate measures to fill such data gaps.

1.7 General Assessment of Completeness

Emissions from the source categories '4B Biological treatment of solid waste' and '4C Incineration and open burning of waste' are not included in the state estimates due to the lack of reliable data for these sources and the absence of considerable number of waste incineration and composting facilities for a large part of the reporting period, especially pre-2010.

Emissions from solid waste disposal are limited to disposal of municipal solid waste in this assessment. Possible emissions from industrial waste and other waste such as clinical waste and hazardous waste are not considered under this source category due to the lack of published information from reliable sources on the generation and management of these solid waste streams in the states. Given the lack of solid waste management systems in rural areas, a majority of the solid waste in rural areas does not decompose under controlled/semi-controlled anaerobic conditions and thereby does not contribute to significant GHG emissions. Thus, the assessment considers GHG emissions from solid waste disposal in urban areas within the states. Further, most of the solid waste disposal sites in Indian states are not scientifically constructed and are inadequately managed as per national government guidance. The sites are also observed to be shallow[11] in general. Therefore, the

[11] Unmanaged solid waste disposal sites having depths of less than 5 meters are classified as shallow as per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

emission estimates account for the source category '4A2: Unmanaged waste disposal sites' which is deemed applicable for India.

Given that during the reporting period, an insignificant quantum of waste is disposed in scientifically designed and managed waste disposal sites within the states, the source category of '4A1: Managed waste disposal sites' is not yet applicable in the Indian context and therefore not considered in the present estimation. It is widely acknowledged and is corroborated from reports that the prevalent mode of waste disposal is in unmanaged open disposal sites and hence 4A3: Uncategorized waste disposal sites' is also not considered.

With regard to the industrial wastewater estimates, 10 industry sectors having significant organic load in their effluent and thereby generating significant GHG emission are included. These sectors are identified using India's National Communication reports, the 2006 IPCC guidelines for National GHG inventories, literature from NEERI and largely include the significant industrial wastewater related GHG emission sources in the country. While emissions from Beer and Soft drinks sector have been included in the national-level emission estimates under this Platform, these sectors have not considered in the state-level emission estimates. This is due to the unavailability of relevant activity data at the state-level to enable emission estimation. Other reliable information related to industrial activity, economic output etc. at the state-level which can be used as proxy data to apportion national-level emissions is also absent for these 2 sectors. Estimates for domestic wastewater cover both the urban as well as rural population in the states and are considered to sufficiently capture the relevant emission sources.

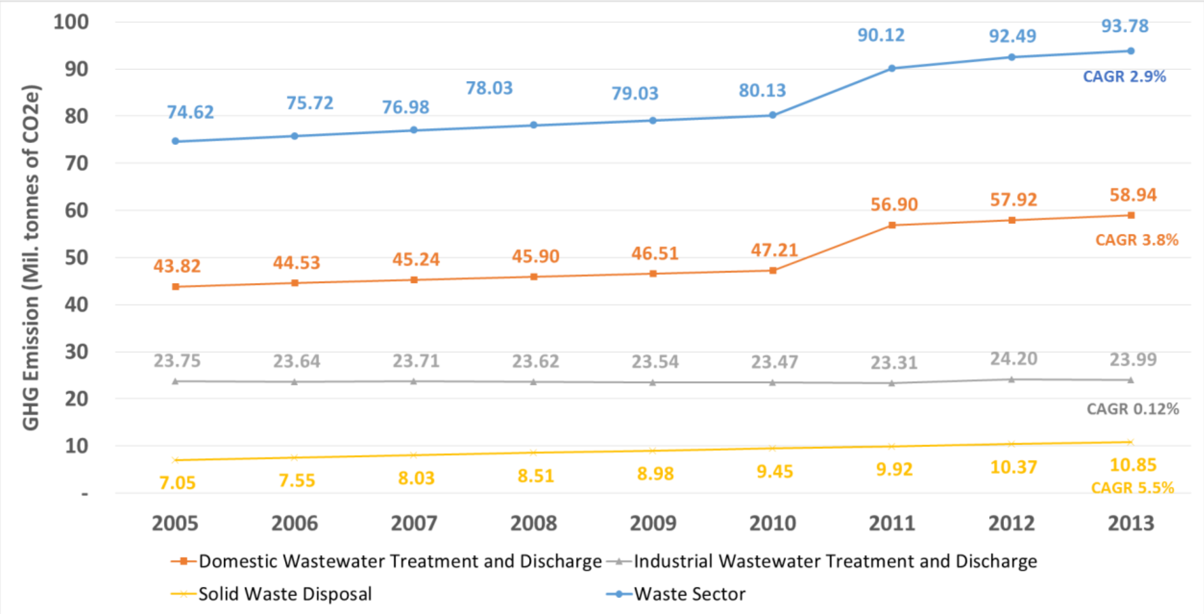
Trends in Emissions

1.8 Overall Waste Sector

India's Waste sector is estimated to contribute to GHG emission of 93.78 Mil. tonnes of CO_2e in the year 2013 (see Figure 3). GHG emissions from treatment and discharge of domestic wastewater have accounted for the highest share of the Waste sector emissions over the reporting period, contributing to 62.9% of the aggregated state-level emissions from the Waste sector in 2013 (see Figure 4). Industrial wastewater treatment and discharge was the 2nd largest contributor to the total Waste sector GHG emissions, with a share of 25.6% in 2013, followed by solid waste disposal which contributed to 11.6% of the country's cumulative state-level Waste GHG emissions.

Cumulative state-GHG emissions from the Waste sector have increased by 26% in the year 2013 as compared to year 2005, rising at a CAGR of 2.9% over the reporting period from 2005-2013. Emissions from solid waste disposal have registered the highest CAGR of 5.5% per year among the 3 sub-sectors. GHG emissions from the domestic and industrial wastewater have grown at CAGR of 3.8% and 0.12% respectively on average from 2005 to 2013. The trend of the overall state-level emission is observed to be quite steady with a relatively higher rise between for the year 2010 and 2011 (see Figure 3), which can be correlated with the corresponding increase in the estimated state-level domestic wastewater emissions[12].

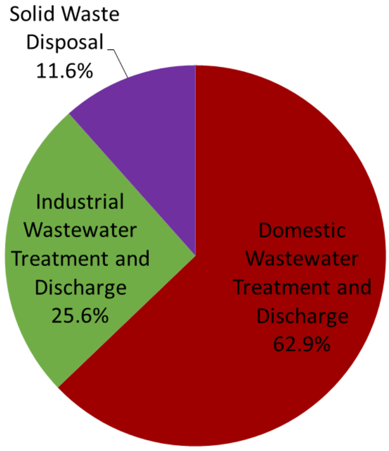
Figure 3: Aggregate State-level GHG Emission from Waste Sector, 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

[12] The overall increase in state-level GHG emissions from domestic wastewater over the reporting period from 2005-2013 is driven by the growing population and changing patterns of use of different treatment systems such as septic tanks, which have a higher methane generation potential. Constraints in availability of data and assumptions used to address the same contribute to the step change observed in emissions from 2010 to 2011. In the domestic wastewater emission calculations, Census 2001 data on the use of different wastewater discharge/treatment systems by rural households in each of the states has been used in the estimation from year 2005-2010 since data is not available for these years. For the estimates for the period from 2011-2013, Census 2011 data on use of different wastewater discharge/treatment systems has been used. Since the proportion of population using different wastewater treatment systems (such as septic tanks, latrines, sewer systems, direct discharge without treatment) changes in year 2011 across the states as compared to the preceding years, the relatively higher change in observed for this year.

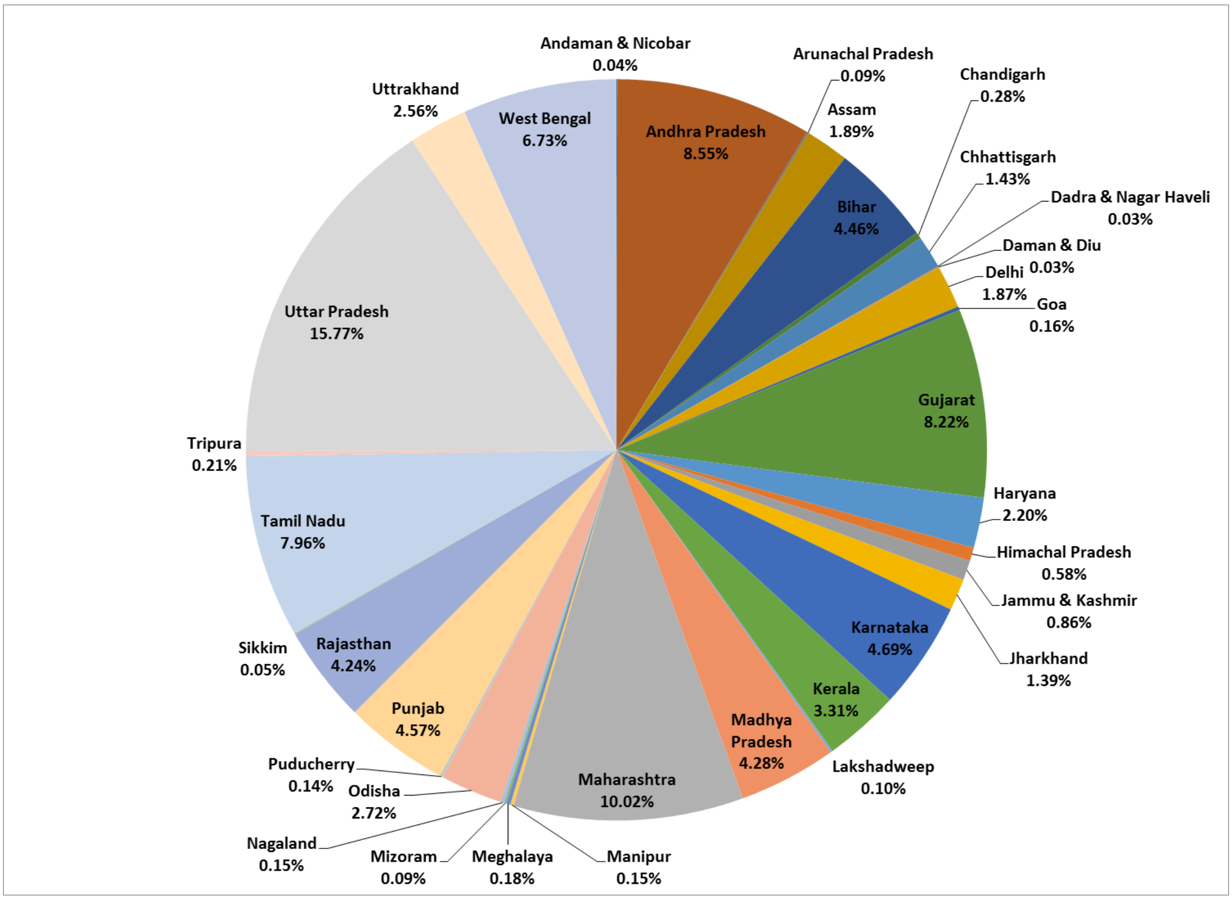
Figure 4: Share of Aggregate State-level GHG emission by source category, 2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

The state of Uttar Pradesh has the highest contribution to the estimated total Waste sector emissions, with a share of 15.8% while Maharashtra contributes to 10% of the aggregate emissions. The states of Uttar Pradesh, Maharashtra, Gujarat, Andhra Pradesh, Tamil Nadu, West Bengal and Karnataka together contribute to more than half of the total estimated Waste sector emissions in the year 2013 (see Figure 5 and Table 3). The states of Dadra & Nagar Haveli, Daman & Diu, Andaman & Nicobar, Sikkim, Arunachal Pradesh, Mizoram, Lakshadweep, Puducherry, Manipur, Nagaland, Goa, Meghalaya, Tripura, Chandigarh and Himachal Pradesh cumulatively contribute to less than 2% of the total emissions.

Figure 5: State-wise share in the Aggregate State-level GHG emission for Waste Sector, 2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Table 3: State-wise estimated GHG emission for the Waste Sector, 2005-2013

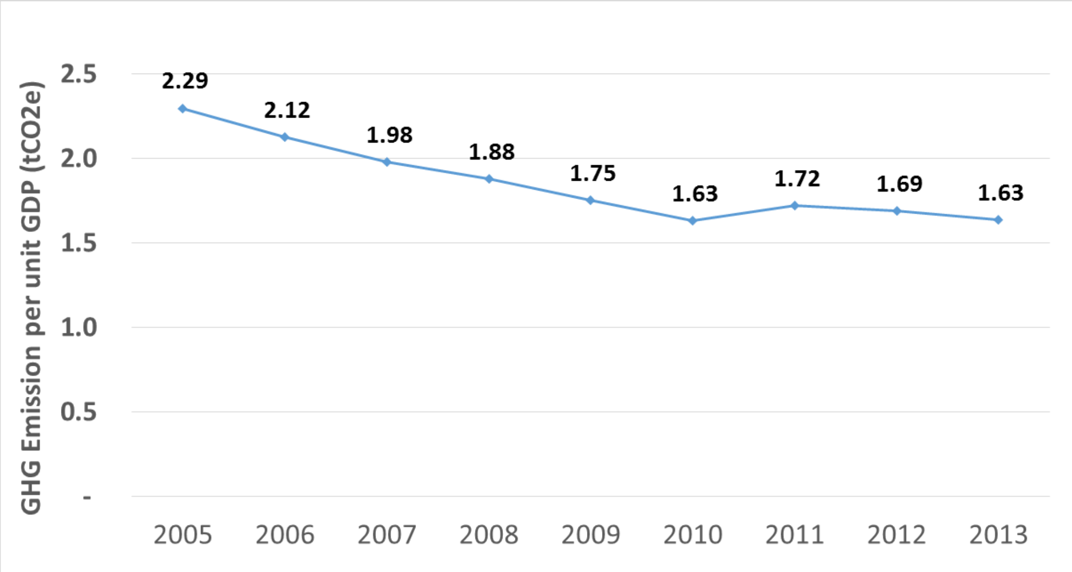
STATE/UNION TERRITORY	GHG EMISSION (MIL. TONNES OF CO_2e)									STATE-WISE PERCENTSHARE (2013)	CAGR (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013		
Andaman & Nicobar	0.03	0.03	0.03	0.03	0.03	0.03	0.04	0.04	0.04	0.04%	5.75%
Andhra Pradesh	6.27	6.35	6.44	6.50	6.67	6.71	7.60	7.94	8.02	8.55%	3.12%
Arunachal Pradesh	0.06	0.06	0.06	0.07	0.06	0.06	0.08	0.08	0.08	0.09%	3.61%
Assam	1.48	1.49	1.51	1.53	1.54	1.53	1.66	1.73	1.77	1.89%	2.28%
Bihar	3.04	3.11	3.18	3.25	3.27	3.34	3.97	4.07	4.18	4.46%	4.06%
Chandigarh	0.09	0.10	0.10	0.17	0.17	0.18	0.25	0.26	0.26	0.28%	13.70%
Chhattisgarh	0.94	0.96	0.99	1.02	1.04	1.06	1.26	1.31	1.34	1.43%	4.59%
Dadra & Nagar Haveli	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03%	8.28%
Daman & Diu	0.01	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03%	8.74%
Delhi	1.24	1.29	1.34	1.37	1.38	1.43	1.65	1.70	1.76	1.87%	4.42%
Goa	0.10	0.11	0.11	0.11	0.12	0.12	0.15	0.15	0.15	0.16%	5.01%
Gujarat	6.63	6.65	6.66	6.64	6.67	6.77	7.29	7.62	7.71	8.22%	1.90%
Haryana	1.31	1.35	1.40	1.43	1.46	1.51	2.00	2.04	2.06	2.20%	5.78%
Himachal Pradesh	0.43	0.44	0.44	0.44	0.44	0.45	0.56	0.56	0.55	0.58%	2.97%
Jammu & Kashmir	0.56	0.58	0.60	0.62	0.63	0.65	0.77	0.79	0.80	0.86%	4.54%
Jharkhand	0.97	1.00	1.03	1.06	1.07	1.10	1.23	1.27	1.30	1.39%	3.82%
Karnataka	3.50	3.58	3.64	3.68	3.77	3.82	4.29	4.39	4.40	4.69%	2.90%
Kerala	2.70	2.75	2.79	2.84	2.89	2.96	2.99	3.05	3.10	3.31%	1.74%
Lakshadweep	0.02	0.02	0.03	0.03	0.03	0.03	0.08	0.09	0.09	0.10%	21.34%
Madhya Pradesh	3.03	3.10	3.16	3.22	3.29	3.36	3.86	3.94	4.01	4.28%	3.56%
Maharashtra	7.78	7.95	8.12	8.22	8.42	8.60	9.21	9.36	9.40	10.02%	2.38%
Manipur	0.10	0.10	0.11	0.11	0.10	0.11	0.14	0.14	0.14	0.15%	4.08%
Meghalaya	0.12	0.12	0.13	0.13	0.13	0.13	0.16	0.16	0.17	0.18%	4.37%
Mizoram	0.06	0.06	0.06	0.06	0.06	0.06	0.08	0.09	0.09	0.09%	5.80%
Nagaland	0.11	0.11	0.10	0.11	0.10	0.11	0.14	0.14	0.14	0.15%	3.66%
Odisha	2.13	2.17	2.20	2.22	2.28	2.33	2.54	2.54	2.55	2.72%	2.24%
Puducherry	0.09	0.09	0.09	0.10	0.11	0.11	0.12	0.13	0.13	0.14%	5.31%
Punjab	3.26	3.29	3.32	3.36	3.38	3.43	4.20	4.22	4.28	4.57%	3.48%
Rajasthan	2.96	3.02	3.08	3.14	3.19	3.25	3.77	3.86	3.98	4.24%	3.74%
Sikkim	0.04	0.03	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05%	2.70%
Tamil Nadu	6.25	6.30	6.40	6.46	6.61	6.71	7.01	7.23	7.46	7.96%	2.24%

STATE/UNION TERRITORY	GHG EMISSION (MIL. TONNES OF CO_2e)									STATE-WISE PERCENTSHARE (2013)	CAGR (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013		
Tripura	0.14	0.15	0.15	0.15	0.17	0.17	0.19	0.19	0.20	0.21%	4.09%
Uttar Pradesh	11.61	11.74	11.96	12.14	12.07	12.24	14.03	14.45	14.79	15.77%	3.08%
Uttrakhand	2.30	2.34	2.34	2.33	2.32	2.38	2.58	2.58	2.40	2.56%	0.55%
West Bengal	5.22	5.25	5.34	5.43	5.47	5.28	6.14	6.29	6.31	6.73%	2.40%
All-India (Total)	**74.62**	**75.72**	**76.98**	**78.03**	**79.03**	**80.13**	**90.12**	**92.49**	**93.78**	**100.00%**	**2.90%**

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

The emission intensity of the Waste sector emissions, in terms of aggregate state GHG emission per unit GDP, is observed to have decreased by 29% in 2013 as compared to the base year of 2005, falling at a CAGR of -4.2% over the reporting period between 2005 to 2013 (see Figure 6). Per capita emissions from the Waste sector, estimated based on aggregated state-level emissions, increased from 67.7 kg of CO_2e in year 2005 to 74.8 kg of CO_2e in the year 2013. The per capita emissions from the Waste sector are estimated to have increased at a CAGR of 1.2% per annum from 2005 to 2013. The spike in per capita emissions in year 2011 is linked to the corresponding rise in the state domestic wastewater emissions due to use of different activity dataset from this year onward as indicated earlier.

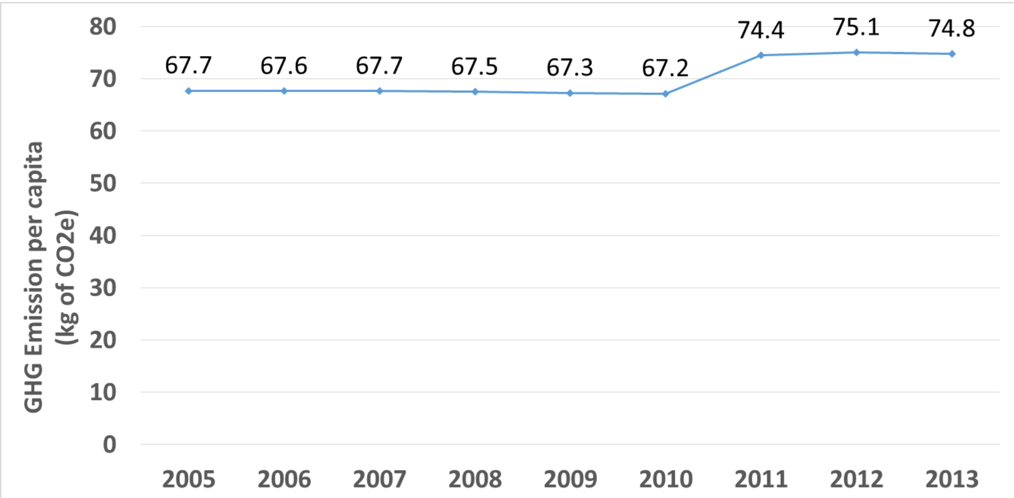
Figure 6: Trend of Waste sector aggregate state GHG emission per unit GDP* (tonnes of CO_2e per Million INR at constant 2004-05 prices), 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series; GDP based on Central Statistics Office, 2014 data)

*Note: Since GDP is reported on financial year basis, the GDP data for 2005-06 has been used to estimate the emission intensity for 2005, GDP data for 2006-07 has been used to estimate the emission intensity for 2006 and so on

Figure 7: Trend of per capita GHG emission from Waste sector, 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

The emission intensity of the Waste sector emissions, in terms of GHG emission per Gross State domestic product shows a decreasing trend across all the states. The states of Uttar Pradesh, Andhra Pradesh, and Tripura have the highest GHG emission intensity (see Table 4). Emission intensity in the states of Punjab, Bihar and Assam, Odisha, Jammu & Kashmir, Madhya Pradesh, West Bengal, Gujarat, Manipur, Uttarakhand, Chandigarh is also notable, being higher than the aggregate state GHG emission of 1.63 tonnes of CO_2e per Million INR. The lowest GHG emission intensity is observed in the state of Goa.

The states of Lakshadweep, Uttarakhand, Punjab, and Gujarat are seen to have the highest per capita GHG emission for the Waste sector, in this order (see Table 5). Per capita emissions are also notably higher in Chandigarh, Tamil Nadu, Kerala and Delhi. The states of Manipur, Tripura, Chhattisgarh, Jharkhand and Bihar are estimated to have the lowest per capita emissions.

Table 4: GHG emission per unit GSDP by state for the Waste sector (at constant 2004-05 prices)

State/Union Territory	GHG emission per unit GSDP (tonnes of CO_2e per Million INR)		CAGR
	2005	2013	
Andaman & Nicobar Islands	1.35	0.96	-4.25%
Andhra Pradesh	4.42	3.25	-3.76%
Arunachal Pradesh	1.69	1.36	-2.66%
Assam	2.68	2.04	-3.35%
Bihar	3.98	2.41	-6.06%
Chandigarh	0.98	1.65	6.67%
Chhattisgarh	1.90	1.41	-3.65%
Delhi	1.12	0.80	-4.20%
Goa	0.76	0.51	-4.95%
Gujarat	2.84	1.70	-6.18%
Haryana	1.26	1.03	-2.43%
Himachal Pradesh	1.66	1.16	-4.39%
Jammu & Kashmir	1.95	1.75	-1.32%
Jharkhand	1.67	1.19	-4.13%
Karnataka	1.90	1.37	-4.01%
Kerala	2.06	1.37	-4.95%
Madhya Pradesh	2.55	1.74	-4.64%
Maharashtra	1.65	1.05	-5.54%
Manipur	1.88	1.70	-1.27%
Meghalaya	1.68	1.25	-3.59%
Mizoram	1.97	1.58	-2.70%
Nagaland	1.67	1.26	-3.45%
Odisha	2.60	1.85	-4.14%
Puducherry	1.21	0.93	-3.18%
Punjab	3.18	2.46	-3.14%
Rajasthan	2.17	1.54	-4.19%
Sikkim	2.13	0.82	-11.27%
Tamil Nadu	2.50	1.55	-5.80%
Tripura	1.52	1.05	-4.48%
Uttar Pradesh	4.18	3.18	-3.34%
Uttarakhand	8.12	3.39	-10.35%
West Bengal	2.35	1.70	-4.00%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series; GDP based on data sourced from Directorate of Economics & Statistics of respective State Governments and published by Niti Aayog. Available at http://niti.gov.in/content/gsdp-constant-2004-05prices-2004-05-2014-15)

*Note: 1) Since GDP is reported on financial year basis, the GDP data for 2005-06 has been used to estimate the emission intensity for 2005 and so on

2) Gross State Domestic Product is not available for Dadra & Nagar Haveli, Daman & Diu, and Lakshadweep and therefore these Union territories are not included in the Table. Telangana state was formed in 2014 and hence not included.

Table 5: State-wise per capita GHG emission for the Waste sector

STATE/UNION TERRITORY	GHG EMISSION PER CAPITA (KG OF CO_2e)		CAGR (2005-2013)
	2005	2013	
Andaman & Nicobar	70.46	71.83	0.24%
Andhra Pradesh	78.84	78.98	0.02%
Arunachal Pradesh	49.91	50.78	0.22%
Assam	51.98	51.53	-0.11%
Bihar	33.28	33.24	-0.01%
Chandigarh	96.29	97.31	0.13%
Chhattisgarh	41.26	41.58	0.10%
Dadra & Nagar Haveli	55.21	55.48	0.06%
Daman & Diu	77.20	78.56	0.22%
Delhi	82.63	84.39	0.26%
Goa	74.71	76.84	0.35%
Gujarat	121.55	119.70	-0.19%
Haryana	57.58	58.02	0.10%
Himachal Pradesh	67.66	67.59	-0.01%
Jammu & Kashmir	50.71	51.35	0.16%
Jharkhand	32.88	33.33	0.17%
Karnataka	62.33	62.77	0.09%
Kerala	83.24	84.42	0.18%
Lakshadweep	311.60	334.62	0.89%
Madhya Pradesh	46.47	46.59	0.03%
Maharashtra	75.51	75.97	0.08%
Manipur	42.79	43.02	0.07%
Meghalaya	46.03	46.22	0.05%
Mizoram	58.05	58.68	0.13%
Nagaland	54.06	54.40	0.08%
Odisha	54.90	55.06	0.04%
Puducherry	80.19	82.17	0.30%
Punjab	126.73	126.28	-0.04%
Rajasthan	48.33	48.26	-0.02%
Sikkim	71.57	59.96	-2.19%
Tamil Nadu	94.25	93.70	-0.07%
Telangana	42.27	42.75	0.14%
Tripura	64.61	64.15	-0.09%
Uttar Pradesh	252.05	252.28	0.01%
Uttarakhand	61.64	61.19	-0.09%
West Bengal	70.46	71.83	0.24%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

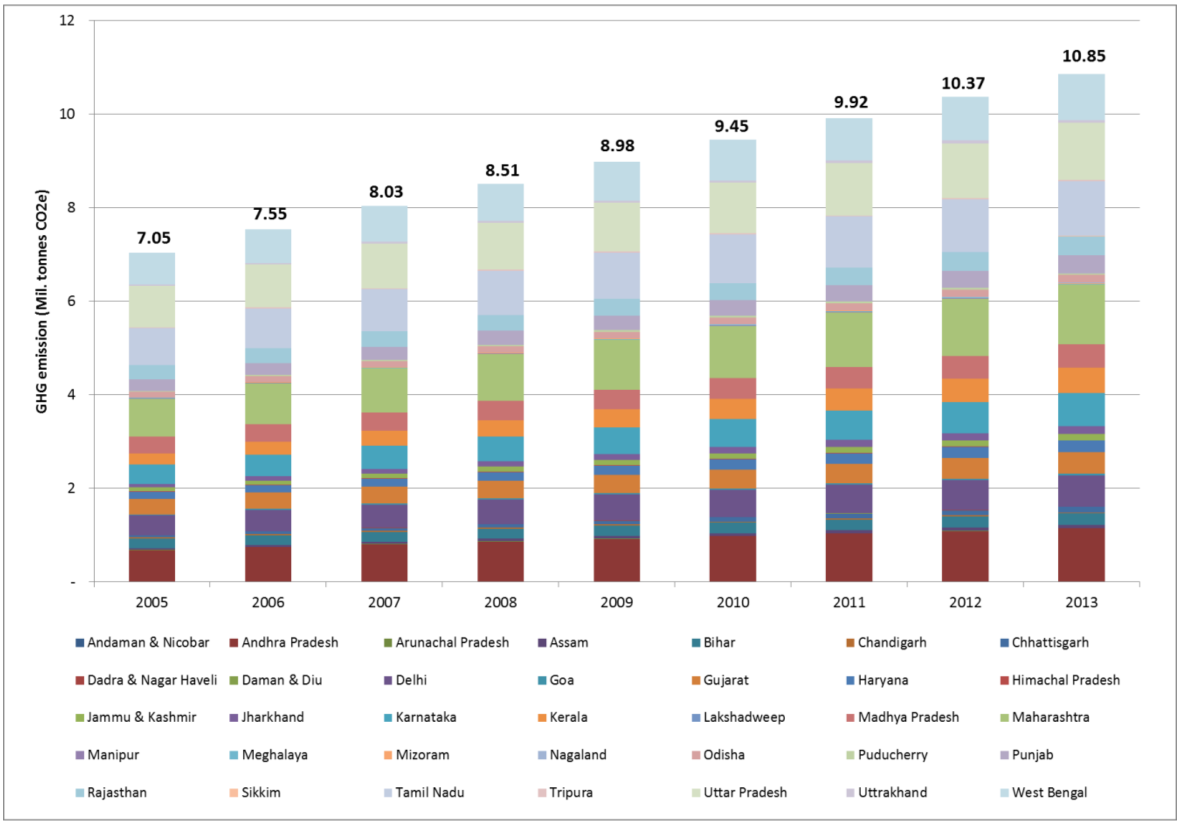
The trends observed and related analysis for each source category considered in the emission estimates is presented in the following sections here.

1.9 4A Solid Waste Disposal

CH_4 emission due to solid waste disposal is estimated to have increased by 54% on an absolute basis from the year 2005 to 2013. Solid waste disposal contributed to cumulative GHG emission of 10.85 Mil. tonnes of CO_2e in 2013 as against 7.04 MtCO_2e in 2005 across the Indian states (see Figure 8). This source category is observed to have the highest year-on-year growth in the aggregated state-level emissions within the Waste sector, with a CAGR of 5.5% from 2005-2013.

The state of Maharashtra is the largest contributor to the aggregate state level emissions from solid waste, with a share of 11.7% (see Table 6). This is followed by Uttar Pradesh which contributes to 11.2% of the state-level emissions from solid waste disposal. The eight states of Maharashtra, Uttar Pradesh, Tamil Nadu, Andhra Pradesh, West Bengal, Karnataka, Delhi and Kerala contribute to 70% of the total solid waste disposal related emissions. Among these states, emissions from Kerala are estimated to have increased at a relatively higher CAGR of 12.3% from 2005-2013 while emissions from Andhra Pradesh and Karnataka have grown significantly as well (CAGR of 7.7% each). Himachal Pradesh, Andaman & Nicobar, Dadra & Nagar Haveli, Daman & Diu, Lakshadweep along with a number of North eastern states (Meghalaya, Manipur, Mizoram, Nagaland, Sikkim, Arunachal Pradesh) contribute to less than 1% of the cumulative emissions from solid waste. Year-wise GHG emission from solid waste disposal for each state from 2005-2013 is given in Table 72 in Annexures.

Figure 8: Trend of GHG emission from Solid Waste Disposal, 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Table 6: State-wise GHG emission from Solid Waste Disposal

STATE/UNION TERRITORY	GHG EMISSION (MIL. TONNES OF CO_2e)		SHARE OF GHG EMISSION IN 2013	CAGR
	2005	2013		
Andaman & Nicobar	0.005	0.008	0.1%	8.9%
Andhra Pradesh	0.677	1.136	10.5%	8.0%
Arunachal Pradesh	0.004	0.008	0.1%	2.4%
Assam	0.040	0.069	0.6%	2.9%
Bihar	0.208	0.246	2.3%	14.7%
Chandigarh	0.019	0.023	0.2%	20.9%
Chhattisgarh	0.044	0.114	1.0%	13.7%
Dadra & Nagar Haveli	0.001	0.004	0.04%	6.7%
Daman & Diu	0.001	0.004	0.03%	8.8%
Delhi	0.424	0.667	6.1%	4.4%
Goa	0.212	0.038	0.4%	7.5%
Gujarat	0.334	0.451	4.2%	3.8%
Haryana	0.151	0.250	2.3%	8.4%
Himachal Pradesh	0.009	0.012	0.1%	12.6%
Jammu & Kashmir	0.079	0.139	1.3%	7.7%
Jharkhand	0.072,	0.164	1.5%	12.3%
Karnataka	0.418	0.701	6.5%	10.5%
Kerala	0.242	0.546	5.0%	5.1%
Lakshadweep	0.0005	0.001	0.01%	6.5%
Madhya Pradesh	0.353	0.500	4.6%	8.9%
Maharashtra	0.815	1.270	11.7%	7.2%
Manipur	0.007	0.012	0.1%	7.9%
Meghalaya	0.009	0.015	0.1%	11.7%

STATE/UNION TERRITORY	GHG EMISSION (MIL. TONNES OF CO_2e)		SHARE OF GHG EMISSION IN 2013	CAGR
	2005	2013		
Mizoram	0.006	0.011	0.1%	4.9%
Nagaland	0.003	0.007	0.1%	7.7%
Odisha	0.118	0.165	1.5%	7.1%
Puducherry	0.023	0.038	0.4%	4.1%
Punjab	0.237	0.384	3.5%	13.7%
Rajasthan	0.306	0.405	3.7%	5.7%
Sikkim	0.001	0.004	0.04%	10.0%
Tamil Nadu	798,476	1.179	10.9%	4.6%
Tripura	0.013	0.026	11.2%	5.0%
Uttar Pradesh	0.885	1.213	0.6%	6.4%
Uttarakhand	0.023	0.063	9.0%	8.9%
West Bengal	0.692	0.976	100.0%	8.0%
State Aggregate CH_4 emission	**7.05**	**10.85**	**0.1%**	**2.4%**

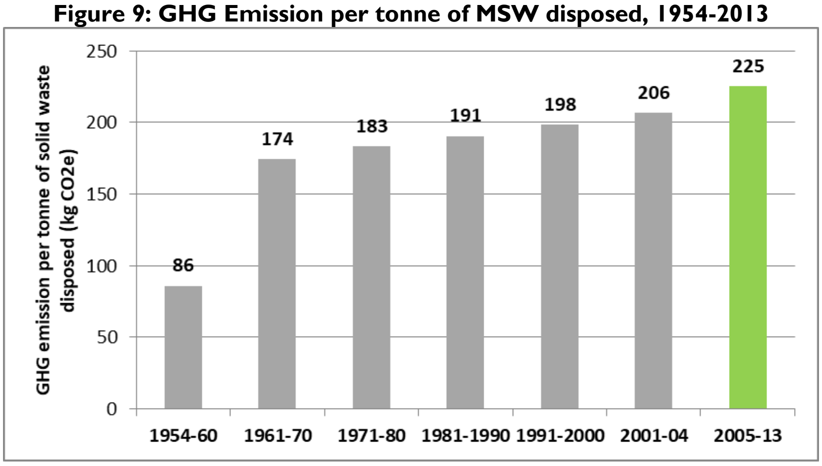
(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Changing trends in GHG emission are primarily due to change in the total quantum of solid waste, its composition, and the method of disposal and characteristics related to the disposal site. In the short-term for the reporting period from 2005-2013, the rise in solid waste disposal emissions is driven by increasing waste generation rates and growing population, leading to higher quantum of waste going to disposal sites. The per capita solid waste generation has been growing by 1.2% per year[13] over the past two decades.

Over the long-term, the changing composition of municipal solid waste is seen to contribute to rising emissions, with higher emissions generated from every tonne of waste that is being disposed. The GHG emissions per tonne for solid waste disposed (on aggregated state-level basis) have more than doubled, rising from 86 kg of CO_2e per tonne of solid waste disposed on average during 1954-60[14] to 225 kg of CO_2e per tonne of solid waste disposed during 2005-2013 (refer Figure 9).

The GHG emission per tonne of waste disposed ranges from 131 kg of CO_2e to 329 kg of CO_2e across the states during 2005-13 (see Table 7). Himachal Pradesh has the highest GHG emission per tonne of waste disposed followed by Chandigarh, Meghalaya and Andhra Pradesh. This is largely driven by the higher DOC value estimated for these states, which results from a higher proportion of organic constituents in the state's solid waste.

Figure 9: GHG Emission per tonne of MSW disposed, 1954-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

[13] This number indicates simple annual growth rate as estimated in Table 25 of this note based on reported per capita waste generation for 1991 and 2005. CAGR growth rates have been indicated as such in the note and all other growth rates mentioned throughout this document refer to simple growth rates.

[14] This analysis and insight into long-term emission related trends for solid waste is a result of the first order decay (FOD) method being followed in this exercise for estimation of emissions from solid waste disposal. The FOD method considers that waste deposited in a disposal site at a point in time decomposes gradually and continues to undergo anaerobic digestion again and generate CH_4 over a long period of time (around 50 years). CH_4 emission will be generated until the waste deposited in the disposal site decomposes completely and reaches its full methane generation potential. Therefore, to fully account for emissions from solid waste disposal in our exercise for year 2005, it is necessary to estimate emissions for a 50-year period before this year i.e. from 1954-2004.

Note: GHG emission per tonne for solid waste disposed (state- aggregates) for the emission estimation period of this exercise is depicted by the green coloured bar in Figure 9 while the historic long trend of GHG emission per tonne of waste disposed that derives from the FOD method for the previous 50-year period is depicted by grey coloured bars.

Table 7: State-wise GHG Emission per tonne of MSW disposed, 1954-2013

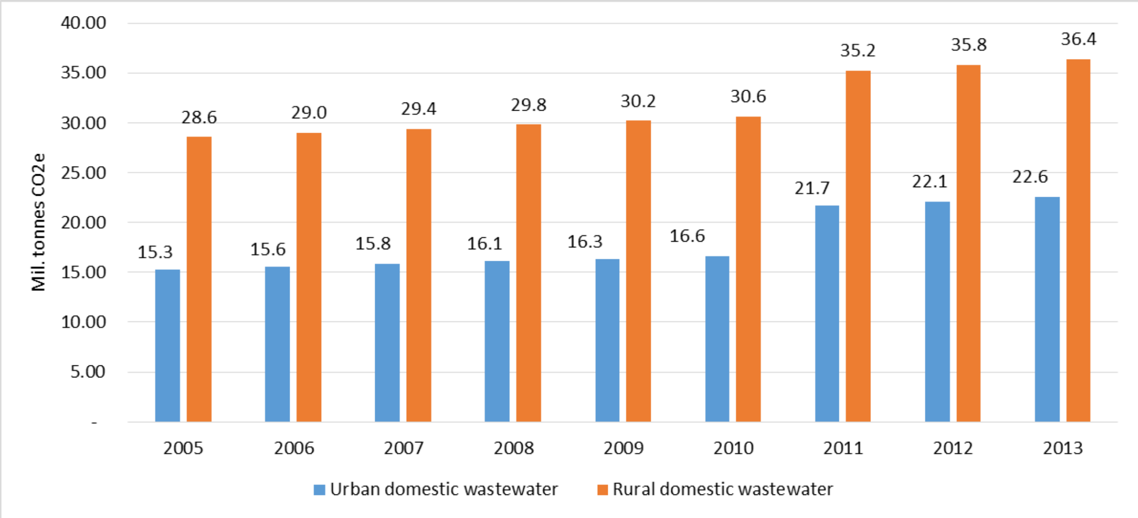
STATE/UNION TERRITORY	KG OF CO_2e GHG EMISSION/TONNE OF MSW DISPOSED						
	1954-60	1961-70	1971-80	1981-1990	1991-2000	2001-04	2005-13
Andaman & Nicobar	82.5	154.4	161.0	176.8	183.1	197.0	246.2
Andhra Pradesh	86.6	177.6	183.2	201.1	203.8	212.9	247.8
Arunachal Pradesh	0.0	0.0	99.7	140.8	157.2	179.2	235.3
Assam	80.6	157.8	180.5	190.1	194.3	203.9	245.3
Bihar	71.8	173.0	178.0	193.1	211.7	300.1	238.0
Chandigarh	0.0	100.8	155.8	182.8	193.2	203.2	261.2
Chhattisgarh	0.0	0.0	0.0	0.0	0.0	53.4	178.4
Dadra & Nagar Haveli	0.0	0.0	0.0	121.1	129.5	129.7	182.2
Daman & Diu	0.0	0.0	0.0	35.2	160.3	163.5	131.2
Delhi	83.3	164.5	175.0	183.3	186.4	198.2	232.2
Goa	0.0	114.9	167.3	197.4	188.5	200.1	244.2
Gujarat	86.2	174.1	184.5	192.2	198.1	204.5	199.9
Haryana	85.1	174.1	178.3	184.8	187.8	194.6	212.6
Himachal Pradesh	86.6	176.8	188.6	192.5	197.5	209.9	329.1
Jammu & Kashmir	85.5	171.4	181.4	186.0	193.3	202.0	236.2
Jharkhand	0.0	0.0	0.0	0.0	0.0	53.8	170.2
Karnataka	86.4	176.6	182.0	192.5	200.9	207.7	238.8
Kerala	84.8	173.4	187.0	182.3	204.7	203.2	219.5
Lakshadweep	0.0	0.0	0.0	108.1	204.2	213.8	213.4
Madhya Pradesh	84.2	168.6	177.3	184.6	195.8	247.5	244.8
Maharashtra	86.1	174.0	185.1	190.6	196.2	206.7	237.1
Manipur	72.1	139.9	142.1	176.2	205.4	212.0	237.9
Meghalaya	80.5	167.7	174.1	184.9	194.2	203.3	261.2
Mizoram	81.4	137.6	131.6	141.5	177.4	199.8	238.9
Nagaland	62.7	120.1	131.8	155.3	166.1	236.8	195.2
Odisha	107.7	172.8	181.4	195.0	207.4	159.1	246.2
Puducherry	0.0	0.0	106.3	180.9	193.9	207.7	239.6
Punjab	85.5	179.0	186.8	194.4	197.2	205.2	239.0
Rajasthan	87.0	176.6	178.4	186.5	197.1	206.7	206.4
Sikkim	79.9	133.0	139.8	208.1	209.9	172.6	191.7
Tamil Nadu	86.0	174.6	190.9	203.0	197.7	202.9	221.9
Telangana	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tripura	80.2	159.4	181.4	172.7	189.6	194.4	206.2
Uttar Pradesh	87.1	179.9	179.4	186.7	196.5	215.6	216.6
Uttarakhand	0.0	0.0	0.0	0.0	0.0	53.5	186.1
West Bengal	85.0	176.7	206.5	197.3	206.2	213.3	218.2

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

1.10 4D1 Domestic Wastewater Treatment and Discharge

The total domestic wastewater related emissions from urban and rural areas are presented in Figure 10. Emissions from rural domestic wastewater are seen to contribute to around 61 to 65% of the state aggregate emissions from domestic wastewater across the period from 2005-2013. The rural population, however, accounted for 72.19% and 68.85% of aggregated state population of India in the year 2001 and 2011 respectively. Therefore, given that a smaller number of the country's population is residing in urban areas, the corresponding per capita GHG emission generated from urban domestic wastewater is considerably higher (by about 22%-36% across the period 2005-2013) as compared to per capita GHG emission from rural domestic wastewater. Per capita GHG emissions from domestic wastewater for the urban population were 56.16 kg as compared to 42.51 kg for the rural population in the year 2013, a difference of 32%.

Figure 10: Trend of Aggregate State-level GHG Emission from Urban and Rural domestic wastewater treatment and discharge, 2005-2013



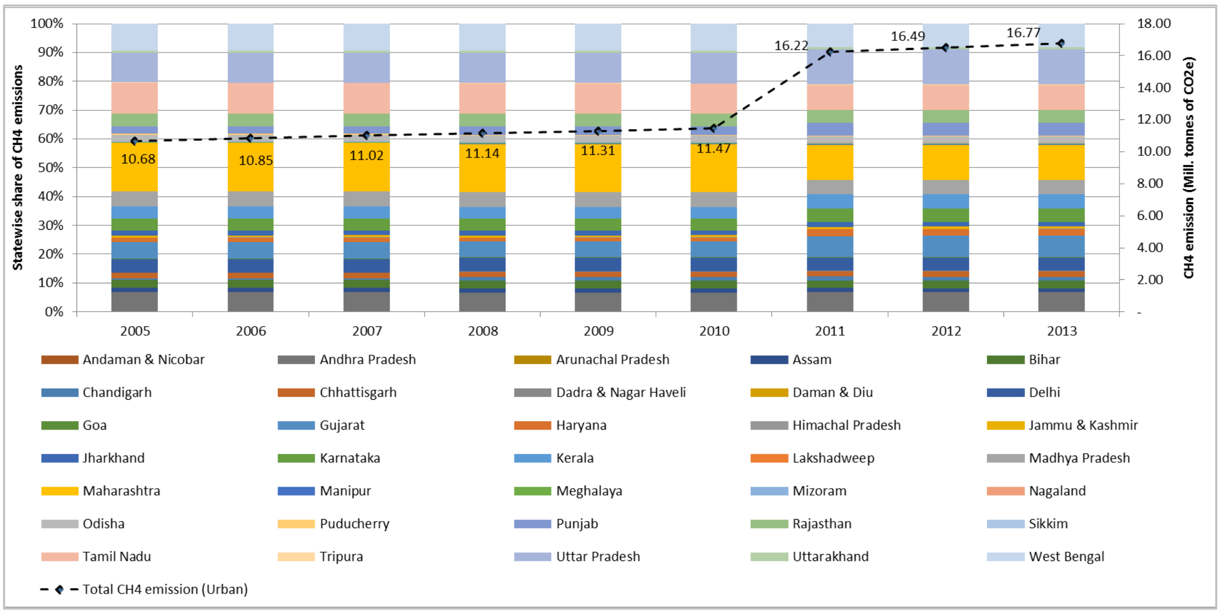
(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

With regard to urban domestic wastewater, CH_4 emissions are estimated to be much higher than N_2O emissions, accounting for 74.27% of the total GHG emission in 2013. CH_4 is emitted from wastewater when it is treated or disposed anaerobically. Therefore, CH_4 emissions have a direct correlation with the percentage of wastewater that is treated or discharged through different systems or pathways. CH_4 emission is also influenced by the income-levels since the accessibility and usage of different wastewater treatment systems/pathways varies by income-groups.

CAGR of CH_4 emission from urban domestic wastewater over the reporting period of 2005-2013 is observed to be 5.8%. According to latest Census data in 2011, the proportion of urban population is 31.15% in 2011, a rise of 12%, in comparison to 2001 (27.81%). This higher proportion of urban population in 2011 also, implies an increase of 41% in the estimation of CH_4 emissions for 2011 as compared to 2010. The average annual growth rate of CH_4 emission drops down to about 1.7% from 2011-2013, in line with the steady population growth considered in the calculations (see Figure 11).

In terms of average state-wise contribution to urban CH_4 emission across 2005-2013, Maharashtra has the highest contribution (14.72%), followed by Uttar Pradesh (11.09%), Tamil Nadu (9.69%), West Bengal (8.67%), Andhra Pradesh (6.67%) and Gujarat (6.28%). This correlates with the order of states with the highest urban population. Most of the north-eastern states along with states such as Jammu & Kashmir, Uttarakhand, Himachal Pradesh and Lakshadweep contribute to less than 1% of the CH_4 emission from urban domestic wastewater (see Table 8).

Figure 11: Emission of CH_4 from Urban domestic wastewater treatment and discharge, 2005-2013



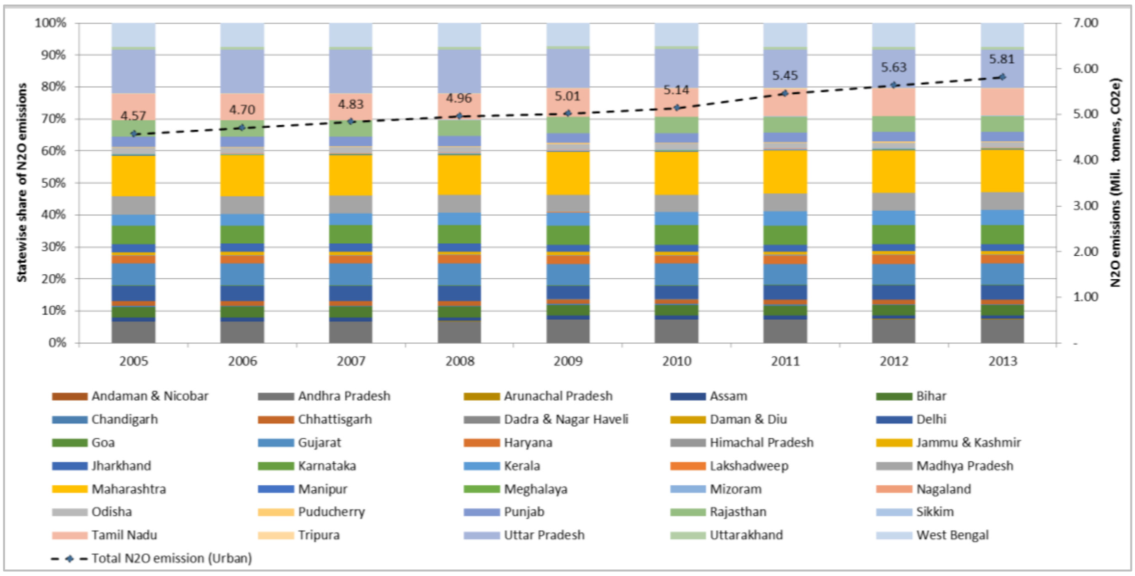
(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Note: CH_4 emission has been converted to CO_2 equivalent values and depicted through the dotted black line in this chart that relates to absolute values on the secondary axis (at the right side of the chart).

N_2O emissions have a direct correlation with the human protein consumption and the size of urban population consuming this protein. Protein is a source of nitrogen and N_2O emissions occur on degradation of this nitrogen in the wastewater. Urban N_2O emissions show a steady trend in line with the steadily rising nutritional intake of protein and the increase in urban population over the years (see Figure 12). N_2O emissions from urban domestic wastewater are observed to grow at a CAGR of 3.0% over the reporting period of 2005-2013.

As observed in the case of CH_4 emissions from urban domestic wastewater, the states having higher urban population are the key contributors to cumulative N_2O emission from urban wastewater as well. Maharashtra is the largest contributor to N_2O emissions, with an average share of 13.1% in the total urban N_2O emission from 2005-2013, followed by Uttar Pradesh (12.71%), Tamil Nadu (8.39%), West Bengal (7.4%), Andhra Pradesh (7.02%) and Gujarat (6.57%) (see Table 9). The states of Jammu & Kashmir, Uttarakhand, Himachal Pradesh, Lakshadweep and most of the north-eastern states have a share of less than 1% in the total N_2O emission from urban domestic wastewater.

Figure 12: Emission of N_2O from Urban domestic wastewater treatment and discharge, 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Note: N_2O emission has been converted to CO_2 equivalent values and depicted through the dotted black line in this chart that relates to absolute values on the secondary axis (at the right side of the chart).

Table 8: State-wise CH_4 emission from Urban domestic wastewater, 2005 to 2013

State/Union Territory	CH_4 Emission From Urban Domestic Wastewater (Mil. tonnes of CO_2e)									Average Percent share in emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Andaman & Nicobar	0.008	0.008	0.008	0.008	0.008	0.008	0.012	0.012	0.012	0.072%
Andhra Pradesh	0.723	0.731	0.739	0.724	0.731	0.739	1.102	1.114	1.126	6.665%
Arunachal Pradesh	0.009	0.009	0.009	0.009	0.010	0.010	0.017	0.017	0.018	0.092%
Assam	0.159	0.162	0.164	0.167	0.169	0.172	0.210	0.213	0.217	1.408%
Bihar	0.281	0.288	0.294	0.301	0.307	0.314	0.427	0.437	0.448	2.670%
Chandigarh	0.056	0.057	0.058	0.130	0.132	0.134	0.212	0.215	0.219	1.045%
Chhattisgarh	0.200	0.204	0.209	0.213	0.217	0.221	0.314	0.321	0.328	1.922%
Dadra & Nagar Haveli	0.004	0.004	0.005	0.005	0.005	0.005	0.011	0.012	0.013	0.055%
Daman & Diu	0.005	0.005	0.006	0.006	0.006	0.006	0.014	0.015	0.016	0.069%
Delhi	0.512	0.522	0.532	0.519	0.528	0.538	0.718	0.734	0.749	4.615%
Goa	0.030	0.030	0.030	0.030	0.031	0.031	0.049	0.049	0.050	0.284%
Gujarat	0.602	0.613	0.624	0.601	0.611	0.622	1.178	1.201	1.224	6.275%
Haryana	0.157	0.160	0.163	0.151	0.153	0.156	0.381	0.389	0.396	1.816%
Himachal Pradesh	0.011	0.011	0.011	0.012	0.012	0.012	0.014	0.015	0.015	0.098%
Jammu & Kashmir	0.076	0.077	0.079	0.080	0.082	0.084	0.131	0.134	0.137	0.758%
Jharkhand	0.169	0.173	0.176	0.180	0.183	0.187	0.253	0.259	0.264	1.591%
Karnataka	0.460	0.467	0.474	0.466	0.473	0.479	0.757	0.769	0.780	4.420%
Kerala	0.446	0.448	0.450	0.452	0.454	0.457	0.827	0.831	0.835	4.486%
Lakshadweep	0.002	0.002	0.002	0.002	0.002	0.002	0.004	0.004	0.004	0.021%
Madhya Pradesh	0.545	0.555	0.565	0.574	0.584	0.594	0.798	0.814	0.831	5.055%
Maharashtra	1.797	1.824	1.851	1.857	1.883	1.910	1.951	1.982	2.013	14.719%
Manipur	0.018	0.018	0.018	0.018	0.019	0.019	0.040	0.040	0.041	0.199%
Meghalaya	0.023	0.023	0.024	0.025	0.025	0.026	0.038	0.039	0.040	0.227%
Mizoram	0.020	0.020	0.020	0.021	0.021	0.022	0.039	0.040	0.041	0.210%
Nagaland	0.011	0.011	0.011	0.011	0.011	0.011	0.038	0.038	0.038	0.158%
Odisha	0.236	0.239	0.242	0.244	0.247	0.250	0.326	0.330	0.335	2.110%
Puducherry	0.037	0.038	0.038	0.040	0.041	0.042	0.048	0.049	0.050	0.329%
Punjab	0.283	0.287	0.290	0.315	0.319	0.323	0.747	0.757	0.767	3.525%
Rajasthan	0.470	0.480	0.489	0.494	0.504	0.513	0.710	0.725	0.740	4.419%
Sikkim	0.003	0.003	0.003	0.003	0.003	0.003	0.007	0.007	0.007	0.036%
Tamil Nadu	1.124	1.141	1.157	1.157	1.174	1.190	1.409	1.431	1.453	9.690%
Tripura	0.023	0.024	0.024	0.024	0.025	0.025	0.042	0.042	0.043	0.235%
Uttar Pradesh	1.090	1.111	1.131	1.167	1.188	1.208	1.950	1.989	2.029	11.093%
Uttarakhand	0.079	0.081	0.082	0.084	0.085	0.086	0.129	0.131	0.133	0.767%

State/Union Territory	CH_4 Emission From Urban Domestic Wastewater (Mil. tonnes of CO_2e)									Average Percent share in emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
West Bengal	1.012	1.025	1.038	1.052	1.065	1.078	1.318	1.337	1.355	8.866%
State Aggregate CH_4 emission (Urban)	**10.680**	**10.848**	**11.016**	**11.140**	**11.307**	**11.474**	**16.220**	**16.494**	**16.768**	**100%**

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Table 9: State-wise N_2O emission from Urban domestic wastewater, 2005 to 2013

State/Union Territory	N_2O Emission From Urban Domestic Wastewater (Mil. tonnes of CO_2e)									Average Percent Share in Emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Andaman & Nicobar	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.041%
Andhra Pradesh	0.301	0.311	0.320	0.329	0.365	0.375	0.399	0.413	0.427	7.027%
Arunachal Pradesh	0.006	0.006	0.007	0.007	0.004	0.004	0.005	0.005	0.005	0.105%
Assam	0.053	0.055	0.056	0.057	0.058	0.060	0.059	0.060	0.062	1.127%
Bihar	0.153	0.158	0.163	0.168	0.165	0.169	0.175	0.181	0.187	3.296%
Chandigarh	0.015	0.015	0.015	0.016	0.016	0.016	0.015	0.016	0.016	0.303%
Chhattisgarh	0.066	0.068	0.070	0.073	0.072	0.075	0.079	0.082	0.086	1.454%
Dadra & Nagar Haveli	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.037%
Daman & Diu	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.003	0.041%
Delhi	0.218	0.223	0.229	0.234	0.209	0.213	0.242	0.248	0.255	4.493%
Goa	0.009	0.009	0.010	0.010	0.012	0.013	0.014	0.014	0.015	0.228%
Gujarat	0.309	0.319	0.328	0.338	0.333	0.342	0.354	0.366	0.379	6.657%
Haryana	0.109	0.113	0.117	0.121	0.126	0.130	0.143	0.150	0.156	2.525%
Himachal Pradesh	0.011	0.011	0.011	0.011	0.011	0.011	0.012	0.013	0.013	0.225%
Jammu & Kashmir	0.044	0.045	0.047	0.048	0.051	0.052	0.056	0.058	0.060	0.997%
Jharkhand	0.117	0.120	0.124	0.127	0.111	0.114	0.117	0.120	0.124	2.329%
Karnataka	0.263	0.270	0.278	0.285	0.303	0.310	0.326	0.337	0.347	5.897%
Kerala	0.160	0.171	0.182	0.192	0.204	0.215	0.237	0.259	0.281	4.124%
Lakshadweep	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.016%
Madhya Pradesh	0.255	0.261	0.267	0.273	0.271	0.277	0.303	0.310	0.318	5.498%
Maharashtra	0.583	0.596	0.609	0.621	0.678	0.692	0.736	0.754	0.771	13.104%
Manipur	0.009	0.009	0.010	0.010	0.009	0.009	0.010	0.010	0.011	0.187%
Meghalaya	0.006	0.007	0.007	0.007	0.006	0.006	0.007	0.007	0.008	0.132%

STATE/UNION TERRITORY	N_2O EMISSION FROM URBAN DOMESTIC WASTEWATER (MIL. TONNES OF CO_2e)									AVERAGE PERCENT SHARE IN EMISSION (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Mizoram	0.008	0.009	0.009	0.009	0.008	0.008	0.008	0.008	0.009	0.162%
Nagaland	0.008	0.008	0.009	0.009	0.008	0.008	0.008	0.009	0.009	0.165%
Odisha	0.084	0.086	0.088	0.090	0.092	0.094	0.095	0.097	0.100	1.793%
Puducherry	0.009	0.010	0.010	0.010	0.012	0.013	0.013	0.014	0.014	0.229%
Punjab	0.144	0.147	0.151	0.154	0.155	0.158	0.164	0.168	0.173	3.068%
Rajasthan	0.235	0.241	0.247	0.253	0.252	0.258	0.275	0.283	0.291	5.062%
Sikkim	0.001	0.001	0.001	0.002	0.002	0.002	0.002	0.002	0.003	0.036%
Tamil Nadu	0.373	0.382	0.391	0.400	0.440	0.450	0.464	0.477	0.489	8.387%
Tripura	0.010	0.011	0.011	0.012	0.014	0.014	0.014	0.015	0.016	0.256%
Uttar Pradesh	0.624	0.640	0.657	0.673	0.615	0.630	0.655	0.674	0.693	12.714%
Uttarakhand	0.040	0.041	0.042	0.044	0.041	0.042	0.050	0.052	0.054	0.882%
West Bengal	0.344	0.353	0.362	0.372	0.361	0.370	0.404	0.416	0.429	7.401%
State Aggregate N2O emission (Urban)	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.003	0.041%

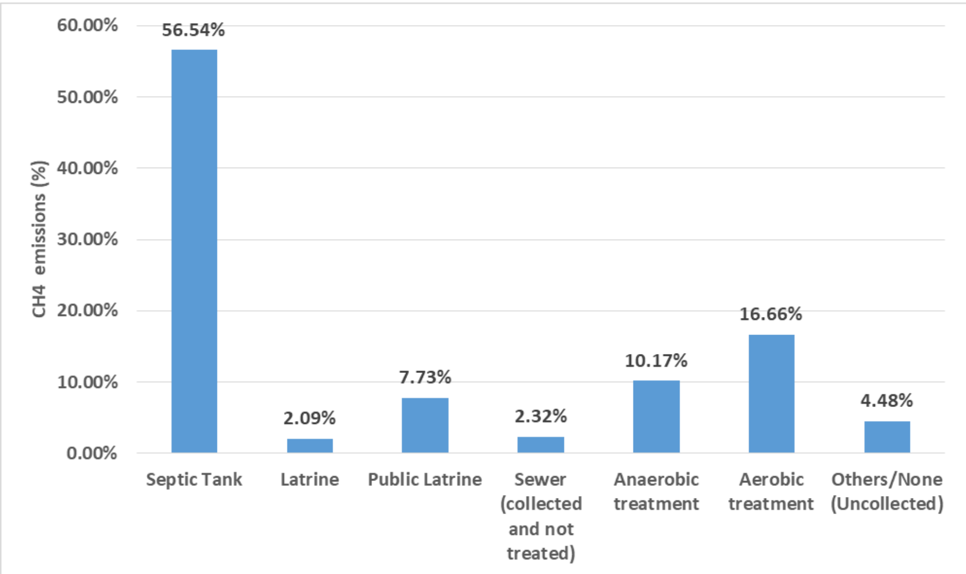
(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

In terms of emission sources, it is seen that septic tanks contribute to 56.5% of the aggregated CH_4 emissions from urban domestic wastewater in the states in year 2013 (see Figure 13). About 47% of the urban households are connected to septic tanks across the states on average as per data from Census 2011[15]. Septic tanks are generally on-site treatment systems having a relatively higher CH_4 emission generation potential (methane correction factor value of 0.5[16]) and thereby contribute significantly to emissions from urban domestic wastewater. Connecting septic tanks with the sewer network and treating the wastewater aerobically downstream in well-managed treatment plants can reduce emissions.

It is seen that aerobic treatment systems are the second highest contributor to the total CH_4 emissions from urban domestic wastewater in the states. This is mainly due to the existing aerobic treatment based sewage treatment plants (STPs) in the country not being well managed. The 'methane correction factor' value defined in the 2006 IPCC Guidelines for 'not well managed aerobic systems' is 0.3 as against a 'methane correction factor' value of 0 (and therefore no CH_4 emission) for 'well managed aerobic treatment systems'[16]. Therefore, it is important to manage aerobic treatment systems across states effectively.

Due to insufficient installed capacity and operational inefficiencies of STPs, some portion of wastewater that is collected through the sewer network is not treated downstream. This wastewater that is collected through sewer systems but does not flow to a STP usually stagnates and leads to CH_4 emission, contributing to 2.3% of the total CH_4 emissions from urban wastewater across the states[17]. The state-wise distribution of CH_4 emissions by type of treatment/discharge system due to handling of urban domestic wastewater is given in Table 10.

Figure 13: Share of Aggregate State-level CH_4 Emission by type of Treatment/Discharge system for Urban population, 2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Table 10: Share of State-wise Urban CH_4 emission by type of Treatment/Discharge System, 2013

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[15] Available at http://censusindia.gov.in/2011census/hlo/Data_sheet/India/Latrine.pdf

[16] MCF values indicated in Table 38 of this note and based on the 2006 IPCC Guidelines, Vol.5, Chapter 6 - Wastewater treatment and discharge, Table 6.3.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

[17] Constraints in data availability limit the inferences that can be drawn from trends with regards to the implications of better access to wastewater collection and treatment systems. Year-on-year information on distribution of wastewater treatment systems is not available and constant values have been used for degree of utilization for the urban population in the states across the reporting period.

State/Union Territory	Septic Tank	Latrine	Public Latrine	Sewer (collected and not treated)	Anaerobic treatment	Aerobic treatment	Others/None (Uncollected)
Andaman & Nicobar	92.28%	0.04%	5.66%	0.13%	0.00%	0.00%	1.89%
Andhra Pradesh	70.22%	1.30%	3.16%	0.00%	0.00%	20.32%	5.00%
Arunachal Pradesh	81.31%	4.22%	5.76%	4.19%	0.00%	0.00%	4.52%
Assam	83.46%	6.97%	2.16%	0.00%	0.00%	3.29%	4.12%
Bihar	83.71%	1.43%	3.49%	0.22%	0.00%	0.53%	10.61%
Chandigarh	0.09%	0.01%	0.89%	0.00%	97.22%	1.72%	0.07%
Chhattisgarh	77.74%	0.35%	8.64%	1.82%	0.00%	0.00%	11.45%
Dadra & Nagar Haveli	86.69%	0.17%	9.19%	1.05%	0.00%	0.00%	2.90%
Daman & Diu	86.46%	0.25%	11.70%	0.59%	0.00%	0.00%	1.00%
Delhi	23.93%	0.33%	6.88%	0.94%	0.00%	66.76%	1.16%
Goa	83.44%	0.98%	7.32%	0.00%	0.00%	4.49%	3.77%
Gujarat	18.73%	0.33%	2.79%	17.01%	26.20%	33.45%	1.50%
Haryana	21.81%	1.41%	1.19%	0.25%	44.09%	28.97%	2.27%
Himachal Pradesh	57.76%	0.20%	5.10%	10.93%	14.16%	9.50%	2.35%
Jammu & Kashmir	69.37%	1.57%	3.29%	0.51%	4.09%	9.92%	11.24%
Jharkhand	82.35%	0.60%	3.01%	0.00%	0.10%	2.82%	11.11%
Karnataka	21.66%	3.03%	5.61%	0.00%	13.07%	53.22%	3.41%
Kerala	87.18%	6.70%	1.38%	0.12%	0.00%	2.68%	1.94%
Lakshadweep	98.85%	0.11%	0.42%	0.11%	0.00%	0.00%	0.51%
Madhya Pradesh	78.60%	0.50%	5.18%	0.14%	2.99%	4.81%	7.78%
Maharashtra	40.50%	0.68%	29.73%	2.95%	1.00%	22.25%	2.89%
Manipur	78.00%	8.43%	3.44%	1.34%	0.00%	0.00%	8.79%
Meghalaya	90.58%	3.24%	2.51%	1.72%	0.00%	0.00%	1.95%
Mizoram	92.79%	4.48%	0.78%	0.45%	0.00%	0.00%	1.51%
Nagaland	88.83%	3.96%	4.22%	0.35%	0.00%	0.00%	2.64%
Odisha	79.76%	1.49%	3.54%	0.00%	0.00%	1.99%	13.22%
Puducherry	81.36%	0.16%	7.75%	0.00%	3.77%	3.54%	3.42%
Punjab	10.85%	0.74%	0.44%	0.83%	65.55%	20.63%	0.96%
Rajasthan	75.89%	1.83%	2.16%	0.00%	2.87%	9.92%	7.32%
Sikkim	72.57%	0.86%	3.39%	11.30%	0.00%	10.85%	1.04%
Tamil Nadu	63.51%	2.31%	14.41%	0.83%	0.00%	12.50%	6.43%
Tripura	75.56%	18.89%	1.61%	0.12%	0.00%	0.65%	3.17%
Uttar Pradesh	68.82%	0.85%	3.08%	0.63%	14.22%	6.58%	5.81%
Uttarakhand	77.19%	1.92%	2.47%	0.00%	0.59%	15.82%	2.01%
West Bengal	77.43%	7.71%	6.31%	5.01%	1.99%	0.00%	1.55%

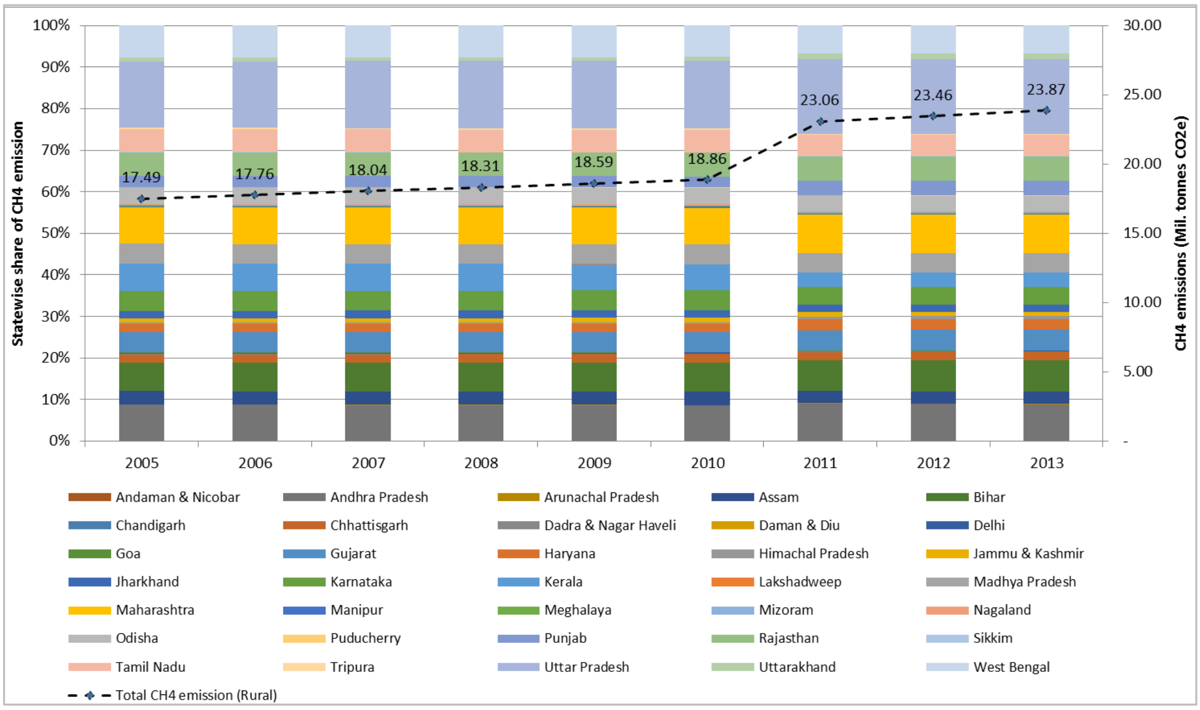
(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

For rural domestic wastewater, the estimated CH_4 emissions lead the N_2O emissions, as seen in the case of urban wastewater. CH_4 emission from rural domestic wastewater has increased at a CAGR of 4.0% over the period 2005-2013, with CH_4 emission rising from year 2011 onwards in particular (see Figure 14). The higher emissions are likely caused due to the increase in the volume of wastewater handled in rural areas as reported in Census 2011, especially in terms of the total percent of rural households connected to septic tanks across the states.

State contribution to the overall rural domestic wastewater CH_4 emission is closely correlated with the size of the rural population. Uttar Pradesh (16.86%) is the leading contributor of CH_4 emission from rural domestic wastewater, followed by Maharashtra (8.93%), Andhra Pradesh (8.70%), West Bengal (7.33%), and Bihar (7.10%) (see Table 11). Himachal Pradesh, Jammu & Kashmir, Chandigarh and most of the North-eastern states contribute to less than 1% of rural wastewater related CH_4 emissions.

N_2O emissions from rural domestic wastewater show a steady growth, with a CAGR of 1.5% over the reporting period of 2005-2013 (see Figure 15). Uttar Pradesh is the largest contributor to N_2O emissions, with an average share of 20.28% in the total rural wastewater related N_2O emissions from 2005-2013 (see Table 12). This is followed by Bihar (10.97%), Rajasthan (7.4%), Maharashtra (7.34%), West Bengal (6.8%), Madhya Pradesh (6.58%) and Andhra Pradesh (6.32%). A number of the states in the North-eastern region along with the states of Himachal Pradesh, Uttarakhand and Chandigarh have a share of less than 1% in the total rural N_2O emission.

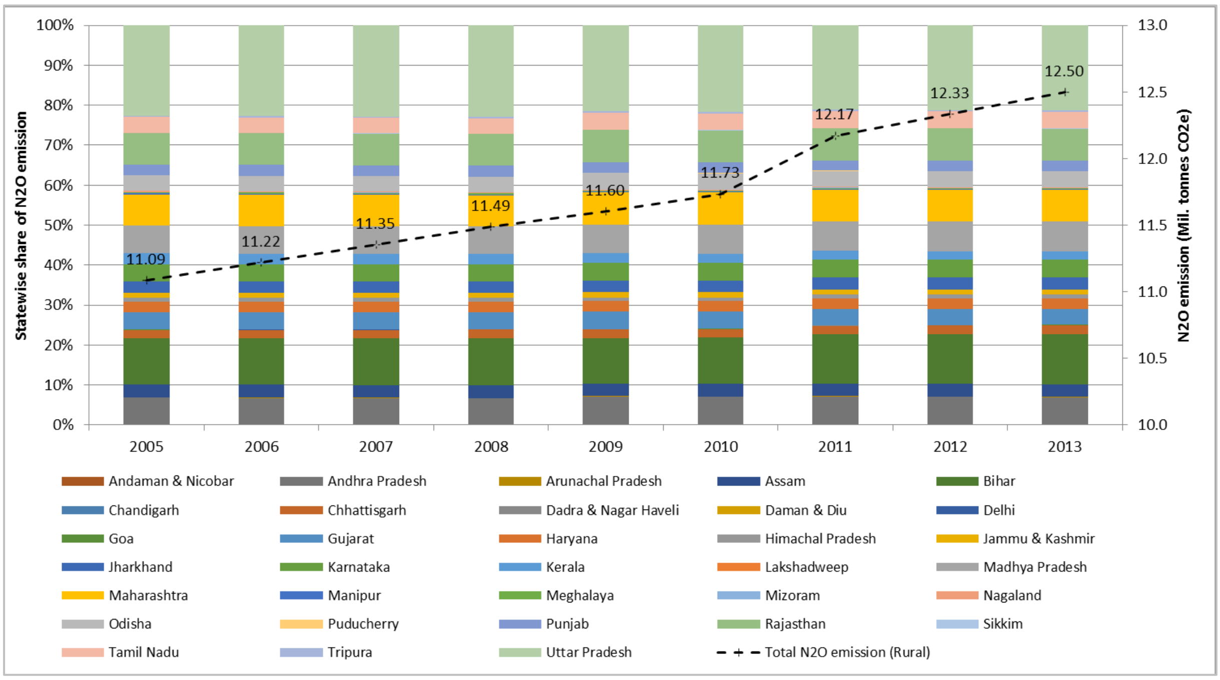
Figure 14: Emission of CH_4 from Rural domestic wastewater treatment and discharge, 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Note: CH_4 emission has been converted to CO_2 equivalent values and depicted through the dotted black line in this chart that relates to absolute values on the secondary axis (at the right side of the chart).

Figure 15: Emission of N_2O from Rural domestic wastewater treatment and discharge, 2005-2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Note: N_2O emission has been converted to CO_2 equivalent values and depicted through the dotted black line in this chart that relates to absolute values on the secondary axis (at the right side of the chart).

Table 11: State-wise CH_4 emission from Rural domestic wastewater, 2005 to 2013

State/Union Territory	CH_4 Emission from Rural Domestic Wastewater (Mil. Tonnes of CO_2e)									Average Percent Share in Emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Andaman & Nicobar	0.008	0.008	0.008	0.008	0.008	0.008	0.013	0.013	0.013	0.049%
Andhra Pradesh	1.524	1.540	1.556	1.572	1.588	1.604	2.056	2.079	2.101	8.703%
Arunachal Pradesh	0.022	0.022	0.023	0.023	0.024	0.025	0.030	0.031	0.032	0.130%
Assam	0.549	0.558	0.567	0.575	0.584	0.593	0.674	0.685	0.697	3.055%
Bihar	1.184	1.211	1.238	1.266	1.293	1.320	1.702	1.745	1.788	7.104%
Chandigarh	0.002	0.002	0.002	0.002	0.002	0.002	0.000	0.000	0.000	0.007%
Chhattisgarh	0.360	0.367	0.375	0.382	0.390	0.397	0.477	0.488	0.499	2.082%
Dadra & Nagar Haveli	0.007	0.007	0.007	0.008	0.008	0.008	0.007	0.007	0.008	0.037%
Daman & Diu	0.006	0.006	0.006	0.007	0.007	0.007	0.004	0.004	0.004	0.028%
Delhi	0.048	0.049	0.050	0.051	0.052	0.053	0.030	0.030	0.031	0.219%
Goa	0.022	0.023	0.023	0.023	0.023	0.023	0.029	0.030	0.030	0.126%
Gujarat	0.847	0.862	0.877	0.892	0.907	0.923	1.133	1.155	1.177	4.890%
Haryana	0.331	0.337	0.344	0.350	0.356	0.362	0.593	0.604	0.616	2.169%
Himachal Pradesh	0.068	0.069	0.069	0.070	0.071	0.072	0.168	0.170	0.172	0.517%
Jammu & Kashmir	0.181	0.185	0.189	0.193	0.197	0.200	0.250	0.256	0.262	1.065%
Jharkhand	0.311	0.317	0.324	0.330	0.336	0.343	0.380	0.389	0.397	1.743%
Karnataka	0.835	0.847	0.859	0.871	0.884	0.896	0.990	1.005	1.021	4.574%
Kerala	1.163	1.169	1.175	1.180	1.186	1.191	0.805	0.809	0.813	5.289%
Lakshadweep	0.003	0.003	0.003	0.003	0.003	0.003	0.001	0.001	0.001	0.012%
Madhya Pradesh	0.825	0.841	0.856	0.872	0.887	0.903	1.101	1.124	1.146	4.768%
Maharashtra	1.542	1.565	1.588	1.611	1.635	1.658	2.112	2.145	2.179	8.936%
Manipur	0.039	0.040	0.040	0.041	0.041	0.041	0.051	0.051	0.052	0.220%
Meghalaya	0.047	0.048	0.049	0.050	0.051	0.053	0.066	0.067	0.069	0.279%
Mizoram	0.011	0.011	0.012	0.012	0.012	0.012	0.018	0.018	0.019	0.070%
Nagaland	0.047	0.047	0.047	0.046	0.046	0.046	0.055	0.055	0.055	0.248%
Odisha	0.706	0.715	0.725	0.734	0.744	0.753	0.877	0.889	0.902	3.927%
Puducherry	0.012	0.013	0.013	0.013	0.013	0.014	0.018	0.019	0.019	0.075%
Punjab	0.475	0.481	0.487	0.493	0.500	0.506	0.819	0.830	0.841	3.027%
Rajasthan	0.975	0.994	1.013	1.032	1.051	1.070	1.336	1.365	1.393	5.700%
Sikkim	0.018	0.019	0.019	0.019	0.019	0.019	0.029	0.029	0.029	0.112%
Tamil Nadu	0.950	0.964	0.978	0.992	1.006	1.020	1.160	1.178	1.196	5.264%
Tripura	0.063	0.063	0.064	0.065	0.066	0.067	0.065	0.066	0.067	0.339%
Uttar Pradesh	2.801	2.853	2.906	2.958	3.010	3.063	4.141	4.225	4.309	16.867%
Uttarakhand	0.157	0.160	0.163	0.165	0.168	0.171	0.292	0.298	0.303	1.047%

State/Union Territory	CH_4 Emission from Rural Domestic Wastewater (Mil. Tonnes of CO_2e)									Average Percent Share in Emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
West Bengal	1.349	1.367	1.384	1.402	1.420	1.438	1.579	1.600	1.622	7.334%
State Aggregate CH_4 emission (Rural)	17.486	17.762	18.037	18.313	18.589	18.865	23.061	23.464	23.866	100.000%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Table 12: State-wise N_2O emission from Rural domestic wastewater, 2005 to 2013

State/Union Territory	N_2O emission from Rural Domestic Wastewater (Mil. tonnes CO_2e)									Average Percent Share in Emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Andaman & Nicobar	0.003	0.003	0.003	0.003	0.004	0.004	0.004	0.004	0.004	0.03%
Andhra Pradesh	0.692	0.693	0.694	0.695	0.752	0.754	0.796	0.798	0.799	6.32%
Arunachal Pradesh	0.016	0.016	0.017	0.017	0.015	0.015	0.014	0.014	0.014	0.13%
Assam	0.323	0.328	0.333	0.338	0.335	0.339	0.348	0.354	0.359	2.90%
Bihar	1.173	1.199	1.225	1.251	1.228	1.253	1.381	1.415	1.449	10.97%
Chandigarh	0.001	0.001	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.01%
Chhattisgarh	0.210	0.214	0.217	0.221	0.221	0.225	0.242	0.247	0.251	1.94%
Dadra & Nagar Haveli	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.02%
Daman & Diu	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.01%
Delhi	0.010	0.010	0.009	0.008	0.007	0.007	0.006	0.006	0.006	0.07%
Goa	0.007	0.007	0.007	0.007	0.008	0.008	0.007	0.007	0.007	0.06%
Gujarat	0.437	0.441	0.445	0.449	0.467	0.471	0.451	0.455	0.460	3.86%
Haryana	0.271	0.273	0.276	0.278	0.278	0.280	0.289	0.292	0.295	2.40%
Himachal Pradesh	0.098	0.099	0.100	0.102	0.106	0.107	0.113	0.114	0.116	0.90%
Jammu & Kashmir	0.130	0.132	0.135	0.137	0.140	0.143	0.149	0.152	0.155	1.21%
Jharkhand	0.288	0.293	0.298	0.304	0.308	0.313	0.331	0.337	0.344	2.67%
Karnataka	0.436	0.439	0.443	0.446	0.471	0.474	0.496	0.500	0.504	3.99%
Kerala	0.291	0.283	0.275	0.266	0.260	0.251	0.251	0.245	0.238	2.24%
Lakshadweep	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.00%
Madhya Pradesh	0.697	0.709	0.721	0.733	0.768	0.780	0.829	0.845	0.860	6.58%
Maharashtra	0.805	0.813	0.821	0.829	0.875	0.883	0.894	0.903	0.913	7.34%
Manipur	0.026	0.026	0.026	0.026	0.021	0.021	0.021	0.021	0.021	0.20%
Meghalaya	0.026	0.027	0.027	0.028	0.025	0.026	0.026	0.027	0.027	0.23%
Mizoram	0.009	0.009	0.009	0.010	0.007	0.007	0.007	0.007	0.007	0.07%
Nagaland	0.025	0.025	0.025	0.024	0.021	0.021	0.020	0.019	0.019	0.19%
Odisha	0.394	0.398	0.403	0.407	0.444	0.449	0.450	0.455	0.460	3.66%
Puducherry	0.004	0.004	0.004	0.004	0.005	0.006	0.006	0.006	0.006	0.04%
Punjab	0.276	0.278	0.280	0.282	0.282	0.284	0.294	0.297	0.299	2.44%

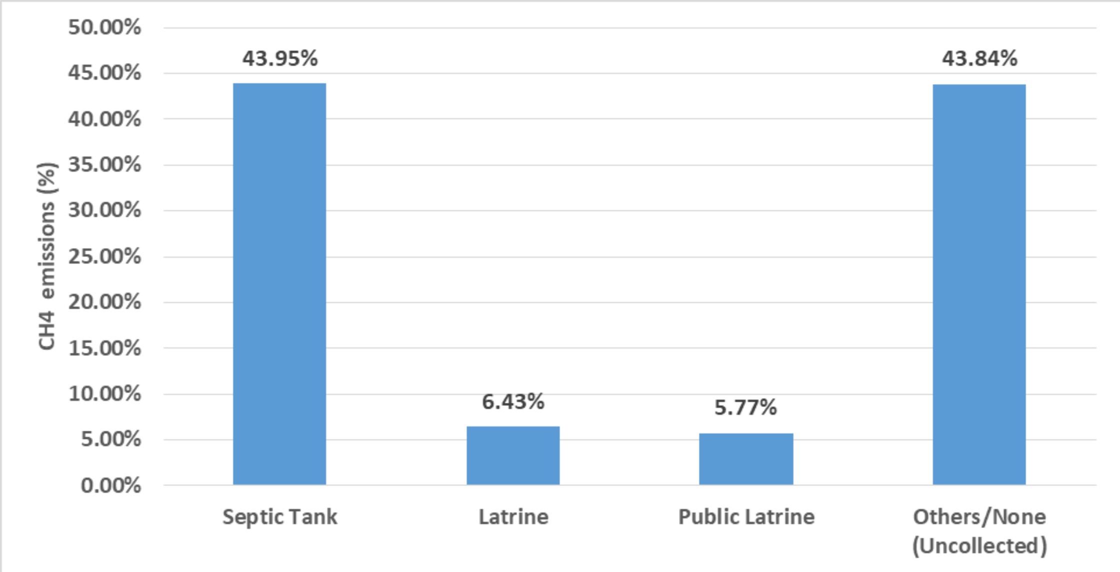
State/Union Territory	N_2O emission from Rural Domestic Wastewater (Mil. tonnes CO_2e)									Average Percent Share in emission (2005-2013)
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Rajasthan	0.807	0.821	0.835	0.850	0.864	0.878	0.899	0.916	0.934	7.40%
Sikkim	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.006	0.05%
Tamil Nadu	0.401	0.403	0.406	0.408	0.454	0.457	0.473	0.476	0.479	3.75%
Tripura	0.031	0.031	0.032	0.032	0.040	0.040	0.038	0.039	0.039	0.31%
Uttar Pradesh	2.315	2.354	2.393	2.431	2.311	2.347	2.372	2.415	2.458	20.28%
Uttarakhand	0.101	0.102	0.103	0.105	0.103	0.104	0.122	0.123	0.125	0.94%
West Bengal	0.770	0.776	0.782	0.788	0.772	0.778	0.830	0.837	0.843	6.80%
State Aggregate N_2O emission (Rural)	11.086	11.220	11.354	11.488	11.602	11.734	12.172	12.335	12.499	100.00%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Domestic wastewater collected through the sewer network in rural areas is not handled or treated downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions. Thus, the 'uncollected' wastewater category is a key source of CH_4 emissions in rural areas (see Figure 16). Among the uncollected type of treatment/discharge systems, the 'Others/None' category, which refers to the wastewater that is not treated and/or directly discharged into 'ground' and 'rivers, lakes, estuaries, sea' is the highest contributor to the total CH_4 emissions from rural domestic wastewater.

This is largely driven by the fact that 51.75% of rural households across the states on average are utilizing this mode of wastewater discharge in the absence of wastewater collection systems. Septic tank systems are used by 25.4% of the rural population on average to handle domestic wastewater as per Census 2011[15] and contributed to 35.8% of the CH_4 emissions from rural domestic wastewater in the states in 2013. Latrine and public latrine systems serve 14.63% and 2.76% of rural population in total respectively across the Indian states as per Census 2011[15]. However, the emissions from public latrine are comparatively higher due to the fact that the MCF of public latrine systems as defined in the 2006 IPCC Guidelines is 0.5 as compared to a MCF value of 0.1 for latrine systems[16]. The state-wise distribution of CH_4 emissions by type of treatment/discharge system due to handling of rural domestic wastewater is given in Table 13.

Figure 16: Share of Aggregate State-level CH_4 Emission by type of Treatment/Discharge system for Rural population, 2013



(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Table 13: Share of State-wise Rural CH_4 emission by type of Treatment/Discharge System, 2013

State/Union Territory	Septic Tank	Latrine	Public Latrine	Others/None (Uncollected)
Andaman & Nicobar	82.93%	1.48%	1.48%	14.11%
Andhra Pradesh	56.37%	2.99%	6.73%	33.90%
Arunachal Pradesh	37.56%	12.88%	9.47%	40.09%
Assam	29.73%	26.65%	7.16%	36.45%
Bihar	38.61%	1.46%	3.33%	56.60%
Chandigarh	26.17%	0.11%	35.08%	38.65%
Chhattisgarh	28.89%	3.12%	1.14%	66.85%
Dadra & Nagar Haveli	56.85%	0.39%	6.89%	35.87%
Daman & Diu	69.25%	0.11%	20.52%	10.12%
Delhi	79.92%	1.42%	13.91%	4.75%
Goa	83.88%	1.87%	2.75%	11.50%
Gujarat	56.84%	3.32%	3.16%	36.69%
Haryana	62.65%	10.96%	3.80%	22.59%
Himachal Pradesh	84.21%	2.89%	1.45%	11.45%
Jammu & Kashmir	34.92%	3.75%	10.02%	51.30%
Jharkhand	20.36%	0.98%	2.85%	75.81%
Karnataka	33.07%	9.47%	11.35%	46.12%
Kerala	81.26%	12.39%	2.19%	4.17%

State/Union Territory	Septic Tank	Latrine	Public Latrine	Others/None (Uncollected)
Lakshadweep	99.30%	0.00%	0.31%	0.39%
Madhya Pradesh	30.72%	1.92%	1.85%	65.51%
Maharashtra	47.83%	7.03%	15.45%	29.70%
Manipur	46.63%	24.53%	5.15%	23.69%
Meghalaya	36.54%	16.92%	9.94%	36.60%
Mizoram	58.33%	23.03%	6.34%	12.30%
Nagaland	48.71%	15.14%	19.62%	16.53%
Odisha	28.70%	2.43%	4.42%	64.46%
Puducherry	72.43%	0.40%	2.80%	24.37%
Punjab	70.09%	11.65%	3.22%	15.03%
Rajasthan	34.75%	4.82%	1.77%	58.65%
Sikkim	88.42%	4.44%	1.44%	5.70%
Tamil Nadu	42.08%	2.98%	10.23%	44.71%
Tripura	19.46%	49.82%	11.83%	18.90%
Uttar Pradesh	39.47%	2.96%	3.62%	53.95%
Uttarakhand	71.92%	5.92%	1.88%	20.28%
West Bengal	32.18%	18.62%	6.92%	42.28%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

1.11 4D2 Industrial Wastewater Treatment and Discharge

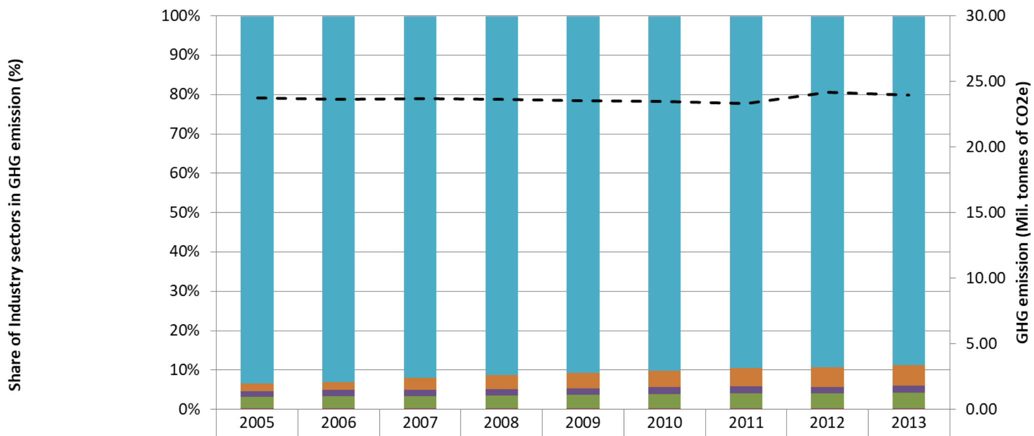
State level GHG emission estimates for industrial wastewater include 10 industrial sectors - Fertilizers, Meat, Sugar, Coffee, Pulp and Paper, Petroleum, Rubber, Dairy and Tannery, Iron and Steel – production in all 10 sectors results in generation of wastewater with significant organic load with potential to release CH_4 emissions, which is dependent on the type of wastewater treatment. As seen from Figure 17, not much variation is observed year on year in the cumulative state-level industrial wastewater emission estimates across sectors.

In the absence of recorded information on sector-wise volume of wastewater generated by industries across the Indian states, industrial production is a key parameter required to estimate the total wastewater generation[18] by industry sector and the CH_4 emission resulting from its degradable organic concentration and the treatment technology used. However, during the assessment it was observed that the requisite industrial production data for the 10 industrial sectors under consideration is not available in a single source dataset, thereby necessitating the use of multiple data sources for each of the industrial sectors. A number of issues have been observed with regard to the availability, reliability and quality of reported activity data on state-level industrial production in particular. This has necessitated of the use of apportionment or approximation in the emission estimation process for 8 of the 10 industry sectors. The inherent inconsistencies and low reliability of data has impacted the reliability of the emission estimates and also limits inferences that can be drawn from the emission trends.

The cumulative GHG emission from industrial wastewater treatment and discharge has increased from 23.75 Mil. tonnes CO_2e in 2005 to 23.99 Mil. tonnes CO_2e in 2013, at a CAGR of 0.12% (see Table 1). The Pulp and Paper sector is observed to have the highest contribution to the state GHG emissions from industrial wastewater treatment/discharge.

Figure 17: Aggregate State-level GHG Emission from Industrial wastewater treatment and discharge, 2005-2013

[18] Total annual volume of wastewater generated (in cubic meters) is estimated based on the industrial production (in tonnes) and the unit wastewater generation per tonne of product (cubic meters/tonne) based on the methodology outlined in the 2006 IPCC Guidelines for National GHG Inventories, Vol.5, Chapter 6 - Wastewater treatment and discharge, Table 6.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf



	2005	2006	2007	2008	2009	2010	2011	2012	2013
Tannery	0.21%	0.22%	0.22%	0.23%	0.24%	0.24%	0.24%	0.24%	0.26%
Rubber	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Pulp & Paper	93.02%	92.55%	91.43%	90.90%	90.34%	89.76%	88.98%	88.84%	88.32%
Petroleum	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Meat	1.98%	1.98%	3.05%	3.59%	3.85%	4.11%	4.63%	4.86%	5.18%
Iron & Steel	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Fertilizers	1.48%	1.65%	1.55%	1.49%	1.64%	1.71%	1.72%	1.65%	1.68%
Dairy	2.85%	3.02%	3.17%	3.32%	3.46%	3.62%	3.83%	3.83%	4.01%
Coffee	0.22%	0.23%	0.21%	0.23%	0.24%	0.24%	0.25%	0.25%	0.24%
Total emissions (Mil. tonnes of CO2e)	23.75	23.64	23.71	23.62	23.54	23.47	23.31	24.20	23.99

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

The cumulative percent change in emissions in 2013 over the 2005 baseline values along with corresponding increase in industrial production, for each industry sector is given in Table 14. Available information on Pulp and Paper sector based on a CSE study indicates that wastewater generation in the Pulp and Paper sector has reduced, at an average annual rate of 7.4%[19]. The impact of reduced wastewater generation on GHG emissions is evident for the Pulp and Paper sector, wherein GHG emissions have decreased by 4.1% cumulatively between 2005 and 2013. It is much lower than the 67% increase recorded in industrial production over this period. Due to unavailability of latest year-on-year values for wastewater generation per unit of product, constant values are used for the other industry sectors in this assessment (see section 3.6.2 for more details). Use of constant value for other industry sector results in limitations in estimations as it restricts capturing impacts of improvements in process and technology on wastewater generation and GHG emissions. Thereby, growth in estimated GHG emission matches the corresponding increase in industrial production for the industry sectors other than Pulp and Paper.

Table 14: Change in Industrial Production and Wastewater emission by industry sector, 2005-2013

Industry Sector[20]	Increase in production in 2013 over 2005	Increase in GHG emissions in 2013 over 2005 baseline
Fertilizers	11.2%	14.3%
Sugar	38.4%	38.4%
Coffee	12.2%	12.2%
Dairy	42.1%	42.1%
Meat	163.8%	163.8%
Pulp & Paper	67.3%	-4.1%
Tannery	20.7%	20.7%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

The Pulp & paper, Coffee, Meat and Tannery sectors, are ones with the highest GHG emission per tonne of product or per unit volume of treated wastewater.

[19] CSE (2013): Paper Through Time – Tracking the Industry's Progress.
Available at http://ipma.co.in/wp-content/uploads/2015/11/CSE-Paper-Industry-Report-2013.pdf

[20] In the assessment, the condition of the prevalent aerobic type wastewater treatment systems for Iron & Steel, Petroleum and Rubber industries is assumed to be well managed, and thereby these systems have Methane Correction Factor value of zero and thereby an emission factor value of zero (based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories), thereby leading to no CH_4 emissions from wastewater treatment. Thus, the Iron & Steel, Petroleum and Rubber sectors are not included in Table 14.

Table 15: Average industrial wastewater GHG emission per tonne of product and per m³ of wastewater generated for Industrial Sectors in India (2005-2013)

INDUSTRY SECTORERROR! BOOKMARK NOT DEFINED.	GHG EMISSION PER TONNE OF PRODUCT (KG OF CO_2e)	GHG EMISSION PER M³ OF WASTEWATER GENERATED (KG OF CO_2e)
Coffee	189.0	37.79
Pulp & Paper	1,749.50	24.78
Meat	201	17.22
Tannery	104	3.25
Fertilizers	25.20	3.15
Sugar	3.15	3.15
Dairy	7.06	2.35

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Based on the estimated emissions, it is seen that the seven states of Uttar Pradesh, Gujarat, Andhra Pradesh, Tamil Nadu, Maharashtra, Punjab and Uttarakhand contribute to nearly 80% of the total industrial wastewater emissions, with Uttar Pradesh and Gujarat contributing nearly 17% each (see Table 17). This stems from the higher level of industrial activity (i.e. industrial production) reported for these states; primarily for the Pulp and paper industry along with the Meat and Dairy sectors. The percent change in estimated emissions for the states in 2013 over the 2005 baseline values is given in Table 16. However, given that the reliability of state-level data used in this assessment varies across the sectors and years, it is advisable to exercise caution while drawing conclusions from the state-wise trend.

Table 16: Change in Industrial Wastewater emission by State, 2005-2013

STATE/UNION TERRITORY	CHANGE IN GHG EMISSIONS IN 2013 OVER 2005 BASELINE
Andaman & Nicobar	298.60%
Andhra Pradesh	3.29%
Arunachal Pradesh	5.47%
Assam	3.76%
Bihar	53.52%
Chandigarh	-9.75%
Chhattisgarh	12.58%
Dadra & Nagar Haveli	286863.79%*
Daman & Diu	539.42%
Delhi	65.97%
Goa	-0.26%
Gujarat	-2.09%
Haryana	17.38%
Himachal Pradesh	-7.01%
Jammu & Kashmir	-3.10%
Jharkhand	5.16%
Karnataka	-3.78%
Kerala	-2.94%
Lakshadweep	546.73%
Madhya Pradesh	0.24%
Maharashtra	0.43%
Manipur	8.70%
Meghalaya	8.48%
Mizoram	34.93%
Nagaland	9.21%
Odisha	-1.83%
Puducherry	119.97%
Punjab	-1.35%
Rajasthan	24.42%
Sikkim	-92.28%
Tamil Nadu	2.34%

STATE/UNION TERRITORY	CHANGE IN GHG EMISSIONS IN 2013 OVER 2005 BASELINE
Telangana	0.00%
Tripura	181.89%
Uttar Pradesh	5.05%
Uttarakhand	-9.26%
West Bengal	3.28%
Total CO_2e emissions (tonnes)	1.00%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Note: The percent change for Dadra & Nagar Haveli is very high due to no industrial activity being reported in 2005, which may be a result of erroneous reporting. Industrial production data has been reported starting from year 2008 for Dadra & Nagar Haveli and the percent change in emissions from 2008-2013 is observed to be 20%.

Table 17: State-wise GHG Emission from Industrial wastewater treatment and discharge, 2005-2013

State/Union Territory	GHG Emission (Mil. Tonnes of CO_2e)									Percent Share in 2013
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Andaman & Nicobar	0.00007	0.00006	0.00006	0.00006	0.00008	0.00008	0.00008	0.00009	0.0003	0.001%
Andhra Pradesh	2.355	2.336	2.326	2.317	2.318	2.274	2.219	2.455	2.433	10.1%
Arunachal Pradesh	0.0003	0.0004	0.0004	0.0004	0.0004	0.0004	0.0004	0.0003	0.0003	0.015%
Assam	0.355	0.344	0.342	0.337	0.335	0.311	0.303	0.348	0.368	1.5%
Bihar	0.043	0.044	0.048	0.050	0.052	0.053	0.0554	0.056	0.066	0.3%
Chandigarh	0.00020	0.00020	0.00020	0.00020	0.00020	0.00020	0.00019	0.00018	0.00018	0.001%
Chhattisgarh	0.058	0.056	0.058	0.058	0.059	0.054	0.053	0.066	0.065	0.3%
Dadra & Nagar Haveli	0.000	0.000	0.000	0.00001	0.00002	0.00002	0.00002	0.00002	0.00002	0.0001%
Daman & Diu	0.00001	0.0	0.00005	0.00005	0.00004	0.00004	0.00004	0.00004	0.00007	0.0003%
Delhi	0.029	0.030	0.031	0,032	0.032	0.036	0.039	0.045	0.048	0.2%
Goa	0.014	0.015	0.015	0.015	0.017	0.016	0.015	0.013	0.014	0.1%
Gujarat	4.10	4.07	4.03	3.99	3.97	4.02	3.76	4.01	4.02	16.8%
Haryana	0.296	0.303	0.329	0.341	0.343	0.371	0.374	0.369	0.347	1.4%
Himachal Pradesh	0.235	0.237	0.235	0.233	0.231	0.236	0.237	0.232	0.219	0.9%
Jammu & Kashmir	0.053	0.055	0.055	0.055	0.054	0.056	0.057	0.055	0.052	0.2%
Jharkhand	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.009	0.038%
Karnataka	1.088	1.094	1.086	1.077	1.073	1.055	1.089	1.110	1.046	4.4%
Kerala	0.400	0.406	0.399	0.399	0.400	0.423	0.409	0.406	0.388	1.6%
Lakshadweep	0.013	0.014	0.023	0.025	0.024	0.025	0.071	0.082	0.083	0.3%
Madhya Pradesh	0.356	0.359	0.359	0.358	0.357	0.361	0.362	0.369	0.357	1.5%
Maharashtra	2.240	2.269	2.304	2.298	2.293	2.345	2.350	2.354	2.250	9.4%
Manipur	0.0046	0.0046	0.0047	0.0047	0.0048	0.0048	0.0049	0.0050	0.0050	0.021%
Meghalaya	0.0074	0.0073	0.0074	0.0075	0.0075	0.0076	0.0077	0.0078	0.0080	0.034%
Mizoram	0.0018	0.0020	0.0022	0.0025	0.0022	0.0020	0.0025	0.0025	0.0025	0.010%
Nagaland	0.013	0.013	0.007	0.011	0.013	0.013	0.015	0.015	0.014	0.1%
Odisha	0.597	0.607	0.613	0.611	0.612	0.639	0.635	0.610	0.586	2.4%
Puducherry	0.0016	0.0022	0.0021	0.0022	0.0025	0.0030	0.0033	0.0034	0.0035	0.014%

STATE/UNION TERRITORY	GHG EMISSION (MIL. TONNES OF CO_2e)									PERCENT SHARE IN 2013
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Punjab	1.844	1.838	1.834	1.821	1.812	1.830	1.824	1.798	1.819	7.6%
Rajasthan	0.172	0.166	0.169	0.171	0.173	0.170	0.176	0.180	0.213	0.9%
Sikkim	0.0104	0.0036	0.0005	0.0004	0.0007	0.0008	0.0008	0.0008	0.0008	0.003%
Tamil Nadu	2.602	2.565	2.571	2.559	2.548	2.551	2.414	2.531	2.663	11.1%
Tripura	0.0023	0.0026	0.0028	0.0036	0.0042	0.0046	0.0050	0.0061	0.0066	0.027%
Uttar Pradesh	3.891	3.859	3.909	3.912	3.899	3.912	3.783	3.982	4.088	17.0%
Uttrakhand	1.900	1.930	1.912	1.893	1.875	1.930	1.930	1.916	1.724	7.2%
West Bengal	1.049	0.998	1.016	1.021	1.018	0.756	1.107	1.163	1.083	4.5%
Total	23.749	23.643	23.705	23.618	23.539	23.468	23.308	24.200	23.986	100%

(Source: Analysis based on GHG Platform India – Phase II: 2005 – 2013 State Estimates – 2017 Series)

Waste Sector

1.12 Overview of the sector

Waste management activities such as collection, treatment and disposal of solid waste and wastewater lead to GHG emission in the form of CH_4 and N_2O gases. Waste sector emissions are a result of the degradation of organic material under anaerobic conditions. Under the reporting structure of the 2006 IPCC Guidelines for National GHG inventories, key sources of GHG emission in the Waste sector include 4A solid waste disposal, 4D1 domestic wastewater treatment and discharge and 4D2 industrial wastewater treatment and discharge.

- The aggregated State-level emissions from the Waste sector in India in the year 2013 were 93.78 Mil. tonnes of CO_2e, an increase of 26% (or 19. 16 Mil. tonnes of CO_2e) from 2005.
- Within the sector, domestic wastewater treatment and discharge emissions grew by 34% (or 15.12 Mil. tonnes of CO_2e) and contributed to 62.9% (58.94 Mil. tonnes of CO_2e) of the Waste sector emissions for year 2013.
- GHG emissions from industrial wastewater treatment and discharge in 2013 were 23.99 Mil. tonnes of CO_2e, contributing to 25.6% of the total Waste sector emissions. The industrial wastewater related emissions increased by 1% (or 0.24 Mil. tonnes of CO_2e) from 2005 to 2013.
- Solid waste disposal contributed to GHG emission of 10.85 Mil. tonnes of tCO_2e in the year 2013, accounting for 11.6% of the Waste sector emissions. The emissions from solid waste disposal have increased by 54% (an absolute increase of 3.80 Mil. tonnes of CO_2e) from the base year 2005.

Table 18: Gas-wise Aggregated State-level GHG emission for Source Categories in the Waste sector, 2013

IPCC ID	GHG SOURCE AND SINK CATEGORIES	CH_4 (MIL. TONNES CH_4)	N_2O (MIL. TONNES N_2O)	CO_2e[2] (MIL. TONNES) BASED ON GWP VALUES FROM IPCC SECOND ASSESSMENT REPORT[3]	CO_2e (MIL. TONNES) BASED ON GWP VALUES FROM IPCC FIFTH ASSESSMENT REPORT[4]
4.	**Waste**	**3.59**	**0.06**	**93.78**	**116.28**
4A	**Solid Waste Disposal**	**0.52**		**10.85**	**14.47**
4A2	Unmanaged Waste Disposal Sites	0.52	-	10.85	14.47
4D	**Wastewater Treatment and Discharge**	**3.08**	**0.06**	**82.93**	**101.81**
4D1	Domestic Wastewater Treatment and Discharge	1.93	0.06	58.94	69.83
4D2	Industrial Wastewater Treatment and Discharge	1.14	-	23.99	31.98

1.13 Boundary of GHG estimates

The geospatial boundary of State-level GHG emission estimates for the Waste sector includes all the 36 states and union territories in India (referred to as 'states' throughout this document), spanning a geographical area of 3.28 million sq. km. India houses a population of 1.2 billion as per Census 2011. It is the seventh largest country by area and second largest by population holding about 18% of the world's population[21]. India lies between latitudes 8° N & 36° N and longitudes 66° E & 98° E[21].

Based on estimates of the Central Statistics Office, India's GDP (at constant 2011-12 prices) in the year 2015-16 stood at INR 136,753,310 million, with economy growing at 7.2% in 2014-15 and 7.6% in 2015-16[22]. Economic development has implications on the Waste sector– with growing urbanization, economic activity, improved standards of living and disposal incomes impacting consumption patterns, waste composition, and leading to higher rates of waste generation[23]. GDP varies across the Indian states as shown in Table 19, and the

[21] India's Second National Communication to the United Nations Framework Convention on Climate Change, Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf
[22] KPMG (2016): India Economic Survey 2015-16 – Key Highlights
[23] World Bank (2012): Urban Development Series Knowledge Papers: What a Waste- A Global Review of Solid Waste Management. Available at

diversity in the Indian states is also seen in the Waste Sector in terms of the quantum of waste and wastewater generation, its characteristics, and management.

Table 19: Gross State Domestic Product, 2005-06 to 2013-14 (at constant 2004-05 prices)

STATE/UNION TERRITORY	GROSS STATE DOMESTIC PRODUCT IN MILLION INR (2005-06)	GROSS STATE DOMESTIC PRODUCT IN MILLION INR (2013-14)	CAGR
Andhra Pradesh	1,419,770	2,467,240	7.15%
Arunachal Pradesh	35,840	59,050	6.44%
Assam	552,140	868,620	5.83%
Bihar	764,660	1,734,090	10.78%
Chhattisgarh	494,080	952,620	8.55%
Goa	136,720	303,450	10.48%
Gujarat	2,337,760	4,526,250	8.61%
Haryana	1,046,080	1,996,570	8.42%
Himachal Pradesh	261,070	472,550	7.70%
Jammu & Kashmir	288,830	458,470	5.95%
Jharkhand	578,480	1,094,080	8.29%
Karnataka	1,842,770	3,214,550	7.20%
Kerala	1,312,940	2,262,080	7.04%
Madhya Pradesh	1,189,190	2,300,950	8.60%
Maharashtra	4,709,290	8,967,670	8.38%
Manipur	54,590	83,300	5.42%
Meghalaya	70,780	133,470	8.25%
Mizoram	28,690	56,080	8.74%
Nagaland	64,360	113,670	7.37%
Odisha	821,450	1,374,680	6.65%
Punjab	1,025,560	1,740,380	6.83%
Rajasthan	1,362,850	2,574,320	8.27%
Sikkim	19,090	61,520	15.75%
Tamil Nadu	2,495,670	4,806,180	8.54%
Telangana	1,042,330	2,064,270	8.92%
Tripura	94,220	187,320	8.97%
Uttar Pradesh	2,778,180	4,645,100	6.64%
Uttarakhand	283,400	709,260	12.15%
West Bengal	2,217,890	3,717,950	6.67%
Andaman & Nicobar Islands	19,070	42,200	10.44%
Chandigarh	94,130	156,880	6.59%
Delhi	1,104,060	2,199,910	9.00%
Puducherry	71,880	140,770	8.76%

http://siteresources.worldbank.org/INTURBANDEVELOPMENT/Resources/336387-1334852610766/What_a_Waste2012_Final.pdf

1.14 Overview of Source Categories and Methodology

The emission estimates for the Waste sector in this assessment include emissions from the following source categories and sub-categories:

- 4A Solid waste disposal:
  - 4A2 Unmanaged Waste Disposal Sites
- 4D Wastewater treatment and discharge:
  - 4D1 Domestic Wastewater Treatment and Discharge
  - 4D2 Industrial Wastewater Treatment and Discharge

4A Solid waste disposal: CH_4 emissions from solid waste disposal depend on the amount and composition of the waste disposed into solid waste disposal sites and the condition of the disposal sites.

- Given that scientific waste disposal practices and landfill facilities are lacking across the states in India, the sub-category '4A2 Unmanaged waste disposal sites' is appropriately selected to represent the prevalent unmanaged waste disposal in the Indian context.
- Given that during the reporting period, an insignificant quantum of waste is disposed in scientifically designed and managed waste disposal sites, the source category of '4A1: Managed waste disposal sites' is not yet applicable in the Indian context and therefore not considered in the present estimation.
- It is widely acknowledged and is corroborated from reports[24] that the prevalent mode of waste disposal is in unmanaged open disposal sites and hence 4A3: Uncategorized waste disposal sites' is also not considered.
- The scope of emission estimation from solid waste disposal is limited to the urban areas within Indian states, given that rural areas lack the requisite waste management and disposal systems and thereby GHG emission generation can be insignificant in the absence of controlled/semi-controlled anaerobic conditions, in line with India's Second National Communication and Biennial Update Report 2010.

4D Wastewater treatment and discharge: Treatment and discharge of wastewater in anaerobic conditions also releases significant amount of CH_4 emissions. N_2O emissions are also generated by bacteria (denitrification and nitrification) in wastewater treatment and discharge.

- This emission source category is further divided into two sub-categories, namely '4D1 Domestic wastewater treatment and discharge' and '4D2 industrial wastewater treatment and discharge'.
- CH_4 and N_2O emissions from domestic wastewater due to treatment and discharge of liquid waste and sludge from housing and commercial sources, through various systems such as centralised sewage systems, open pits/ latrines, anaerobic lagoons, anaerobic reactors and direct discharge into surface waters are included under sub-category 4D1 in the emission estimates.
- CH_4 emissions from industrial wastewater due to treatment and discharge of liquid wastes from industrial processes in 10 industry sectors are included under sub-category 4D2 in the state-level emission estimates.

Emissions from the categories '**4B Biological treatment of solid waste**' and '**4C Incineration and open burning of waste**' are not included in the state estimates due to the lack of reliable activity data for these categories and the absence of considerable number of waste incineration and composting facilities within the reporting period.

The emission estimation for the solid waste disposal is based on a combination of IPCC Tier I and Tier 2 approaches. Emissions related to treatment and discharge of both domestic and industrial wastewater is largely based on Tier I approach due to limited availability of state-level and country-specific data as well as emission factors for these sources. While use of state-level activity data has been prioritized, national-level and IPCC default values are used where requisite reliable state-level activity data is not available. Data gaps have been addressed through assumptions as appropriate, particularly for the industrial wastewater sub-sector. Further details of methodological approach and data sources for the source categories considered in the estimates are provided in the following sections.

[24] ADB (2009): Project Document on 'Best Practices for Municipal Solid Waste Management in South Asia: A New Knowledge Product'. Available at https://www.adb.org/sites/default/files/project-document/63293/40124-reg-spr-09.pdf

1.15 4A2 Unmanaged Waste Disposal Sites

1.15.1 Category Description

When solid waste is disposed in landfills or in dumpsites and in the presence of anaerobic conditions, methanogenic bacteria break-down the degradable organic component in the waste, releasing CH_4 emissions. Decomposition of the organic content occurs slowly and the CH_4 emissions from a given mass of solid waste deposited continue to be released over a time period spanning a few decades.

This assessment covers the disposal of municipal solid waste in the Indian states. Municipal solid waste is generally defined as waste collected by local municipal governments or other local authorities, typically including residential, commercial and institutional waste, street sweepings, and garden and park waste in either solid or semi-solid form (excluding industrial, hazardous, bio-medical and e-waste). Industrial waste and other waste such as clinical waste and hazardous waste are not considered in the emission estimation, given the lack of reliable information for these waste streams and in accordance with India's Second National Communication Report[6]. Furthermore, as indicated previously, disposal of municipal solid waste in rural areas is not included in the estimation since decomposition of rural waste occurs largely in the absence of anaerobic conditions and thereby does not lead to significant CH_4 emission generation.

Systematic and scientific disposal of waste is lacking in most of the Indian cities. The landfill sites are not properly constructed, and operation and maintenance of the landfill is inadequate as well. Most of the disposal sites are thereby unmanaged and are generally observed to be shallow[11]. Therefore, the source category '4A2: Unmanaged waste disposal sites' is considered for emission estimation from solid waste disposal in India.

Secondary state-level activity data obtained from key governmental organizations and research institutes including the CPCB, SPCB, CPHEEO, and NEERI has been primarily used in this assessment. The activity data used is of medium quality as data has been extrapolated using specific data sets and appropriate assumptions have been used to address data gaps in the state level datasets. National level data has been used where reliable state level data is not available.

Table 20: Principal Sources and Quality of Data for Solid Waste Disposal Estimates

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
4	**Waste**			
4A	**Solid Waste Disposal**			
4A2	Unmanaged Waste Disposal Sites	Secondary	Medium	CPCB, SPCB, NEERI, CPHEEO

A combination of country specific emission factors and default values for coefficients as per the 2006 IPCC Guidelines have been used in the estimation across the reporting period. The emission factors and assumptions have largely been sourced from India's Second National Communication[6], relevant publications from NEERI[25], and the 2006 IPCC Guidelines[8], in this order of preference, to prioritize the use of country specific emission factors and parameters (see the section 3.4.2 on methodology for further details on assumptions and emission factors used).

An assessment of the quality of activity data and emission factors used in the estimation is indicated in the Table 21 below. The quality has been assessed based on the source of the data[25] and its availability. Published data sourced from government institutions and agencies is deemed to be of 'high' quality for the years where such published data is available. For years wherein no data has been published for the parameter, the quality is assigned as 'low', with suitable assumptions used to address data gaps in such cases. Emission factors and default values sourced from the 2006 IPCC Guidelines[8] have been assessed to be of 'high' quality.

- Data and trends from Census of India, 2001 and Census of India, 2011 has been used for state population estimates and therefore, the quality of data is considered as 'high' across all years.
- Published data relating to mass of waste deposited (i.e. waste generation, processing and disposal) is available from NEERI, CPCB[25] and India's Second National Communication[6] for the years 2005, 2007,

[25] Data sources for all parameters for solid waste disposal are indicated further in section 3.4.2 of this note.

2011, 2013 and 2014. Therefore, the quality for the activity data on mass of waste deposited[26] is assessed to be 'High' for these years and 'low' for the rest of the years wherein information is not available. A qualitative assessment of the activity data relating to 'mass of waste deposited' for each state is provided in Table 85 in Annexure 6.4.

- The degradable organic carbon (DOC) content is a key parameter for emission estimation using the FOD model and its value depends on the waste composition. To factor in the differences in waste composition across the states, the DOC content has been estimated using available secondary data from NEERI and CPCB[25] on waste composition in each state for year 2005 and the data quality is deemed to be 'high'. Since reliable data on waste composition is not available for the rest of the years, the data is assessed to be of 'low' quality.
- Values for the following emission factors and related parameters are sourced from the 2006 IPCC Guidelines[8]. Therefore, the quality is assessed to be 'high' across the emission estimation period.
    - Fraction of Degradable Organic Carbon which Decomposes (DOC_f)
    - Methane Correction Factor (MCF)
    - Fraction of CH_4 in generated landfill gas (F)
    - Oxidation factor (OX)
    - Methane Recovery (R)
    - Reaction constant (k)

Table 21: Qualitative Assessment of Year-wise Activity and Emission Factor Data used in the Solid Waste Disposal Estimates

S. No.	Data/Emission Factor	Quality									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	**Activity Data**										
(a)	Population	H	H	H	H	H	H	H	H	H	H
(b)	Mass of Waste deposited (W)	H	L	H	L	L	L	H	L	H	H
2	**Emission Factors**										
(a)	Degradable Organic Carbon (DOC)	H	L	L	L	L	L	L	L	L	L
(b)	Fraction of Degradable Organic Carbon which Decomposes (DOC_f)	H	H	H	H	H	H	H	H	H	H
(c)	Methane Correction Factor (MCF)	H	H	H	H	H	H	H	H	H	H
(d)	Fraction of CH_4 in generated landfill gas (F)	H	H	H	H	H	H	H	H	H	H
(e)	Oxidation factor (OX)	H	H	H	H	H	H	H	H	H	H
(f)	Methane Recovery (R)	H	H	H	H	H	H	H	H	H	H
(g)	Reaction constant (k)	H	H	H	H	H	H	H	H	H	H

Notes: H- high, L-low

1.15.2 Methodology

The overall methodology followed for state-level solid waste disposal emission estimates is a mix of Tier I and Tier 2 approach. A top-down approach is followed in the collection of secondary activity data and estimation of CH_4 emissions from solid waste disposal for the states.

Table 22: Type of Emission Factor and Level of Methodological Tiers adopted for Solid Waste Disposal Estimates

IPCC ID	GHG source & sink categories	CH_4	
		Method Applied	Emission Factor

[26] Time series data on mass of waste going to disposal sites for the 50 years before 2005 is not available at the state-level. Therefore, it becomes necessary to estimate the total waste generated using data on urban population and the per capita waste generation and subsequently work out the extent of generated waste that is dumped in disposal sites based on information on waste processing.

4A2	Unmanaged Waste Disposal Sites	T1, T2	D, CS

Notes: T1: Tier 1; T2: Tier 2; CS: Country-specific; D: IPCC default

The FOD model outlined in the 2006 IPCC Guidelines[8] to estimate emissions from decomposition of solid waste in disposal sites over a period of time is used in this assessment. The FOD model considers that waste deposited in a disposal site at a point in time decomposes gradually and the residual waste (material that remains after the partial decomposition of waste during anaerobic digestion process) continues to undergo anaerobic digestion again and generate CH_4 over a subsequent period of time (around 50 years). CH_4 emission will be generated until the waste deposited in the disposal site decomposes completely and reaches its full methane generation potential. The FOD model estimates the actual methane generation at a given point of time, accounting for the total methane generation over a preceding time period. The CH_4 generation potential of the waste that is disposed in a certain year will decrease gradually throughout the following decades. In this process, the release of CH_4 from this specific amount of waste decreases gradually.

As per the 2006 IPCC Guidelines[27] and India's Second National Communication[6], the following equations are used to estimate CH_4 emission from Solid waste disposal:

CH_4 EMISSION FROM SOLID WASTE DISPOSAL SITES

$$CH4\ Emissions = [\sum CH_4\ generatedT - R_T] * (1 - OXT)$$

CH_4 Emissions = CH_4 emitted in year T, Gg
T = inventory year
x = waste category or type/material
R_T = recovered CH_4 in year T, Gg (default value of 0[28])
OX_T = oxidation factor in year T, (fraction) (default value of 0[29])

The amount of CH_4 formed from decomposable material is found by multiplying the CH_4 fraction in generated landfill gas and the CH_4/C molecular weight ratio (16/12).

CH_4 GENERATED FROM DECAYED DDOCm

$$CH4\ generatedT = DDOCm_{decompT} * F * 16/12$$

Where,
$CH_{4generatedT}$ = amount of CH_4 generated from decomposable material
$DDOC_{m,decompT}$ = Decomposable Degradable Organic Carbon ($DDOC_m$) decomposed in year T, Gg
F = fraction of CH_4, by volume, in generated landfill gas (fraction) (default value of 0.5[28])
16/12 = molecular weight ratio CH_4/C (ratio)

The basis for the calculation is the amount of $DDOC_m$. $DDOC_m$ is the part of the organic carbon that will degrade under the anaerobic conditions in the solid waste disposal site.

It equals the product of the mass of waste deposited (W) for each state, the fraction of degradable organic carbon in the waste (DOC), the fraction of the degradable organic carbon that decomposes under anaerobic conditions (DOC_f), and the part of the waste that will decompose under aerobic conditions (prior to the conditions becoming anaerobic) in the solid waste disposal site, which is interpreted with the methane correction factor (MCF).

DECOMPOSABLE DOC FROM WASTE DISPOSAL DATA[30]

$$DDOC_m = W * DOC * DOCf * MCF$$

[27] As per IPCC 2006 Guidelines, Vol. 5
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[28] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Section 3.2.3.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[29] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.2.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[30] As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.2.

Where,

$DDOC_m$	= mass of decomposable DOC deposited, Gg
W	= mass of waste deposited for the state, Gg
DOC	= degradable organic carbon for the respective state in the year of deposition, fraction, Gg C/Gg waste
DOC_f	= fraction of DOC that can decompose (fraction) (Default value of 0.5[28])
MCF	= CH_4 correction factor for aerobic decomposition in the year of deposition (fraction) (default value of 0.4[31])

The DOC in bulk waste is estimated based on the composition of waste and can be calculated from a weighted average of the degradable carbon content of various components (waste types/material) of the waste stream. The following equation estimates DOC using default carbon content values:

ESTIMATED DOC USING DEFAULT CARBON CONTENT VALUES[32]

$$DOC = \sum_i (\mathrm{DOCi} * \mathrm{Wi})$$

Where,

DOC	= fraction of degradable organic carbon in bulk waste, Gg C/Gg waste
DOC_i	= fraction of degradable organic carbon in waste type i
W_i	= fraction of waste type i by waste category

The default DOC values for various fractions in MSW are given in Table 23. Since plastics, glass and metals do not contain degradable organic carbon they have DOC value as zero.

Table 23: Default DOC content of different MSW components

MSW COMPONENT	DOC CONTENT IN % OF WET WASTE	DOC CONTENT IN % OF DRY WASTE
Paper/cardboard	40	44
Textiles	24	30
Food waste	15	38
Wood	43	50
Garden and Park waste	20	49
Nappies	24	60

(Source: 2006 IPCC Guidelines, Vol. 5, Chapter 2, Table 2.6)

With a first order reaction, the amount of product is always proportional to the amount of reactive material. This means that the year in which the waste material was deposited in the disposal site is irrelevant to the amount of CH_4 generated each year. It is only the total mass of decomposing material currently in the site that matters.

$DDOC_m$ ACCUMULATED IN THE SWDS AT THE END OF YEAR T[33]

$$DDOCmaT = DDOCmdT + (DDOCmaT - 1 \times e^{-k})$$

$DDOC_m$ DECOMPOSED AT THE END OF YEAR T[34]

$$DDOCmdecompT = DDOCmaT - 1 \times (1 - e^{-k})$$

Where,

Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[31] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.1.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[32] As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.7.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[33] As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.4.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[34] As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.5.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

T	= inventory year
$DDOC_{maT}$	= DDOCm accumulated in the SWDS at the end of year T, Gg
$DDOC_{maT-1}$	= DDOCm accumulated in the SWDS at the end of year (T-1), Gg
$DDOC_{mdT}$	= DDOCm deposited into the SWDS in year T, Gg
$DDOC_{m,decompT}$	= DDOCm decomposed in the SWDS in year T, Gg
k	= reaction constant,
k	= ln(2)/t1/2 (y-1) = 0.17[35]
t1/2	= half-life time (y)[36]

Data Sources and Assumptions

1. Population

The urban population of each state for the estimation period from 2005-2014 and for the preceding 50-year time period between the years 1954-2004 is estimated on the basis of population data and decadal population growth trends as per the Census of India data reported for the years 1951, 1961, 1971, 1981, 1991, (acquired by visiting the Census office in Delhi) 2001 and 2011[37]. Formation and re-organization of states and union territories of Arunachal Pradesh, Chandigarh, Chhattisgarh, Daman & Dui, Dadra & Nagar Haveli, Goa, Jharkhand, Lakshadweep, Puducherry, Telangana, Uttarakhand has been considered since the emission estimation extends from year 1954 onwards. The decadal population data reported in Census and used in the estimates has been given in Table 71 in the Annexure.

The state of Telangana was separated from Andhra Pradesh in year 2014 and therefore, is not covered in the latest Census for 2011. The population of Telangana state is obtained from the Telangana State portal[38] and has been subtracted from the estimated population of Andhra Pradesh based on Census 2011 data (to obtain the updated population for bifurcated Andhra Pradesh for year 2014).

2. Mass of Waste deposited (W)

The FOD method assumes that carbon in waste decays gradually for decades to produce CH_4 emission. As per India's Second National Communication, it takes about 50 years for CH_4 emissions to come down to insignificant levels. Hence, it is necessary to estimate or collect 50-year data on waste disposal prior to the base year 2005 i.e. from 1954-2004. Time series data on mass of waste going to disposal sites for the 50 years before 2005 is not available at the state-level. Therefore, it becomes necessary to estimate the total waste generated using data on urban population and the per capita waste generation and subsequently work out the extent of generated waste that is dumped in disposal sites.

Reported data on per capita waste generation for the states is available for the years 1999, 2005, 2011, 2013 and 2014 (see Table 24). However, the waste generation datasets show high variation for each state across the years and are inconsistent. The per capita waste generation values reported by the CPCB in 1999 seem too low, even compared to the national-level average per capita waste generation given for year 1991 in Table 24. Further, data is not available for all the states in the year 1999. Data reported by CPCB for the years 2011, 2013 and 2014 shows inconsistent trends, with decreasing per capita waste generation reported for several states across the years 2011 to 2014. This is in contrast with available national-level information which shows that per capita waste generation is increasing at 1.2% annually (see Table 25). Therefore, the state-level waste generation data reported in 2005 is assessed to be more appropriate and in order to maintain consistency across the states, this single dataset is selected as a basis to estimate waste generation.

The 2005 data is based on a CPCB and NEERI study[39] that reports per capita waste generation data for selected cities within each state. Given that data on waste generation is not available for all the cities in a particular state, data reported for select cities is considered to be applicable across the state. Further since reliable time-series data on waste generation is not available in order to assess the waste generation trend specific to each state, the average growth rates available at national-level over the decades are assumed to be applicable for all the states. The state-wise per capita generation data reported for the year 2005 in Table 24 is

[35] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.3.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[36] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.4.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf
[37] Census 2011 available at http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf
[38] Available at http://www.telangana.gov.in/about/state-profile
[39] Available at http://www.cpcb.nic.in/wast/municipalwast/Waste_generation_Composition.pdf

selected as the basis for emission estimation and the per capita generation rate for the rest of the years from 2006 to 2013 has been calculated using the national-level average growth rates given in Table 25. These annual growth rates are consistent with other publications[40] which indicate a growth rate of 1.3% per annum for this period across the country.

Table 24: State-wise estimated per capita waste generation based on data reported by NEERI and CPCB

State/Union Territory	Per Capita Waste Generation (kg/day)				
	1999[41]	2005[42]	2011[43]	2013[44]	2014[45]
Andaman & Nicobar	-	0.760	0.348	0.466	0.456
Andhra Pradesh	0.216	0.533	0.408	0.380	0.270
Arunachal Pradesh	-	0.340	0.296	0.321	0.327
Assam	0.088	0.200	0.261	0.140	0.136
Bihar	0.130	0.310	0.142	0.133	0.128
Chandigarh	0.262	0.400	0.370	0.324	0.333
Chhattisgarh	-	0.300	0.197	0.295	0.284
Dadra & Nagar Haveli	-	0.320	0.119	0.172	0.149
Daman & Diu	-	0.420	0.119	0.172	0.149
Delhi	0.333	0.570	0.451	0.485	0.473
Goa	-	0.540	0.213	0.199	0.449
Gujarat	-	0.296	0.287	0.334	0.35
Haryana	0.742	0.420	0.061	0.362	0.31
Himachal Pradesh	1.28	0.270	0.442	0.423	0.383
Jammu & Kashmir	0.015	0.530	0.522	0.487	0.471
Jharkhand	-	0.350	0.216	0.423	0.41
Karnataka	0.191	0.390	0.275	0.35	0.336
Kerala	0.159	0.450	0.523	0.083	0.066
Lakshadweep	-	0.300	0.417	0.356	0.331
Madhya Pradesh	0.140	0.337	0.224	0.241	0.309
Maharashtra	0.233	0.338	0.378	0.504	0.415
Manipur	0.071	0.190	0.135	0.194	0.186
Meghalaya	0.082	0.340	0.478	0.424	0.319
Mizoram	0.110	0.250	0.829	0.911	0.887
Nagaland	-	0.170	0.329	0.417	0.502
Odisha	0.125	0.360	0.320	0.333	0.314
Puducherry	0.111	0.590	0.446	0.546	0.530
Punjab	0.162	0.490	0.269	0.357	0.366
Rajasthan	0.156	0.390	0.295	0.279	0.272
Sikkim	-	0.440	0.260	0.243	0.217
Tamil Nadu	0.209	0.497	0.358	0.395	0.384
Telangana	-	-	-	-	0.495
Tripura	0.063	0.400	0.374	0.367	0.351
Uttar Pradesh	0.171	0.422	0.260	0.408	0.397
Uttarakhand	-	0.310	0.247	0.308	0.269

[40] The CPHEEO, Ministry of Urban Development, GoI (2016): Manual on Municipal Solid Waste Management-2016, Part II: The Manual. Available at http://cpheeo.nic.in/WriteReadData/Cpheeo_SolidWasteManagement2016/Manual.pdf

[41] Estimated based on corresponding state population in 1999 intrapolated from Census of India datasets and reported state-wise total municipal solid waste generation in Annexure- B of CPCB (n.d.): Status Report on Municipal Solid Waste Management. Available at http://www.cpcb.nic.in/divisionsofheadoffice/pcp/MSW_Report.pdf

[42] Reported data from CPCB: Waste Generation and Composition, Table 1. State-wise per capita waste generation is based on reported per capita waste generation for cities in the state. Where data has been reported for multiple cities in a single state, per generation for the particular state has been estimated by taking simple mathematical average of per capita generation for cities in the state. Available at http://www.cpcb.nic.in/wast/municipalwast/Waste_generation_Composition.pdf

[43] Estimated based on corresponding state population in 2011 from Census of India datasets and reported state-wise total municipal solid waste generation in Annexure- C of CPCB (n.d.): Status Report on Municipal Solid Waste Management. The data is stated to be updated up to 2012 but most of the data pertains to information forwarded to CPCB by SPCBs in 2011 and is thereby assumed to be applicable for 2011 across all states for consistency. Available at http://www.cpcb.nic.in/divisionsofheadoffice/pcp/MSW_Report.pdf

[44] Estimated based on corresponding state population in 2013 projected from Census of India datasets and reported state-wise total municipal solid waste generation in Annexure- VI of CPCB (2015): Annual Review Report: 2013-14. The data is stated to be updated up to 2015 but refers to data reported by SPCBs for 2013-14 as indicated in Annexure-VII and is thus is considered for year 2013 in Table 24 of this note. Available at http://www.cpcb.nic.in/MSW_AnnualReport_2013-14.pdf

[45] Estimated based on corresponding state population in 2014 projected from Census of India datasets and reported state-wise total municipal solid waste generation in Annexure- VIII of CPCB (2016): Annual Review Report: 2014-15. The data is stated to be updated up to 2016 but refers to data reported by SPCBs for 2014-15 as indicated in Annexure-IX and is thus is considered for year 2014 in Table 24 of this note. Available at http://www.cpcb.nic.in/MSW_AnnualReport_2014-15

State/Union Territory	Per Capita Waste Generation (kg/day)				
	1999[41]	2005[42]	2011[43]	2013[44]	2014[45]
West Bengal	0.213	0.510	0.432	0.281	0.300

Table 25: Decadal daily Per capita Waste generation and Annual growth rates at national-level for India

Year	Daily Per capita Waste generation (kg/day)[46]	Estimated Annual Per capita Waste generation based on Daily per capita waste generation (kg/annum)	Annual Growth rate[47]
1951	0.305	111.33	1.1%
1961	0.340	124.10	1.0%
1971	0.375	136.88	1.5%
1981	0.430	156.95	0.7%
1991	0.460	167.90	1.2%
2005	0.540	197.1	1.2%[48]

Data on the proportion of solid waste going to landfill has been estimated based on the available state-wise data on the amount of waste that undergoes treatment. The quantum of solid waste that is treated through processes such as composting, anaerobic digestion, refuse derived-fuel, recycling etc. is diverted from being dumped in disposal sites. Reliable information at the state level on the quantity or proportion of waste going to landfill is not available for the time period 1954-2010. Therefore, it is assumed that 70% of the generated waste decomposes under anaerobic conditions in disposal sites during this period, in consonance with the assumption for National level estimates under the GHG Platform India[49] and as also assumed in India's Second National Communication[6].

The states and the SPCBs report state-level data on solid waste treatment/processing to the CPCB. State-level data available in CPCB annual reports on quantum of waste treated for the years 2011, 2013 and 2014 for each state is subtracted from the estimated waste generation data (extrapolated from state-wise 2005 data on waste generation), to get the corresponding proportion of solid waste going to disposal sites in the respective years. It is assumed that all waste that is generated and not treated gets dumped at the disposal site. It is observed that the initial estimate of the proportion of waste going to disposal sites for the years 2011, 2013 and 2014 exceeds 70% for some states (see Table 26).

This estimate, however, becomes inconsistent with the assumed condition for the period 1954-2010 that 70% of the waste generated in all states (and nationally) decomposes under anaerobic conditions in disposal sites, since the extent of waste treatment should increase over the years and thereby the proportion of solid waste going to disposal sites should decrease from 2011-2014 as compared to that up to 2010 (i.e. 70%). To maintain consistency across the estimation period, the proportion of waste being disposed should be 70% or lower for the years 2011, 2013 and 2014; not higher than 70%. Thus, the estimated value of proportion of waste to disposal site has been adjusted and a value of 70% is considered in the case of states wherein the initial estimate of proportion of waste going to landfill is obtained as higher than 70%. This is a reasonable assumption given that conditions for anaerobic decomposition (which lead to CH_4 generation) are not necessarily available for all waste that is dumped in disposal sites in India due to lack of systematic waste management and disposal.

In the case of states wherein the proportion of waste being disposed is calculated to be lower than 70%, this initial estimate value has been retained for the years 2011-2014 (see Table 27). For instance, in the case of Andhra Pradesh, the initial estimate of proportion going to landfill based on reported data is 77% for 2011, 47% for 2013 and 39% for 2014 (see Table 26). Since the estimated proportion of waste going to disposal site for 2011 is higher than 70%, this value is adjusted to 70% for 2011. Since the proportion of waste going to disposal site for both the years 2013 (i.e. 47%) and 2014 (i.e. 39%) is lower than 70%, this value is retained and

[46] TERI (1998): Looking Back to Think Ahead: Green India 2047'
[47] Annual Growth rates have been estimated based on per capita generation rates reported for certain years as given in the Table 25 and have been used in the emission estimation to calculate per capita generation rates for the intervening years.
[48] The annual growth rate of 1.2% estimated based on data for 1991 and 2007 has been used to calculate per capita generation rates from 2005-2014.
[49] Available at http://www.ghgplatform-india.org/methodology-waste-sector

used in the emission estimation (see Table 27). As data is not available for year 2012, proportion of waste going to disposal sites estimated for 2011 is used for 2012 for all the states.

Table 26: Initial Estimate of state-wise waste going to disposal site based on treatment reported by CPCB

State/Union Territory	Proportion of waste going to disposal site		
	2011 [50]	2013 [51]	2014 [52]
Andaman & Nicobar	100%	96%	96%
Andhra Pradesh	77%	47%	39%
Arunachal Pradesh	100%	42%	100%
Assam	92%	90%	100%
Bihar	100%	100%	100%
Chandigarh	32%	47%	49%
Chhattisgarh	87%	92%	92%
Dadra & Nagar Haveli	100%	100%	100%
Daman & Diu	100%	100%	100%
Delhi	81%	62%	71%
Goa	100%	68%	70%
Gujarat	89%	85%	72%
Haryana	100%	87%	96%
Himachal Pradesh	23%	29%	42%
Jammu & Kashmir	84%	85%	86%
Jharkhand	98%	98%	98%
Karnataka	79%	81%	73%
Kerala	77%	95%	96%
Lakshadweep	74%	100%	100%
Madhya Pradesh	87%	90%	100%
Maharashtra	89%	76%	71%
Manipur	99%	100%	100%
Meghalaya	54%	59%	78%
Mizoram	100%	100%	100%
Nagaland	100%	85%	100%
Odisha	99%	99%	100%
Puducherry	100%	100%	100%
Punjab	100%	99%	94%
Rajasthan	100%	94%	94%
Sikkim	56%	100%	100%
Tamil Nadu	97%	92%	92%
Telangana	-	-	63%
Tripura	90%	100%	52%
Uttar Pradesh	100%	76%	77%
Uttarakhand	100%	100%	100%
West Bengal	96%	92%	95%

Table 27: Adjusted Estimate of State-wise Proportion of waste going to Disposal Site and corresponding time periods considered in the estimates

State/Union Territory	Proportion of waste going to disposal site			
	1954 – 2010	2011 & 2012	2013	2014
Andaman & Nicobar	70%	70%	70%	70%
Andhra Pradesh	70%	70%	47%	39%
Arunachal Pradesh	70%	70%	42%	70%
Assam	70%	70%	70%	70%
Bihar	70%	70%	70%	70%
Chandigarh	70%	32%	47%	49%

[50] Estimated based on extrapolated quantity of waste generation in this assessment (using reported per capita generation data of 2005) and reported quantity of waste treated in the states for year 2011 in Annexure- C of CPCB (n.d.): Status Report on Municipal Solid Waste Management. Available at http://www.cpcb.nic.in/divisionsofheadoffice/pcp/MSW_Report.pdf
[51] Estimated based on extrapolated quantity of waste generation in this assessment (using reported per capita generation data of 2005) and reported quantity of waste treated in the states for year 2013 in Annexure- VI of CPCB (2015): Annual Review Report: 2013-14. Available at http://www.cpcb.nic.in/MSW_AnnualReport_2013-14.pdf
[52] Estimated based on extrapolated quantity of waste generation in this assessment (using reported per capita generation data of 2005) and reported quantity of waste treated in the states for year 2014 in Annexure- VIII of CPCB (2016): Annual Review Report: 2014-15. Available at http://www.cpcb.nic.in/MSW_AnnualReport_2014-15

STATE/UNION TERRITORY	PROPORTION OF WASTE GOING TO DISPOSAL SITE			
	1954 – 2010	2011 & 2012	2013	2014
Chhattisgarh	70%	70%	70%	70%
Dadra & Nagar Haveli	70%	70%	70%	70%
Daman & Diu	70%	70%	70%	70%
Delhi	70%	70%	62%	70%
Goa	70%	70%	68%	70%
Gujarat	70%	70%	70%	70%
Haryana	70%	70%	70%	70%
Himachal Pradesh	70%	23%	29%	42%
Jammu & Kashmir	70%	70%	70%	70%
Jharkhand	70%	70%	70%	70%
Karnataka	70%	70%	70%	70%
Kerala	70%	70%	70%	70%
Lakshadweep	70%	70%	70%	70%
Madhya Pradesh	70%	70%	70%	70%
Maharashtra	70%	70%	70%	70%
Manipur	70%	70%	70%	70%
Meghalaya	70%	54%	59%	70%
Mizoram	70%	70%	70%	70%
Nagaland	70%	70%	70%	70%
Odisha	70%	70%	70%	70%
Puducherry	70%	70%	70%	70%
Punjab	70%	70%	70%	70%
Rajasthan	70%	70%	70%	70%
Sikkim	70%	56%	70%	70%
Tamil Nadu	70%	70%	70%	70%
Telangana	-	-	-	63%
Tripura	70%	70%	70%	52%
Uttar Pradesh	70%	70%	70%	70%
Uttarakhand	70%	70%	70%	70%
West Bengal	70%	70%	70%	70%

3. Degradable Organic carbon (DOC)

The DOC value depends on the prevalent composition of solid waste. The national-level value for DOC as indicated in India's Second National Communication[6] is 0.11. This aggregate DOC value is based on an assumed composition of solid waste in India. However, the composition of waste is changing over time as seen from waste composition data available for three different years (1971, 1995 and 2005) from studies conducted by the CPCB and NEERI (see Table 28). Since DOC is dependent on waste composition, the DOC value will also change over the years and should be factored into the estimation.

It is seen that reliable state-wise waste composition data is available only for year 2005 (refer Table 29). Since reliable historical waste composition data for the states is not available for the years before 2005, national-level data on waste composition for years 1971 and 1995 (refer Table 28) has been assumed to be applicable for the states. Further, as year-on-year data on waste composition is not available for the 50-year period before 2005, the available waste composition across the years of 1971 and 1995 is assumed to be applicable for time periods of 1954-1994 and 1995-2004 respectively. Using the default values for DOC content for the degradable fractions in waste, the DOC values for the organic portion of the waste are calculated based on national-level solid waste composition for the time periods 1954-1994 and 1995-2004 and used in the emission estimation for the same time periods. State-level waste composition data for year 2005 is used to estimate state-specific DOC value which is subsequently used in the emission estimates for the time period 2005-2014.

Table 28: Estimated Degradable Organic Content using Waste Composition

COMPONENT	WASTE COMPOSITION		DEFAULT DOC CONTENT VALUES (WET WASTE) IN PERCENT FROM TABLE
	1971[54]	1995[54]	

			12 AS PER 2006 IPCC GUIDELINES[53]
Paper	4.14%	5.78%	40%
Rags	3.83%	3.5%	24%
Compostable Matter	41.24%	41.8%	15%
DOC Estimated for overall waste (in fraction)	**0.088**	**0.094**	-
Applicable time period considered for estimated DOC value	**1954-1994**	**1995-2004**	-

Table 29: Estimated State-wise DOC Value applicable for the time period 2005-2014

STATE/UNION TERRITORY	REPORTED STATE-WISE WASTE COMPOSITION (2005)[55]				ESTIMATED STATE-WISE DOC CONTENT ASSUMED TO BE APPLICABLE FOR TIME PERIOD 2005-2014
	COMPOSTABLE	TOTAL RECYCLABLES	PAPER	RAGS	
Andaman & Nicobar	48.25%	27.66%	9.68%	5.24%	**0.124**
Andhra Pradesh	53.19%	21.06%	7.37%	3.99%	**0.119**
Arunachal Pradesh	52.02%	20.57%	7.20%	3.89%	**0.116**
Assam	53.69%	23.28%	8.14%	4.41%	**0.124**
Bihar	51.72%	11.21%	3.92%	2.12%	**0.098**
Chandigarh	57.18%	10.91%	3.82%	2.07%	**0.106**
Chhattisgarh	51.4%	16.31%	5.71%	3.09%	**0.107**
Dadra & Nagar Haveli	71.67%	13.97%	4.89%	2.64%	**0.133**
Daman & Diu	29.6%	22.02%	7.70%	4.17%	**0.085**
Delhi	54.42%	15.52%	5.43%	2.94%	**0.110**
Goa	61.75%	17.44%	6.10%	3.30%	**0.125**
Gujarat	44.18%	12.35%	4.32%	2.34%	**0.089**
Haryana	42.06%	23.31%	8.15%	4.41%	**0.106**
Himachal Pradesh	43.02%	36.64%	12.82%	6.94%	**0.132**
Jammu & Kashmir	56.64%	19.42%	6.79%	3.68%	**0.121**
Jharkhand	45.15%	15.92%	5.57%	3.01%	**0.097**
Karnataka	51.84%	22.43%	7.85%	4.25%	**0.119**
Kerala	65.15%	16.86%	5.90%	3.19%	**0.129**
Lakshadweep	46.01%	27.2%	9.51%	5.15%	**0.119**
Madhya Pradesh	53.16%	17.17%	6.01%	3.25%	**0.112**
Maharashtra	52.95%	18.49%	6.47%	3.50%	**0.114**
Manipur	60.00%	18.51%	6.47%	3.50%	**0.124**
Meghalaya	62.54%	17.27%	6.04%	3.27%	**0.126**
Mizoram	54.24%	20.97%	7.34%	3.97%	**0.120**
Nagaland	57.485	22.67%	7.93%	4.29%	**0.128**
Odisha	49.81%	12.69%	4.44%	2.40%	**0.098**
Puducherry	49.96%	24.29%	8.50%	4.60%	**0.120**
Punjab	57.41%	16.63%	5.82%	3.15%	**0.117**
Rajasthan	45.5%	12.1%	4.23%	2.29%	**0.091**
Sikkim	46.01%	27.2%	9.51%	5.15%	**0.119**
Tamil Nadu	48.9%	16.37%	5.73%	3.10%	**0.104**
Telangana	53.19%	21.06%	7.37%	3.99%	**0.119**
Tripura	58.57%	13.68%	4.79%	2.59%	**0.113**
Uttar Pradesh	46.08%	15.11%	5.29%	2.86%	**0.097**
Uttarakhand	51.37%	19.58%	6.85%	3.71%	**0.113**
West Bengal	50.44%	12.84%	4.49%	2.43%	**0.099**

[54] Integrated Modeling of Solid Waste in India (March,1999) CREED Working Paper Series no 26 and CPCB, 1999
[53] As per 2006 IPCC Guidelines for National GHG Inventories, Vol. 5, Chapter 2: Waste Generation, Composition and Management Data, Table 2.6.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf
[55] Based on NEERI and CPCB study in 2005.
Available at http://www.cpcb.nic.in/wast/municipalwast/Waste_generation_Composition.pdf

4. $DDOC_m$ decomposed in year T ($DDOC_{m,decompT}$)

The DDOCm (i.e. the Decomposable Degradable Organic Carbon) decomposed in the year T ($DDOC_{m,decompT}$) depends on the $DDOC_m$ deposited in the year T ($DDOC_{mdT}$), the $DDOC_m$ accumulated at the end of year T ($DDOC_{maT}$), and the $DDOC_m$ accumulated at the end of the previous year (T-1) ($DDOC_{maT-1}$). It is assumed the $DDOC_m$ accumulated in the initial year of the 50-year time period considered under the FOD model (i.e. 1954) is zero for all the states.

Using the values estimated for $DDOC_m$ deposited and $DDOC_m$ accumulated, the $DDOC_m$ decomposed is calculated for all the 50-year period from 1954-2004 and subsequently is used to estimate CH_4 emissions from 2005-2014.

1.15.3 Uncertainties

Uncertainties in the emission estimates from solid waste disposal result due to the following factors

- **Limited reliable information on waste generation and disposal:** The FOD method used in the emission estimation, assumes that carbon in waste decays gradually for decades to generate CH_4 emission long after it is disposed and therefore, it is necessary to estimate or collect 50-year data on waste disposal prior to the base year of 2005 i.e. from 1954-2004. Reliable state-level data on municipal solid waste generation and disposal rates is not available for the said period. The Municipal Solid Waste (Management and Handling) Rules, 2000[56] (amended recently in 2016[57]) and the Manual on Municipal Solid Waste Management Systems[58] that lays down guidelines for urban local bodies to collect and treat solid waste first came into existence in the year 2000. As per the guidelines in the Rules, urban local bodies are mandated to report to the respective SPCB's and CPCB on the status of their waste generation and treatment rates. Given that a reporting mandate and mechanism was only established in the year 2000 under the ambit of the Municipal Solid Waste (Management and Handling) Rules, 2000, official datasets relating to solid waste generation and its management before this time are not available. Therefore, in absence of an official source of data before the year 2000, data from other sources has been used and interpolated. Even in the post-2000 period, reliable year-on-year state-level data on solid waste generation and disposal is not available. Data that is being reported by states is observed to be inconsistent. Given the lack of information, it is assumed that 70% of the waste generated goes to the landfill across the period from 1954-2010, contributing to uncertainty in the estimates.
- **Functionality of treatment systems:** The available state-level datasets on the treatment rates are presently based on the capacity of the processing plants existing in cities across the states. It does not take into account the functionality of the plants. A number of treatment plants across states are either non-operational or not working to their full potential which is resulting in additional amount of waste going to disposal sites than the recorded values. Due to lack of consolidated datasets on the functionality of the waste treatment plants at the state level, it is difficult to factor this in the estimations.
- **Limited data for DOC estimation:** The DOC estimation is a function of waste composition, which has changed over time and varies from state to state based on consumption patterns. Since regularly updated data on state-level waste composition is not available across the period from 1954-2004, nationally available average waste composition data available for the two years of 1971 and 1995 is assumed to be applicable for the time periods 1954-1994 and 1995-2004 respectively. Reliable state-level waste composition data is available for year 2005 only and has been assumed to be applicable across the period 2005-2014. The corresponding DOC values have been estimated based on this intermittently available waste composition data and applied across the three time periods of 1954-1994, 1995-2004, and 2005-2014 to calculate state emissions. While waste composition may not change drastically, this approximation due to unavailability of reliable data contributes to a certain level of uncertainty in the estimates.

[56] Available at http://eptrienvis.nic.in/All%20PDF%20Files/LEGSLA/The-Municipal-Solid-Wastes-Management-and-Handling-Rules-2000.pdf
[57] Available at http://www.moef.gov.in/sites/default/files/SWM%202016.pdf
[58] Available at http://moud.gov.in/publication/manual-on-solid-waste-management-systems-cpheeo-2000.php

As per 2006 IPCC Guidelines[59], uncertainty of GHG emissions from the disposal of solid waste based on activity data and emission factors are as follows:

- Total municipal solid waste generated: 30% is a typical value for countries which collect waste generation data on a regular basis; for countries with poor quality data: more than a factor of two.
- Fraction of municipal solid waste sent to solid waste disposal site: ± 30% for countries collecting data on disposal at SWDS
- Total uncertainty of waste Composition: ± 30% for countries with country-specific data based on studies including periodic sampling
- Degradable Organic Carbon (DOC): ±10% for country-specific value and based on the experimental data over longer time periods
- Methane Correction Factor (MCF): ± 30% for IPCC default value of 0.4
- Fraction of CH_4 in generated landfill gas: ± 5% for IPCC default value of 0.5
- Methane Recovery: ± 50% if metering is not in place.

Sensitivity Analysis

Scenario 1: Based on DOC Value

India's Second National Communication[6] uses an aggregated DOC value of 0.11 in the emission estimation for year 2007 which is based on an assumed composition of solid waste for India. However, the DOC value depends on the composition of waste and should vary over the years with changing waste composition.

The present state level emission estimates factor in the impact of changing composition on the DOC value for each state. Based on the changing waste composition over the three time periods of 1954-1994, 1995-2004 and 2005-2014, a more realistic DOC value has been calculated using the IPCC default DOC content defined for each of the constituent degradable fractions. This estimated national-level DOC value has been considered and applied across the time periods of 1954-1994 and 1995-2004 and the state-specific DOC values has been used for the period 2005-2014 in the emission calculation.

An alternate scenario 1 has been considered that uses the DOC value of 0.11 across the period 1954-2014 as per India's Second National Communication[6] to assess the deviation in emission from the considered estimates (see Table 30). The state-wise average deviation over 2005-2014 observed in the emission results with respect to the final estimates considered in the assessment has been given in Table 31, with overall deviation in aggregate state-level emissions being 1.4%.

Table 30: Alternate Scenario for DOC value in the Solid Waste Disposal Emission Estimates

Time Periods	DOC- consideration in emission estimates	DOC – Scenario 1
1954 – 1994	0.088	0.11
1995 – 2004	0.094	0.11
2005 – 2014	State-wise DOC values as given in Table 29	0.11

Table 31: Deviation in State-wise Solid Waste Disposal GHG emission results based on Alternate Scenario 1

State/Union Territory	Total Emissions for 2005-2014 as per GHG Platform India- Final Estimates (Mil. Tonnes of CO_2e)	Total Emissions for 2005-2014 as per Scenario 2 (Mil. Tonnes of CO_2e)	Scenario 1 – percent deviation w.r.t. GHG Platform India Final emission estimates (2005-2014)
Andaman & Nicobar	0.072	0.067	-7.0%
Andhra Pradesh	9.319	8.890	-4.6%

[59] As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Table 3.5.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

STATE/UNION TERRITORY	TOTAL EMISSIONS FOR 2005-2014 AS PER GHG PLATFORM INDIA- FINAL ESTIMATES (MIL. TONNES OF CO_2e)	TOTAL EMISSIONS FOR 2005-2014 AS PER SCENARIO 2 (MIL. TONNES OF CO_2e)	SCENARIO 1 – PERCENT DEVIATION W.R.T. GHG PLATFORM INDIA FINAL EMISSION ESTIMATES (2005-2014)
Arunachal Pradesh	0.063	0.061	-3.4%
Assam	0.572	0.532	-7.0%
Bihar	2.267	2.406	6.1%
Chandigarh	0.229	0.234	2.1%
Chhattisgarh	0.848	0.863	1.8%
Dadra & Nagar Haveli	0.025	0.022	-13.9%
Daman & Diu	0.027	0.032	20.4%
Delhi	5.629	5.616	-0.2%
Goa	0.312	0.288	-7.7%
Gujarat	3.971	4.491	13.1%
Haryana	2.065	2.109	2.2%
Himachal Pradesh	0.122	0.110	-10.1%
Jammu & Kashmir	1.133	1.068	-5.8%
Jharkhand	1.263	1.380	9.2%
Karnataka	5.814	5.530	-4.9%
Kerala	4.101	3.683	-10.2%
Lakshadweep	0.008	0.008	-5.2%
Madhya Pradesh	4.360	4.324	-0.8%
Maharashtra	10.788	10.576	-2.0%
Manipur	0.099	0.092	-7.4%
Meghalaya	0.128	0.118	-7.9%
Mizoram	0.090	0.086	-5.3%
Nagaland	0.057	0.052	-9.7%
Odisha	1.439	1.538	6.9%
Puducherry	0.319	0.302	-5.2%
Punjab	3.229	3.111	-3.6%
Rajasthan	3.595	4.021	11.8%
Sikkim	0.032	0.030	-5.7%
Tamil Nadu	10.153	10.516	3.6%
Telangana	-	-	
Tripura	0.21	0.20	-1.9%
Uttar Pradesh	10.67	11.47	7.5%
Uttarakhand	0.47	0.46	-2.2%
West Bengal	8.50	9.02	6.1%

Scenario 2: Based on Proportion going to Landfill

In the emission estimates, the proportion of solid waste going to disposal sites is considered as 70% for the states up to year 2010 since reliable historical information at the state-level is not available. For the period 2011-2014, proportion of waste going to landfill is deduced from the extrapolated state-wise waste generation and reported data on quantity of waste undergoing treatment. However, it is observed that the initial estimate of the proportion of waste going to disposal sites for the years 2011, 2013 and 2014 exceeds 70% for some states, which implies an increasing trend (see Table 26).

Given the improvements in waste management and increase in waste processing facilities across states, the extent of waste treatment should increase over the years and thereby the proportion of waste disposed should decrease and not increase. Thus, to maintain consistency across the estimation period, a value of 70% or lower has been considered for the proportion of waste being disposed for the period 2011-2013 in the state estimates. For states wherein, the initial estimate of proportion of waste going to landfill is obtained as higher than 70%, the estimated value of proportion of waste to disposal site has been adjusted and a value of 70% is considered instead in the calculation (see Table 27). This consideration is also based on the fact that all waste dumped in disposal sites in the country does not undergo anaerobic decomposition and releases CH_4.

For sensitivity analysis, an alternate scenario 2 has been considered where proportion of waste going to landfill is assumed to be 100% till year 2010. Under this alternate scenario, it is assumed that 100% of the waste generated gets dumped in disposal sites and undergoes decomposition under anaerobic conditions releasing CH_4. For the period from 2011-2014, the initially estimated proportion of waste going to landfill based on state-wise waste generation and reported data on quantity of waste undergoing treatment has been retained (see Table 32). No adjustment, as indicated above for the published emission estimates, has been done in alternate scenario 2 for states wherein this value is above 70%. The state-wise average deviation over 2005-14 observed in the emission results using alternate scenario 2 is given in Table 33, with overall deviation in aggregate state-level emissions being 41.3%.

Table 32: State-wise proportion of waste going to disposal site considered under Alternate scenario 2

State/Union Territory	Scenario 2- Proportion of waste going to disposal site			
	1954-2010	2011 & 2012	2013	2014
Andaman & Nicobar	100%	100%	96%	96%
Andhra Pradesh	100%	77%	47%	39%
Arunachal Pradesh	100%	100%	42%	100%
Assam	100%	92%	90%	100%
Bihar	100%	100%	100%	100%
Chandigarh	100%	32%	47%	49%
Chhattisgarh	100%	87%	92%	92%
Dadra & Nagar Haveli	100%	100%	100%	100%
Daman & Diu	100%	100%	100%	100%
Delhi	100%	81%	62%	71%
Goa	100%	100%	68%	70%
Gujarat	100%	89%	85%	72%
Haryana	100%	100%	87%	96%
Himachal Pradesh	100%	23%	29%	42%
Jammu & Kashmir	100%	84%	85%	86%
Jharkhand	100%	98%	98%	98%
Karnataka	100%	79%	81%	73%
Kerala	100%	77%	95%	96%
Lakshadweep	100%	74%	100%	100%
Madhya Pradesh	100%	87%	90%	100%
Maharashtra	100%	89%	76%	71%
Manipur	100%	99%	100%	100%
Meghalaya	100%	54%	59%	78%
Mizoram	100%	100%	100%	100%
Nagaland	100%	100%	85%	100%
Odisha	100%	99%	99%	100%
Puducherry	100%	100%	100%	100%
Punjab	100%	100%	99%	94%
Rajasthan	100%	100%	94%	94%
Sikkim	100%	56%	100%	100%
Tamil Nadu	100%	97%	92%	92%
Telangana	100%	-	-	63%
Tripura	100%	90%	100%	52%
Uttar Pradesh	100%	100%	76%	77%
Uttarakhand	100%	100%	100%	100%
West Bengal	100%	96%	92%	95%

Table 33: Deviation in State-wise Solid Waste Disposal GHG emission results based on Alternate Scenario 2

State/Union Territory	Total Emissions for 2005-2014 as per GHG Platform India- Final Estimates (Mil. Tonnes of CO_2e)	Total Emissions for 2005-2014 as per Scenario 2 (Mil. Tonnes of CO_2e)	Scenario 2 – percent deviation w.r.t. GHG Platform India Final emission estimates (2005-2014)

STATE/UNION TERRITORY	TOTAL EMISSIONS FOR 2005-2014 AS PER GHG PLATFORM INDIA- FINAL ESTIMATES (MIL. TONNES OF CO_2e)	TOTAL EMISSIONS FOR 2005-2014 AS PER SCENARIO 2 (MIL. TONNES OF CO_2e)	SCENARIO 2 – PERCENT DEVIATION W.R.T. GHG PLATFORM INDIA FINAL EMISSION ESTIMATES (2005-2014)
Andaman & Nicobar	0.072	0.102	42.7%
Andhra Pradesh	9.319	12.934	38.8%
Arunachal Pradesh	0.063	0.089	42.2%
Assam	0.572	0.809	41.4%
Bihar	2.267	3.238	42.9%
Chandigarh	0.229	0.321	40.2%
Chhattisgarh	0.848	1.189	40.2%
Dadra & Nagar Haveli	0.025	0.036	42.9%
Daman & Diu	0.027	0.039	42.9%
Delhi	5.629	7.839	39.3%
Goa	0.312	0.442	41.8%
Gujarat	3.971	5.598	41.0%
Haryana	2.065	2.940	42.4%
Himachal Pradesh	0.122	0.172	40.9%
Jammu & Kashmir	1.133	1.585	39.9%
Jharkhand	1.263	1.800	42.5%
Karnataka	5.814	8.088	39.1%
Kerala	4.101	5.684	38.6%
Lakshadweep	0.008	0.012	38.5%
Madhya Pradesh	4.360	6.136	40.8%
Maharashtra	10.788	15.158	40.5%
Manipur	0.099	0.141	42.6%
Meghalaya	0.128	0.177	38.4%
Mizoram	0.090	0.129	42.9%
Nagaland	0.057	0.081	42.2%
Odisha	1.439	2.054	42.7%
Puducherry	0.319	0.455	42.9%
Punjab	3.229	4.612	42.8%
Rajasthan	3.595	5.129	42.7%
Sikkim	0.032	0.044	38.0%
Tamil Nadu	10.153	14.432	42.2%
Telangana	-	-	-
Tripura	0.21	0.29	41.3%
Uttar Pradesh	10.67	15.16	42.1%
Uttarakhand	0.47	0.67	42.9%
West Bengal	8.50	12.08	42.1%

1.15.4 Source Category specific QA/QC

The internal QC procedures outlined previously in 'GHG estimation preparation, data collection, process and storage' in section 1.3 are carried out for this source category. Discussions were conducted with experts from CPCB and NEERI over the datasets available for solid waste, in particular for state-level waste generation and waste processing. These discussions contributed towards selection of year 2005 data as basis to estimate waste generation and towards assumptions for estimating proportion of waste going to landfill.

Specific considerations for the solid waste disposal category, in view of the emission estimation approach, are indicated below.

The FOD model for emission estimation from solid waste disposal considers historical disposal of solid waste (from year 1995 onwards). Since the solid waste generation and waste composition has changed over time, published state-level or national-level data available for these two parameters across the time period from 1955-2014 has been used in the state emission estimation. The state-level and national-level per capita MSW generation values for 2005 (used as a basis in this assessment) have been compared and also examined against the default 2006 IPCC Guidelines value of 0.12 tonnes/capita/year[60] to check that these fall within the IPCC specified uncertainty range of factor of 2 for MSW generation[59] and are therefore deemed to reasonably acceptable based on expert judgment of the authors of this note[61]. The relevant data sources and the method used to apply this data across the years have been documented in the previous section 3.4.2 of this reporting document. Since this assessment is limited to solid waste disposal in urban areas in the Indian states, it is checked that the applied data and emission factors refer to the urban context and to the respective state as well and are deemed to be appropriate.

1.15.5 Recalculation

No recalculations have been done since this is the first instance of estimating state-level emissions under the GHG Platform-India.

1.15.6 Verification

An external verification of the state-level emission estimates for this source category has not been undertaken at present. However, relevant QA/QC procedures have been applied internally to ensure reliability of calculations, processing of data, consistency, and transparent and clear documentation of methodology, assumptions and results. The state emission estimates have also undergone a peer review process and have been finalized subsequently.

The aggregated state-level emission estimates for solid waste disposal under this assessment have also been compared with the estimates reported for year 2007 and 2010 in India's National communication documents – the Second National Communication, 2012[6] and the First Biennial Update Report, 2015[7]. The aggregate state estimates for 2007 and 2010 show under-estimation, with a deviation of 36.1% and 31.2% respectively as compared to the official national estimates reported by India for solid waste disposal (see Table 34).

Table 34: Comparison of the Aggregate State GHG emission estimates for Solid Waste Disposal with Nationally Reported Values

Year	GHG Platform India Emission Estimates for Solid Waste Disposal (Mil. Tonnes of CO_2e)	Official Emission Estimates for Solid Waste Disposal As per Second, National Communication (2007) and Biennial Update Report (2010) (Mil. Tonnes of CO_2e)	Percent Deviation w.r.t. Official Emission Estimates
2007	8.03	12.69	-40.6%
2010	9.45	13.96	-35.7%

The possible reasons for deviation from the officially reported emissions are discussed below:

- **Variation in per capita waste values:** To accurately account for accumulated DOC and potential CH_4 emission generation from historic solid waste disposal, the FOD model suggests that emission estimations should be done for a 50-year period before the initial year of emission estimation (i.e. year 2005 in this assessment). Since historic and reliable time-series data on waste disposed in solid waste disposal sites is not available for the states, the waste disposal is estimated based on state-wise population and per capita generation. India's Second National Communication indicates a value of 0.55 kg/day/capita for the average per capita waste generation rate for year 2007. The Second National Communication[6] and the First Biennial Update Report[7] do not provide details of the per capita generation values that are used in the estimations of historic solid waste generation and subsequent calculation of Decomposable Degradable Organic Carbon ($DDOC_m$). In this assessment, per capita waste generation rates reported in 2005 for select cities in the states have been used as a basis to calculate state-wise waste generation. State-level data reported in recent years of 2011, 2013 and 2014 is found to be inconsistent and therefore 2005 data is used. The mathematical average of all the state-wise per capita generation values considered in the estimates data works out to 0.395 kg/per capita/day for 2005. The waste generation rates for the rest of

[60] As per IPCC 2006 Guidelines, Vol. 5, Chapter 2: Waste Generation, Composition and Management Data, Table 2A.1. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_2_Ch2_Waste_Data.pdf

[61] This is observed for all states and union territories, except for Andaman and Nicobar wherein the solid waste generation is higher by a factor of 2.3 times for year 2005. However, in the absence of alternate data on waste generation for Andaman and Nicobar and to maintain consistency with other states, the per capita waste generation value of 0.76 kg/capita/year (i.e. 0.27 tonnes/capita/year) for year 2005 has been used as a basis for Andaman and Nicobar.

the years (2005-2013 & 1954-2004) have been extrapolated based on average annual growth rate in per capita waste generation observed for India in the estimation period. National level growth rates have been used given the unavailability of reliable time-series data on waste generation for the states. Given the variations in the per capita generation rates considered over the years and given that the historic values considered in the official National GHG emission estimates are unknown, deviation is observed in the two estimations.

- **Variation in DOC values**: India's Second National Communication documents[6] indicate that a DOC value of 0.11 is used in the emission estimation, which is an aggregate DOC value based on an assumed composition of solid waste for India. The DOC value depends on the composition of waste and should vary over the years with changing waste composition. This assessment factors in the impact of prevalent composition within each state on the DOC value. Based on available state specific data on waste composition for 2005, a more realistic DOC value for the organic portion of the waste has been calculated for each of the constituent degradable fractions. This calculated state-wise DOC value is used in the estimates for all states over the period 2005-2013. For this assessment, the mathematical average of the state-wise DOC value works out to 0.113. In the absence of reliable historic state-level waste data, national level waste composition data has been used to estimate DOC values of 0.088 and 0.094 for the periods 1954-1994 and 1995-2004 respectively. The use of varying values of DOC over time has possibly resulted in deviation of the aggregate state-level estimates as compared to India's official national emission estimates.
- **Urban population**: The Urban population used in this assessment to calculate the total waste generated and disposed for each state in the emission reporting period 2005-2013 and for the fifty years preceding 2005 is based on population data and decadal growth trends as per the information reported by the Census of India. The Second National Communication[6] and the First Biennial Update Report[7] do not provide details of the urban population figures that are used in the estimations across the years. Possible variation in the methods used to arrive at urban population can be a likely source of deviation.

1.15.7 Planned improvements

Historical data on state-wise municipal solid waste generation and disposal is not available. Reliable and year-on-year data on municipal solid waste generation, waste composition for the past decade is lacking as well, with inconsistencies observed in reported data for states available from different sources. Thereby, reliable data is sought on waste generation and on the changing composition of waste across all states in the country. This will limit the need for approximations and assumptions and improve accuracy of the state emission estimates.

Inconsistent and inaccurate reporting in datasets on waste processing/treatment and on the proportion of waste going to landfill is a challenge. Reporting of waste treatment rates is largely done based on the installed capacities of the processing plants and does not account for operational status (non-operational/low capacity utilization) and therefore the volume of waste going to landfill cannot be assessed for the states accurately. Thereby, how well the processing plants are operating and any impacts of improved waste treatment over time cannot be factored into the state estimates. Improved data on these aspects is sought to improve accuracy of estimation and capture corresponding emission reductions for each state.

Going forward, the GHG Platform India could look at including activities to collect primary state-level data on solid waste and waste processing, to some extent, to improve reliability of the estimates. The Platform could help promote and provide technical inputs towards recording and reporting of relevant activity data in an accurate, consistent and transparent manner. The Platform could also engage further with the Ministry of Environment, Forests and Climate Change to gain access to the underlying datasets and assumptions used for the official National GHG emission estimates. This will greatly help in improving the accuracy of this assessment, enable better comparability, and help identify and address any limitations in the solid waste estimates prepared under this assessment as well as official emission estimates.

1.16 4D1 Domestic Wastewater Treatment and Discharge

1.16.1 Category Description

Domestic wastewater includes human sewage mixed with other household wastewater, which can include effluent from shower drains, sink drains, washing machines, etc. This source category refers to CH_4 and N_2O emissions generated due to the treatment and discharge of domestic wastewater. CH_4 emissions are generated from domestic wastewater on its treatment (on site through septic tanks, connected by sewer network to a centralized treatment plant) or untreated disposal via an outfall under anaerobic conditions[62]. The extent of CH_4 emission from wastewater depends primarily on the quantity of degradable organic material in the wastewater, the volume of wastewater generated, and the type of treatment system used.

The characteristics of domestic wastewater and consequently the associated GHG emissions vary from place to place depending on factors such as economic status, community food intake, water supply status, treatment systems and climatic conditions of the area. To account for these factors in the CH_4 emission estimation for the Waste Sector, the 2006 IPCC Guidelines on National GHG Inventories[62] categorizes the population in the following groups

- Urban high income
- Urban low income
- Rural

However, the 2006 IPCC Guidelines does not include information on sub-national (i.e. state-level) activity datasets for India such as distribution of state-population into income groups and corresponding use of different discharge/treatment systems as per the 3 population categories indicated above. State-level information in terms of urban high-income and urban low-income population is not available in country-specific datasets such as the Census of India. Therefore, while the overall approach and calculations for the state-level domestic wastewater emission estimation is in line with the 2006 IPCC guidelines, under this assessment the population is categorized broadly into two categories only - urban population and rural population.

N_2O emission occurs from the degradation of the nitrogen present in domestic wastewater, which mainly results from human protein consumption. The degradation of nitrogen occurs on the disposal of domestic wastewater into waterways, lakes or sea.

Secondary sources including published reports and studies of key governmental and research institutions such as the CPCB, SPCB, the National Sample Survey Organization (NSSO), the Census of India, and the NEERI have been used to source state specific activity data in this assessment. Either national-level data (where available) or IPCC defined default values have been used where state-level data is not available. The data is gauged to be of medium quality overall since data is available intermittently and the same has been applied across the reporting period.

Table 35: Principal Sources and Quality of Data for Domestic Wastewater Treatment and Discharge Estimates

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
4	**Waste**			
4D	**Wastewater treatment and discharge**			
4D1	Domestic wastewater treatment and discharge	Secondary	Medium	CPCB; SPCB; Census of India; NSSO, NEERI

For the CH_4 emission estimates, the Census of India data for 2001 and 2011 has been used to estimate the distribution of state-wise population into urban and rural residents across the reporting period. Data from the Census of India surveys has been used to work out the distribution of different wastewater discharge/treatment systems for the urban and rural population in the states. For CH_4 emission estimates relating to urban domestic wastewater, this has been supplemented with state-level data from CPCB studies to

[62] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

further estimate the extent of wastewater collected through the sewerage network and its treatment downstream. With regards to the estimates for N_2O emission from domestic wastewater, state specific values of per capita protein intake have been used from NSSO surveys (see the section 3.5.2 on methodology for further details on assumptions, data sources and emission factors used).

An assessment of the quality of activity data and emission factors used in the estimation is indicated in the Table 36 below. The quality has been assessed based on the source of the data[63] and its availability. Published data sourced from government institutions and agencies is deemed to be of 'high' quality for the years where such published data is available. For years wherein no data has been published for the parameter, the quality is assigned as 'low', with suitable assumptions used to address data gaps in such cases. Emission factors and default values sourced from the 2006 IPCC Guidelines[62] have been assessed to be of 'high' quality.

- Population data is available for 2001 and 2011. Population estimates for the intermediate years' have been found using decadal growth rate trends and therefore the quality of data is considered as 'high' across all years.
- The state specific per capita BOD values are sourced from NEERI data available for year 2007 and data quality for this parameter is thus assessed to be of 'high' quality for year 2007[64]. For the rest of the years where data is not available, quality is assessed to be 'low'. A further state-wise qualitative assessment for BOD is available in Table 86 in Annexure 6.4.
- The degree of utilization of treatment/discharge pathway or system is based on the Latrine facility dataset, Census of India. The data is available for 2001 and 2011 and is considered to be of 'high' quality for year 2011 within the emission estimation period and of 'low' quality for the rest of the years where data is unavailable. A further qualitative assessment of the activity data relating to the 'degree of utilization' for 'sewer' pathway for each state is provided in the Table 87 in Annexure 6.4.
- The values of fraction of population in the income group (i.e. fraction of urban and rural population) have been sourced from Census of India data for 2001 and 2011. Thus, the data quality is considered as 'high' for year 2011 within the reporting period and 'low' for rest of the years wherein data is unavailable.
- The annual per capita protein consumption value is available from NSSO surveys. The data is available for the years 2005, 2009 and 2011 for which data quality is considered 'high'. For the rest of the years', since data is unavailable the quality is assigned as 'low'.
- Values for the following parameters and emission factors are sourced from the 2006 IPCC Guidelines[62]. Therefore, the quality is assessed to be 'high' across the emission estimation period.
    - Organic Component removed as Sludge in inventory year (S)
    - Correction factor for additional industrial BOD discharged into sewers (I)
    - Amount of CH_4 recovered in inventory year (R)
    - Maximum CH_4 producing capacity (B_o)
    - Methane correction factor (MCF_j)
    - Fraction of Nitrogen in Protein (F_{NPR})
    - Factor for Non-consumed protein added to the wastewater ($F_{NON\text{-}CON}$)
    - Factor for Industrial and commercial co-discharged protein into the sewer system ($F_{IND\text{-}COM}$)
    - Nitrogen removed with sludge (N_{SLUDGE})

Table 36: Qualitative Assessment of Year-wise Activity Data used in the State Domestic Wastewater Treatment and Discharge Estimates

Sr. No.	Activity Data/Emission Factor	Quality									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
I	**Activity data**										
(a)	State population (P)	H	H	H	H	H	H	H	H	H	H

[63] Data sources for all parameters for domestic wastewater are indicated further in section 3.5.2 of this note.
[64] The values are available for Bihar, Chandigarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Uttar Pradesh, Uttarakhand and West Bengal. For rest of the States, the national average BOD values are used.

(b)	Per capita BOD in inventory year, g/person/day	L	L	H	L	L	L	L	L	L	L
(c)	Degree of utilisation of treatment/discharge pathway or system, j, for each income group fraction i (Ti,j)	L	L	L	L	L	L	H	L	L	L
(d)	Fraction of population in income group i (Ui)	L	L	L	L	L	L	H	L	L	L
(e)	Organic Component removed as Sludge, kg BOD/year (BOD)	H	H	H	H	H	H	H	H	H	H
(f)	Correction factor for additional industrial BOD discharged into sewers (I)	H	H	H	H	H	H	H	H	H	H
(g)	Amount of CH_4 recovered in inventory year (R)	H	H	H	H	H	H	H	H	H	H
(h)	Annual per capita protein consumption, kg/person/yr	H	L	L	L	H	L	H	L	L	L
2	**Emission factors**										
(a)	Maximum CH_4 producing capacity, kg CH4/kg BOD (Bo)	H	H	H	H	H	H	H	H	H	H
(b)	Methane correction factor (MCF_j)	H	H	H	H	H	H	H	H	H	H
(c)	Fraction of Nitrogen in Protein (F_{NPR})	H	H	H	H	H	H	H	H	H	H
(d)	Factor for Non-consumed protein added to the wastewater ($F_{NON-CON}$)	H	H	H	H	H	H	H	H	H	H
(e)	Factor for Industrial and commercial co-discharged protein into the sewer system ($F_{IND-COM}$)	H	H	H	H	H	H	H	H	H	H
(f)	Nitrogen removed with sludge (N_{SLUDGE})	H	H	H	H	H	H	H	H	H	H

Notes: H- high, L-low

1.16.2 Methodology

The overall methodology followed for domestic wastewater related state-level CH_4 emission estimates is consistent with the IPCC Tier I approach. For N_2O emission estimates, a Tier I approach has been largely followed with state-wise average protein consumption values over the years used to estimate emissions. As indicated earlier, while a majority of the activity data used is state/country specific, default values of the emission factors as per the 2006 IPCC Guidelines[62] have been used in the estimates for CH_4 and N_2O emission. A top-down approach is largely followed to estimate CH_4 and N_2O emission from domestic wastewater, with bottom up data on STPs used to some extent in the estimates for urban areas.

Table 37: Type of Emission Factor and Level of Methodological Tier adopted for Domestic Wastewater Treatment and Discharge State-level Estimates

IPCC ID	GHG SOURCE & SINK CATEGORIES	CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
4D1	Domestic wastewater treatment and discharge	T1	D	T1	D

Notes: T1: Tier 1; CS: Country-specific; D: IPCC default

1.16.2.1 CH_4 Emissions from Domestic Wastewater Treatment and Discharge

Calculation of CH_4 emission from treatment of domestic wastewater is largely based on the State population and the degree of utilization of treatment system or discharge pathways relevant to urban and rural residents respectively. The total organics in wastewater determine the quantum of CH_4 emissions.

As per the 2006 IPCC Guidelines[65] and India's Second National Communication[6], the following equation is used to estimate CH_4 emissions from domestic wastewater treatment and discharge

$$CH4\ Emissions = \sum_{i,j} [(U_i * Ti_{,j} * EFj)](TOW - S) - R$$

Where,

CH_4 Emissions	= Methane emissions in inventory year, kg CH_4/yr
TOW	= total organics in wastewater in inventory year, kg BOD/yr
S	= organic component removed as sludge in inventory year, kg BOD/yr (default value of 0[66])
Ui	= fraction of population in income group i in inventory year
Ti,j	= degree of utilization of treatment/discharge pathway or system, j, for each income group Fraction i in inventory year
i	= income group: rural, urban residents for the respective state
j	= each treatment/discharge pathway or system
EFj	= emission factor, kg CH_4 / kg BOD
R	= amount of CH_4 recovered in inventory year, kg CH_4/yr (default value of 0[67])

The emission factor EF_j is applicable for the various type treatment system or discharge pathways based on the corresponding MCF values as listed in Table 38. It is a function of the maximum CH_4 producing potential (Bo) and the methane correction factor (MCF) for the wastewater treatment and discharge system[68]. The MCF indicates the extent to which the CH_4 producing capacity (Bo) is realized in each type of treatment and discharge pathway and system.

$$CH4\ Emission\ Factor\ EF_j = B_O * MCFj$$

Where,

EFj	= emission factor, kg CH_4/kg BOD
j	= each treatment/discharge pathway or system
Bo	= maximum CH_4 producing capacity, kg CH4/kg BOD (Default value 0.6[69])
MCFj	= methane correction factor (fraction)

The default MCF values for different types of domestic wastewater treatment and discharge pathways as available in the 2006 IPCC guidelines[62] are given in Table 38.

Table 38: Default MCF values for Domestic Wastewater by treatment type and discharge pathway

TYPE OF TREATMENT AND DISCHARGE PATHWAY OR SYSTEM	DESCRIPTION	MCF
Untreated system		
Sea, river and lake discharge	Rivers with high organic loadings can turn anaerobic	0.1

[65] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.1. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[66] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Section 6.2.1. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[67] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Section 6.2.1 and NEERI document on Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf
[68] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.2. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[69] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.2. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

Stagnant sewer	Open and warm	0.5
Flowing sewer (open or closed)	Fast moving, clean. (Insignificant amounts of CH_4 from pump stations, etc.)	0
Treated system		
Centralized, aerobic treatment plant	Must be well managed. Some CH_4 can be emitted from settling basins and other pockets.	0
Centralized, aerobic treatment plant	Not well managed. Overloaded.	0.3
Anaerobic digester for sludge	CH_4 recovery is not considered here.	0.8
Anaerobic reactor	CH_4 recovery is not considered here.	0.8
Anaerobic shallow lagoon	Depth less than 2 metres, use expert judgment	0.2
Anaerobic deep lagoon	Depth more than 2 metres	0.8
Septic system	Half of BOD settles in anaerobic tank	0.5
Latrine	Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1
Latrine	Dry climate, ground water table lower than latrine, communal (many users)	0.5
Latrine	Wet climate/flush water use, ground water table higher than latrine	0.7
Latrine	Regular sediment removal for fertilizer	0.1

(Source: 2006 IPCC Guidelines, Vol. 5, Chapter 6; Table 6.3)

A key parameter for this source category is the total amount of organically degradable material in the wastewater (TOW). This parameter is a function of human population and Biochemical Oxygen Demand (BOD)[70] content of wastewater generated per person. It is expressed in terms of biochemical oxygen demand (kg BOD/year).

The equation for TOW in domestic wastewater is[71]:

$$\boldsymbol{TOW = P * BOD * 0.001 * I * 365}$$

Where,

TOW = total organics in wastewater in inventory year, kg BOD/yr

P = population in inventory year, (person)

BOD = state-specific per capita BOD in inventory year, g/person/day,

0.001 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers

Data Sources and Assumptions

1. Population

The urban and rural population for the Indian states for the emission estimation period of 2005-2014[72] is based on the population data and decadal population growth trends as per the Census of India, 2001 and Census of India, 2011. The state of Telangana was separated from Andhra Pradesh in year 2014. The population of Telangana state is obtained from the Telangana State portal[73] and has been subtracted from the estimated population of Andhra Pradesh based on Census 2011 data (to obtain the updated population for bifurcated Andhra Pradesh for year 2014).

[70] The principal factor in determining the CH_4 generation potential of domestic wastewater is the amount of degradable organic material in the wastewater i.e. BOD content. Wastewater with higher BOD concentrations will generally yield more CH_4 than wastewater with lower BOD concentrations. Both the type of wastewater and the type of bacteria present in the wastewater influence the BOD concentration of the wastewater.

[71] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

[72] For '4D1 Domestic wastewater treatment and discharge', the emission estimation has been undertaken for year 2014 as well since relevant data is available for this source category. However, to maintain consistency with regards to the emission accounting and reporting period across the Waste sector, the overall emissions reported in this document are limited to the period 2005-2013.

[73] Available at http://www.telangana.gov.in/about/state-profile

2. Fraction of Population in income group i (U_i)

The 2006 IPCC Guidelines[62] do not include information on sub-national or state-level data on distribution of India's population in urban and rural areas. State-wise data on the proportion of urban and rural population for India is available from the population estimates of Census of India for 2001 and 2011 and has been used in the emission estimates for 2005-2014 (see Table 73 in Annexures). However, the Census data does not provide information to help estimate the distribution of urban population into two income groups- urban low income and urban high income - as classified in the 2006 IPCC Guidelines[62]. Therefore, urban and rural are the only two population categories considered in the state emission estimation.

Assumption: Since only decadal information on the share of urban and rural population is available from the Census of India, the proportion of urban and rural population as per Census of India 2001 and Census of India 2011 is assumed to be applicable for the two time-periods 2005-2010 and 2011-2014 respectively which cover the reporting period in the emission estimates. For the state of Telangana, the rural and urban population values available for 2014 have been used in the estimates.

3. Degree of Utilization of treatment/discharge pathway or system j, for each income group fraction i ($T_{i,j}$)

The degree of utilization expresses the contribution or share (in terms of a fraction) of each discharge system in the treatment of all the wastewater generated by each income group viz., Rural and Urban. This is a key parameter since this relates to the proportion of the resident population using different wastewater treatment/discharge pathways or systems. For example, the IPCC default degree of utilization rates listed for Urban High-Income group in Table 39 implies that of the total urban high-income population, 18% use on-site septic tanks, 8% use on-site latrines, 67% are served by sewer systems and 7% use systems other than these to discharge and treat their domestic wastewater.

Each of treatment/discharge pathways or systems will have different CH_4 emission factors (based on IPCC defined MCF values as listed in Table 38); thereby having a varying contribution to the GHG emissions. The default national-level values of degree of utilization rates specified in the 2006 IPCC Guidelines for Urban high income, urban low income, and rural population in India are given in Table 39. The treatment/discharge pathways or systems are broadly classified by the 2006 IPCC Guidelines[62] into collected systems (i.e. wherein wastewater is conveyed using a sewer network) and uncollected systems (wastewater not conveyed using a sewer network).

The 2006 IPCC Guidelines, however, do not include activity data on state-level values for degree of utilization of different treatment/discharge pathway or system across India. Therefore, country-specific state-level data available on connectivity to wastewater treatment/discharge systems from Census of India 2001 and 2011 has been used to estimate the corresponding degree of utilization rates for the urban and rural population. Information recorded in the Census surveys on household connectivity to different treatment/discharge system types has been reclassified into the corresponding IPCC defined categories. For the urban population, this has been further disaggregated using state specific data available on the extent and type of treatment for wastewater collected through sewerage network. The following sections further describe the approach for degree of utilization for urban wastewater and rural wastewater.

Table 39: Default India specific Degree of Utilization Rates for Domestic Wastewater Treatment/Discharge Pathways or Systems

Income Group	Treatment/discharge type used as per 2006 IPCC Guidelines	Classification of the system as per 2006 IPCC Guidelines (Collected/ UNCOLLECTED and Treatment)	Degree of utilization of treatment/ Discharge pathway or system j, for each income group fraction i ($T_{i,j}$)
Urban High Income	Septic Tank	Uncollected (Treatment on-site)	0.18
	Latrine	Uncollected (Treatment on-site)	0.08
	Other	Uncollected (No Treatment)	0.07
	Sewer	Collected (Treatment/No Treatment)	0.67
	None	Uncollected (No Treatment)	0

Income Group	Treatment/Discharge type used as per 2006 IPCC Guidelines	Classification of the system as per 2006 IPCC Guidelines (Collected/ UNCOLLECTED and Treatment)	Degree of utilization of treatment/ Discharge pathway or system j, for each income group fraction i ($T_{i,j}$)
Urban Low Income	Septic Tank	Uncollected (Treatment on-site)	0.14
	Latrine	Uncollected (Treatment on-site)	0.10
	Other	Uncollected (No Treatment)	0.03
	Sewer	Collected (Treatment/No Treatment)	0.53
	None	Uncollected (No Treatment)	0.20
Rural	Septic Tank	Uncollected (Treatment on-site)	0
	Latrine	Uncollected (Treatment on-site)	0.47
	Other	Uncollected (No Treatment)	0.1
	Sewer	Collected (Treatment/No Treatment)	0.1
	None	Uncollected (No Treatment)	0.33

(Source: Based on 2006 IPCC Guidelines, Vol. 5, Chapter 6 Figure 6.1, Table 6.1 and Table 6.5)

Urban Domestic Wastewater:

The Census household survey through its dataset on the 'availability of several types of latrine facilities'[74] provides state-wise information on the use of different wastewater treatment/discharge systems by urban households (see Table 40 for sample data for the state of Andhra Pradesh). This 'Latrine facility' related dataset captures the portion of domestic wastewater that is collected through the sewer network in urban areas as well as the portion of wastewater that is not collected through the sewer network (either treated on-site through systems such septic tanks/latrines or discharged without any kind of treatment). For instance, the 'piped sewer system' category in Table 40 refers to sewer network to collect faecal sludge and wastewater and thus, it is inferred that 33.7% of the urban households in Andhra Pradesh were connected to sewer network in 2011.

It is possible to utilize this state-wise data available from the 'Latrine facility' dataset and classify it as per the IPCC defined wastewater treatment/discharge pathways i.e. septic tank, sewer, latrine, others and none. The 'Latrine facility' dataset covers the collected and uncollected as well as the treated and untreated portions of domestic wastewater. The derived degree of utilization rates (which indicate the distribution of wastewater flows through different treatment/discharge pathways) using this dataset sum up to 100 percent, as recommended by the 2006 IPCC Guidelines[62].

Other datasets are available from the Census of India surveys (independent of 'latrine facility' dataset) that provide information on 'type of drainage connectivity in households'[75]. However, the classification of wastewater discharge pathways reported in these datasets is limited and therefore it is difficult to align this information with the IPCC defined classification of wastewater treatment/discharge pathways. Therefore, the 'Latrine facility' dataset from the Census 2011 and 2001 has been used a single data source for the state-level activity data on degree of utilization. The approach adopted is explained further using the case of Andhra Pradesh state below.

The Census of India 2001 in its household survey classified 'latrine facilities' into four types namely Water closet, pit latrine, other latrine and no latrine (see Table 40). In the Census of India 2011 survey on household amenities and assets, these 'latrine facilities' are further sub divided into additional categories as follows-

- 'Water closet is further categorized into 'Piped sewer system', 'Septic tank', and 'Other system'
- Other latrine: 'Night soil disposed into open drain', 'Service latrine' (Night soil removed by human, Night soil serviced by animals)
- Pit latrine: With slab/ventilated improved pit, without slab/open pit
- No latrine within premises

Table 40: Latrine facility types as reported in Census of India for Urban Households in Andhra Pradesh

[74] Available at http://censusindia.gov.in/2011census/hlo/Data_sheet/India/Latrine.pdf
[75] Available at http://www.censusindia.gov.in/2011census/Hlo-series/HH09.html

Census of India – 2001		Census of India – 2011		Remarks on CH_4 emission generation
Classification of latrine facility	Percent of Urban Households connected	Classification of latrine facility	Percent of Urban Households connected	
Water Closet	47.0%	Water Closet	79.4%	
		- **Piped sewer system**	33.7%	Generates CH_4 emission, Emission is dependent on what proportion undergoes treatment downstream & the type of treatment (aerobic or anaerobic) and the proportion of collected wastewater that is discharged without any treatment
		- Septic tank	44.4%	Generates CH_4 emission
		- Other system	1.3%	Does not generate CH_4 emissions as Census of India defines these as latrine systems which discharge wastewater to open areas such as streets, yards, drainage ditch, which will therefore lead to wastewater decomposition in aerobic condition
Pit Latrine	15.1%	**Pit Latrine**	4.1%	
		- With slab/ ventilated improved pit	3.9%	Generates CH_4 emission
		- Without Slab/ Open pit	0.2%	Generates CH_4 emission
Other Latrine	16.0%	Other Latrine	2.6%	
		- Night soil disposed into open drain	2.1%	Does not generate CH_4 emission as the wastewater is disposed into open drain, which will therefore lead to wastewater or septage decomposition under aerobic conditions
		- Night soil removed by humans	0.1%	Does not generate CH_4 emissions as Census of India indicates that these systems will discharge wastewater/ septage into open areas which will therefore lead to wastewater decomposition in aerobic condition
		-Night soil serviced by animals	0.4%	Does not generate CH_4 emissions as Census of India indicates that these systems will discharge wastewater/ septage into open areas which will therefore lead to wastewater decomposition in aerobic condition
No latrine within premises	21.9%	No latrine within premises	13.9%	
		- Public latrine	2.0%	Generates CH_4 emission
		- Open Defecation	11.9%	Does not generate CH_4 emission as decomposition under aerobic conditions

Note: Discharge or treatment systems which generate CH_4 emission in rural areas indicated in bold in the table

For 2011, the degree of utilization for septic tank and latrine systems (including public, other latrine system) for Andhra Pradesh can be estimated directly based on the Census of India 2011 data (see Table 41 and Figure 18). However, the classification of septic tank and latrine systems in the Census of India 2001 is not as detailed as that in Census 2011, thereby presenting challenges in estimating corresponding degree of utilization. For instance, based on the Census 2001 data it is not possible to infer how many of the 47% urban households connected to 'Water closet' facility in Andhra Pradesh are using septic tanks.

In such cases, corresponding proportions of these systems which are available in the Census 2011 data have been used to estimate the percentage distribution of these systems in year 2001. For example, from the Census 2011 data, the percentage contribution of Septic tank in 'Water closet' latrine facility works out to

55.92% (i.e.44.4% ÷ 79.4%) (see Table 40 and Table 42). This proportion has been applied to the total percentage of households connected to 'Water closet' in 2001 to further estimate the percentage of households connected to septic tanks in 2001 as 26.28% i.e. 55.92% of 47% (see Table 42). The proportion of 'piped sewer systems' in 2001 under the 'Water closet' category has been estimated similarly. Public latrines in the 'No latrine within premises' category in 2011 (i.e. 2% ÷ 13.9% = 14.39%) has been used to estimate the proportion of public latrines in 2001 as 2.14% (i.e. 14.39% of 21.9%). Figure 20 in the Annexures depicts the classification of wastewater discharge/treatment systems and corresponding degree of utilization rates estimated for the urban population in 2001.

Assumption for Overall Degree of Utilization Rates: Since only decadal information on the use of different wastewater treatment/discharge pathways by the Urban population is available from the Census of India, the corresponding degree of utilization estimated for the Urban population as per Census of India 2001 and Census of India 2011 data is assumed to be applicable for the two-time periods- 2005-2010 and 2011-2014 respectively across the reporting years in the emission estimates.

Further Assessment of Degree of Utilization for 'Sewer' to account for Untreated Wastewater and Type of Treatment (Aerobic/Anaerobic):
Regarding the urban households that are served by 'piped sewer system' category (i.e. 33.7% as per Census 2011), it is necessary to further assess what proportion of the wastewater discharged by this subset undergoes either aerobic treatment or anaerobic treatment or is discharged without any treatment. This is because the quantum of CH_4 emission generated will vary for each of these discharge pathways, given that the corresponding MCF value is different for each pathway (see Table 38). Therefore, reported data on wastewater generation, installed capacity of sewage treatment, the treatment technologies used in STPs has been analyzed for each state and subsequently the fractions for degree of utilization for 'sewer systems' have been further split up in to three pathways –

- 'Sewer - collected and not treated'
- 'Sewer - collected and anaerobic treatment' and
- 'Sewer - collected and aerobic treatment'

State-wise information related to STPs it not available for all the years from 2005-2014. Therefore, reported state-wise information on sewage generation and STPs that is available for the three years of 1999, 2008, and 2014 has been used in the assessment (see Table 74 in Annexures). Further, the data reported in these three years is not available for all the states consistently. For some states, the data is not available either for any of the years or is available for one year or two years. Therefore, in the case of unavailability of STP related information for a particular state and a particular year, datasets available in previous/subsequent point of time have been used accordingly.

The assumptions used to further estimate the state-wise degree of utilization for the three sewer pathways – sewer (collected and not treated), sewer (collected and anaerobic treatment), and sewer (collected and aerobic treatment) – based on different cases of state-level data availability are as follows:

- State-level STP data is available for 1999, 2008 and 2014:
    - STP data reported in 1999 is assumed to be applicable for the time period 2005-2007
    - STP data reported in 2008 is assumed to be applicable for the time period 2008-2010 (since a number of STPs sanctioned after the commencement of the Jawaharlal Nehru National Urban Renewal Mission (2005-2012) were completed post 2007 and therefore this point in time is assumed to represent a significant change in the status of sewage treatment)
    - STP data reported in 2014 is assumed to be applicable for the time period 2011-2014 (to be consistent with the time period considered in using Census 2011 dataset for the degree of utilization rates)

  States/union territories falling under this case include Andhra Pradesh, Delhi, Goa, Gujarat, Haryana, Karnataka, Kerala, Maharashtra, Tamil Nadu, Uttar Pradesh and West Bengal.
- State-level STP data is available for 1999 and 2014:
    - STP data reported in 1999 is assumed to be applicable for the time period 2005-2007
    - STP data reported in 2014 is assumed to be applicable for the time period 2008-2014

  States/union territories falling under this case include Chandigarh, Madhya Pradesh, Odisha, Puducherry, Punjab and Rajasthan
- State-level STP data is available for 2008 and 2014:
    - STP data reported in 2008 is assumed to be applicable for the time period 2005-2010
    - STP data reported in 2014 is assumed to be applicable for the time period 2011-2014

States falling under this case include Assam, Bihar and Uttarakhand

- State-level STP data is available only for 2014:
    - All the wastewater collected through the 'piped sewer system' is assumed to not undergo any treatment until the year 2010. Therefore, the corresponding degree of utilization value of 'piped sewer system' based on Census 2001 data is allocated solely to 'sewer -collected and not treated' category for the period 2005-2010.
    - STP data reported in 2014 is assumed to be applicable for the time period 2011-2014

  States falling under this case include Jammu and Kashmir, Jharkhand, Sikkim, Tripura and Himachal Pradesh. Telangana state was formed in the year 2014 and therefore the STP data on reported in 2014 is used for the same year.
- State-level STP data is not available for any year
    - All the wastewater collected through the 'piped sewer system' is assumed to not undergo any treatment across all the years. Therefore, the corresponding degree of utilization value of 'piped sewer system' based on Census 2001 data is allocated solely to 'sewer -collected and not treated' category for the period 2005-2010.

  States/union territories falling under this case include Andaman and Nicobar Islands, Arunachal Pradesh, Chhatisgarh, Dadra and Nagar Haveli, Daman and Diu, Lakshadweep, Manipur, Meghalaya, Mizoram and Nagaland.

The classification of wastewater discharge/treatment systems and corresponding estimated values of degree of utilization for urban population for the state of Andhra Pradesh, based on Census 2011 data and state-level STP data reported for 2014, are given in Figure 18 and Table 41. These estimated values are assumed to be applicable for the time period 2011-2014.

The classification of wastewater discharge/treatment systems and corresponding estimated values of degree of utilization for the urban population in Andhra Pradesh, based on Census 2001 data and state-level STP data reported for 1999 and 2008, are given in Table 42 in this section and in Figure 20 in Annexure. These estimated values are assumed to be applicable for the two time-periods of 2005-2007 and 2008-2010 as indicated.

The state-wise degree of utilization values considered for urban domestic wastewater in this assessment, based on Census 2011 and 2001 data, are listed in Table 43 and Table 44.

Figure 18: Classification of Wastewater Treatment Systems and Estimated Degree of Utilization for Urban population, Andhra Pradesh, 2011

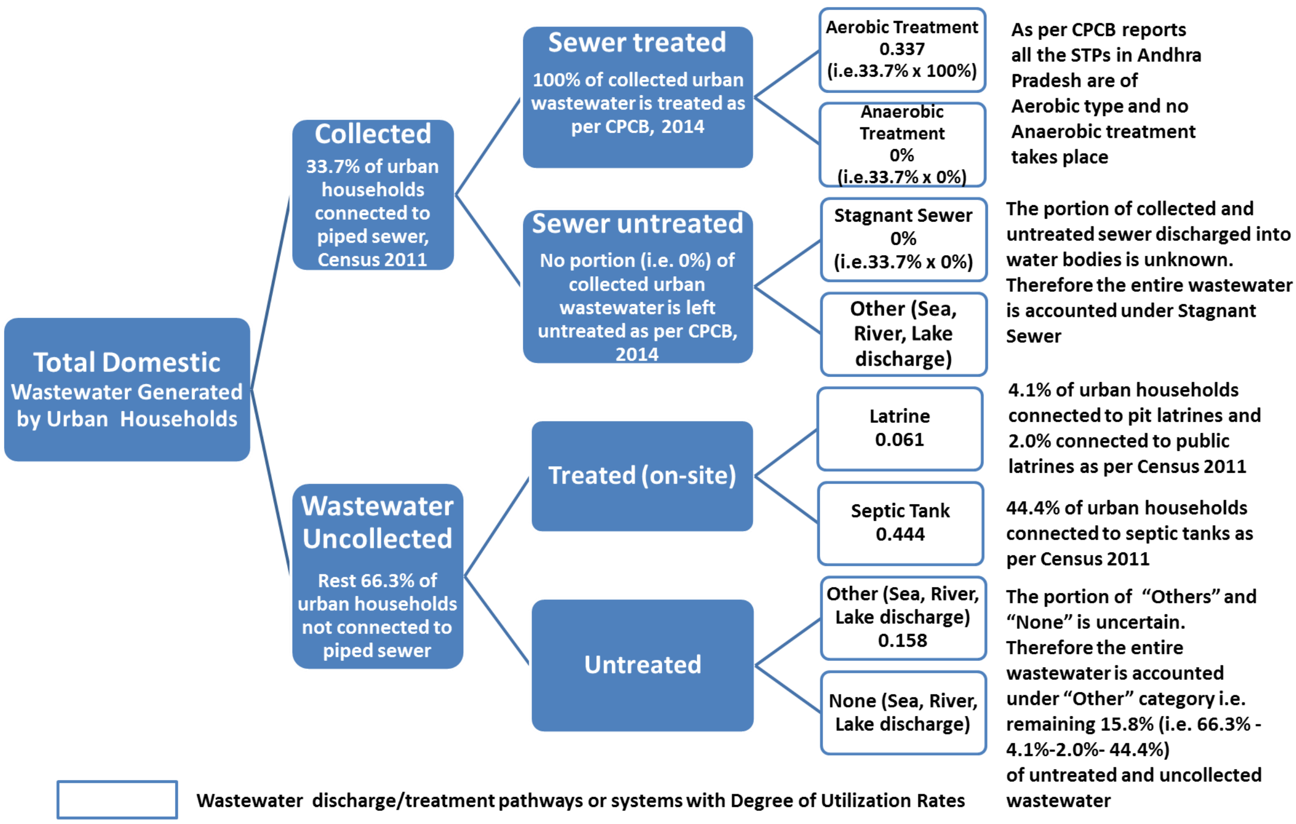


Table 41: Estimated degree of utilization of treatment/ Discharge pathway or system j, for Andhra Pradesh State Urban group fraction i (Ti,j), 2011 based on Census of India data

Classification of wastewater treatment/discharge system based on Census data[74]	Applicable treatment/discharge pathway or system (j) selected from Table 38 as per 2006 IPCC Guidelines[76]	Estimated degree of utilization of treatment/ discharge pathway or system j, for Urban group fraction i (Ti,j) - 2011	Remarks
Piped sewer systems	-	0.337	33.7% of urban households connected to sewer network as per Census 2011. This cumulative degree of utilization value for 'piped sewer system' is split further based on STP data reported for the state.
	Stagnant Sewer (collected and not treated)	0.337x0%= 0	0% of collected domestic wastewater for Andhra Pradesh is not treated as per STP data reported for year 2014 (see Table 74 in Annexure).
	Sewer (collected and aerobic treatment - Centralized, aerobic treatment plant, not well managed)	0.337x100%x 100%=0.337	100% of domestic wastewater is treated for Andhra Pradesh (i.e. 0% of not treated); of which 100% is treated with aerobic technology as per STP data reported for Andhra Pradesh year 2014 (see Table 74 in Annexure).
	Sewer (collected and anaerobic treatment - Anaerobic Reactor/ Anaerobic digester for sludge)	0.337x100%x0%=0	100% of domestic wastewater is treated for Andhra Pradesh (i.e. 0% of not treated); of which 0% is treated with anaerobic technology as per STP data reported for Andhra Pradesh year 2014 (see Table 74 in Annexure).

[76] Based on India's Second National Communication. Available at http://unfccc.int/resource/docs/natc/indnc2.pdf and the 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

CLASSIFICATION OF WASTEWATER TREATMENT/DISCHARGE SYSTEM BASED ON CENSUS DATA[74]	APPLICABLE TREATMENT/DISCHARGE PATHWAY OR SYSTEM (J) SELECTED FROM TABLE 38 AS PER 2006 IPCC GUIDELINES[76]	ESTIMATED DEGREE OF UTILIZATION OF TREATMENT/ DISCHARGE PATHWAY OR SYSTEM J, FOR URBAN GROUP FRACTION I ($T_{I,J}$) - 2011	REMARKS
Septic tank (under Water Closet)	Septic tank (Uncollected and Treatment on-site)	0.444	44.4% of urban households connected to septic tanks as per Census 2011
Pit Latrine	Latrine (Uncollected and Treatment on-site)	0.041	4.1% of urban households connected to pit latrines as per Census 2011
Public Latrine (under No latrine within premises	Latrine (Uncollected and Treatment on-site)	0.020	2.0% of urban households using public latrines as per Census 2011
Pathway for rest of wastewater that is uncollected and untreated	Others and None (Uncollected and No Treatment)	100%-33.7%-44.4%-4.4%-2.0%= 15.8% i.e. 0.158	The remaining proportion of the urban wastewater is estimated by deducting proportions of all the systems listed above in this table. This proportion represents wastewater that is neither collected nor treated. As per 2006 IPCC guidelines, the wastewater discharge/treatment pathways for uncollected and untreated wastewater are categorized as 'Others' and 'None'. The distribution of Urban wastewater handled between these two categories cannot be estimated based on available information for Andhra Pradesh (also for other States and UTs) and hence the 'Others' and 'None' categories are clubbed together in the degree of utilization estimation.

Note: Percentage values given in the Census data have been converted into fractions to express the degree of utilization rates

Table 42: Estimated Degree of utilization of treatment/ Discharge pathway or system j, for Andhra Pradesh State Urban group fraction i ($T_{i,j}$), 2001 based on Census of India data

CLASSIFICATION OF WASTEWATER TREATMENT/DISCHARGE SYSTEM BASED ON CENSUS DATA[74]	APPLICABLE TREATMENT/DISCHARGE PATHWAY OR SYSTEM (J) SELECTED FROM TABLE 38 AS PER 2006 IPCC GUIDELINES[76]	ESTIMATED DEGREE OF UTILIZATION OF TREATMENT/ DISCHARGE PATHWAY OR SYSTEM J, FOR URBAN GROUP FRACTION I ($T_{I,J}$) - 2001	REMARKS
Piped sewer system	-	(33.7% ÷ 79.4%) x 47% = 19.95% i.e. 0.199	Piped sewer system accounts for 42.44% (i.e. 33.7% ÷ 79.4%) of 'Water closet' latrine facility as per Census 2011 data. This percentage is applied to the percentage of households connected to 'Water closet' in Andhra Pradesh (i.e. 47%) as per Census 2001 in order to estimate the corresponding proportion of households connected to septic tanks in 2001. This cumulative degree of utilization value for 'piped sewer system' is split

Classification of wastewater treatment/discharge system based on Census data[74]	Applicable Treatment/Discharge pathway or system (j) selected from Table 38 as per 2006 IPCC Guidelines[76]	Estimated degree of utilization of treatment/ Discharge pathway or system j, for Urban group fraction i ($T_{i,j}$) - 2001	Remarks
			further based on STP data reported for the state.
	Stagnant Sewer (collected and not treated)	a) 0.199 x 1.57% = 0.0031 (applicable for year 2008-2010)	1.57% of collected domestic wastewater for Andhra Pradesh is not treated as per STP data reported for year 2008 (see Table 74 in Annexure). The estimated degree of utilization value of 0.0031 is assumed to be applicable for the period 2008-2010 for Andhra Pradesh.
		b) 0.199 x 55.5% = 0.110 (applicable for year 2005-2007)	55.5% of collected domestic wastewater for Andhra Pradesh is not treated as per STP data reported for year 1999 (see Table 74 in Annexure). The estimated degree of utilization value of 0.110 is assumed to be applicable for the period 2005-2007 for Andhra Pradesh.
	Sewer (collected and aerobic treatment - Centralized, aerobic treatment plant, not well managed) Sewer (collected and aerobic treatment - Centralized, aerobic treatment plant, not well managed)	a) 0.199 x 98.43% x 100%= 0.1964 (applicable for year 2008-2010)	Remaining 98.43% of domestic wastewater is treated (i.e. 100%-1.57% that is not treated) for Andhra Pradesh; of which 100% is treated with aerobic technology for Andhra Pradesh as per STP data reported for year 2008. The estimated degree of utilization value of 0.1964 is assumed to be applicable for the period 2008-2010 for Andhra Pradesh.
		b) 0.199 x 44.5% x 100%= 0.0888 (applicable for year 2005-2007)	Remaining 44.5% of domestic wastewater is treated (i.e. 100%-55.5% that is not treated) for Andhra Pradesh; of which 100% is treated with aerobic technology as per STP data reported for Andhra Pradesh for year 1999. The estimated degree of utilization value of 0.0888 is assumed to be applicable for the period 2005-2007 for Andhra Pradesh.
	Sewer (collected and anaerobic treatment - Anaerobic Reactor/ Anaerobic digester for sludge)	a) 0.199 x 98.43% x 0%= 0(applicable for year 2008-2010)	Remaining 98.43% of domestic wastewater is treated (i.e. 100%-1.57% that is not treated) for Andhra Pradesh; of which 0% is treated with anaerobic technology as per STP data reported for Andhra Pradesh year 2008. The estimated degree of utilization value of 0 is assumed to be applicable for the period 2008-2010 for Andhra Pradesh.
		b) 0.199 x 98.43% x 0%=0 (applicable for year 2005-2007)	Remaining 45.5% of domestic wastewater is treated (i.e. 100%-55.5% that is not treated) for Andhra Pradesh; of which 100% is treated with aerobic technology as per STP data reported for Andhra Pradesh for year 1999. The estimated degree of utilization value of 0 is assumed to be applicable for the period 2005-2007 for Andhra Pradesh.
Septic tank (under Water Closet)	Septic tank (Uncollected and Treatment on-site)	(44.4% ÷ 79.4%) x 47% = 26.3% i.e. 0.263	Septic tanks account for 75.77% of 'Water closet' latrine facility as per Census 2011. This percentage is applied to the percentage of households connected to 'Water closet' (i.e. 7.1%) as per Census 2001 in order to estimate the corresponding proportion of households

Classification of wastewater treatment/discharge system based on Census data[74]	Applicable Treatment/Discharge pathway or system (j) selected from Table 38 as per 2006 IPCC Guidelines[76]	Estimated degree of utilization of treatment/ Discharge pathway or system j, for Urban group fraction i ($T_{i,j}$) - 2001	Remarks
			connected to septic tanks in 2001.
Pit Latrine	Latrine (Uncollected and Treatment on-site)	0.15	10.3% of urban households connected to pit latrines as per Census 2001
Public Latrine (under No latrine within premises)	Latrine (Uncollected and Treatment on-site)	(2% ÷ 13.9%) x 21.9% = 3.15% i.e. 0.032	Census 2001 does not include information for public latrines separately. Public latrines account for 14.39% of 'No latrine within premises' category as per Census 2011. This percentage is applied to the percentage of households having 'No latrine within premises' (i.e. 21.9%) as per Census 2001 to estimate the corresponding proportion of households using public latrines in 2001.
Pathway for rest of wastewater that is uncollected and untreated	Others and None (Uncollected and No Treatment)	100%-19.95%-26.28%-0.15%-3.15%= 35.52% i.e. 0.3552	The remaining proportion of the urban wastewater is estimated by deducting proportions of all the systems listed above in this table. This proportion represents wastewater that is neither collected nor treated. As per 2006 IPCC guidelines, the wastewater discharge/treatment pathways for uncollected and untreated wastewater are categorized as 'Others' and 'None'. The distribution of Urban wastewater handled between these two categories cannot be estimated based on available information for Andhra Pradesh and hence the 'Others' and 'None' categories are clubbed together in the degree of utilization estimation.

Table 43:State-wise Degree of utilization considered in the estimates- Urban, 2011

State/Union Territory	Piped sewer system	Septic tank	Pit Latrine	Public Latrine	Others/None
Andaman and Nicobar Islands	3.00%	83.20%	0.20%	5.10%	8.50%
Andhra Pradesh	33.70%	44.40%	4.10%	2.00%	15.80%
Arunachal Pradesh	13.80%	53.60%	13.90%	3.80%	14.90%
Assam	15.00%	50.30%	21.00%	1.30%	12.40%
Bihar	7.20%	52.70%	4.50%	2.20%	33.40%
Chandigarh	85.90%	0.90%	0.50%	9.20%	3.50%
Chhatisgarh	9.10%	48.60%	1.10%	5.40%	35.80%
Dadra and Nagar Haveli	8.00%	71.70%	0.70%	7.60%	12.00%
Daman and Diu	6.30%	77.60%	1.10%	10.50%	4.50%
Delhi	60.50%	24.70%	1.70%	7.10%	6.00%
Goa	18.60%	59.30%	3.50%	5.20%	13.40%
Gujarat	60.40%	24.20%	2.10%	3.60%	9.70%
Haryana	54.80%	23.80%	7.70%	1.30%	12.40%
Himachal Pradesh	40.70%	45.30%	0.80%	4.00%	9.20%
Jammu and Kashmir	25.30%	37.90%	4.30%	1.80%	30.70%
Jharkhand	14.00%	49.20%	1.80%	1.80%	33.20%
Karnataka	53.30%	17.00%	11.90%	4.40%	13.40%
Kerala	14.30%	56.70%	21.80%	0.90%	6.30%
Lakshadweep	2.90%	93.80%	0.50%	0.40%	2.40%
Madhya Pradesh	20.20%	50.10%	1.60%	3.30%	24.80%
Maharashtra	37.80%	28.60%	2.40%	21.00%	10.20%
Manipur	7.40%	43.10%	23.30%	1.90%	24.30%
Meghalaya	9.70%	68.70%	12.30%	1.90%	7.40%
Mizoram	5.10%	71.30%	17.20%	0.60%	5.80%
Nagaland	4.50%	67.30%	15.00%	3.20%	10.00%
Odisha	11.50%	45.00%	4.20%	2.00%	37.30%
Puducherry	19.90%	60.90%	0.60%	5.80%	12.80%
Punjab	63.70%	19.90%	6.80%	0.80%	8.80%
Rajasthan	25.60%	45.60%	5.50%	1.30%	22.00%
Sikkim	34.40%	55.70%	3.30%	2.60%	4.00%
Tamil Nadu	27.40%	37.90%	6.90%	8.60%	19.20%
Telangana	0.00%	0.00%	0.00%	0.00%	100.00%
Tripura	6.70%	37.60%	47.00%	0.80%	7.90%
Uttar Pradesh	28.30%	46.90%	2.90%	2.10%	19.80%
Uttarakhand	31.70%	53.10%	6.60%	1.70%	6.90%
West Bengal	13.60%	45.40%	22.60%	3.70%	14.70%

Table 44: State-wise Degree of utilization considered in the estimates- Urban, 2001

State/Union Territory	Piped sewer system	Septic tank	Pit Latrine	Public Latrine	Others/None
Andaman and Nicobar Islands	2.03%	56.27%	6.70%	9.29%	25.72%
Andhra Pradesh	19.95%	26.28%	15.10%	3.15%	35.52%
Arunachal Pradesh	5.18%	20.11%	32.10%	4.70%	37.91%
Assam	12.43%	41.67%	26.40%	1.11%	18.39%
Bihar	4.93%	36.08%	11.40%	2.14%	45.45%
Chandigarh	69.90%	0.73%	1.00%	14.76%	13.60%
Chhatisgarh	6.01%	32.12%	5.20%	6.43%	50.23%
Dadra and Nagar Haveli	7.14%	64.01%	3.50%	9.27%	16.08%
Daman and Diu	4.53%	55.85%	3.40%	24.88%	11.33%
Delhi	33.31%	13.60%	15.20%	14.76%	23.13%
Goa	8.98%	28.62%	18.70%	10.90%	32.81%
Gujarat	44.08%	17.66%	9.80%	5.71%	22.76%
Haryana	21.08%	9.15%	26.50%	2.48%	40.79%
Himachal Pradesh	23.28%	25.91%	12.00%	8.37%	30.45%
Jammu and Kashmir	9.79%	14.66%	20.20%	1.89%	53.46%
Jharkhand	8.91%	31.33%	7.40%	1.83%	50.53%
Karnataka	33.47%	10.68%	20.70%	7.23%	27.93%
Kerala	14.21%	56.32%	11.10%	2.77%	15.60%
Lakshadweep	2.09%	67.74%	0.80%	2.82%	26.54%
Madhya Pradesh	11.61%	28.80%	11.90%	4.13%	43.56%
Maharashtra	24.94%	18.87%	7.10%	30.66%	18.44%
Manipur	2.38%	13.87%	67.00%	2.13%	14.62%
Meghalaya	5.09%	36.05%	33.10%	3.71%	22.05%
Mizoram	2.18%	30.44%	54.50%	0.80%	12.08%
Nagaland	1.13%	16.91%	40.50%	3.50%	37.96%
Odisha	8.43%	32.98%	9.50%	2.29%	46.80%
Puducherry	14.58%	44.60%	2.20%	11.28%	27.34%
Punjab	34.64%	10.82%	20.50%	1.64%	32.40%
Rajasthan	14.12%	25.15%	18.20%	1.73%	40.80%
Sikkim	32.57%	52.73%	1.90%	4.44%	8.36%
Tamil Nadu	18.78%	25.97%	11.20%	12.38%	31.67%
Telangana	-	-		-	-
Tripura	5.78%	32.41%	44.80%	1.14%	15.87%
Uttar Pradesh	11.73%	19.44%	18.10%	2.49%	48.24%
Uttarakhand	15.04%	25.19%	26.70%	3.48%	29.59%
West Bengal	12.21%	40.75%	22.90%	3.75%	20.39%

Rural Domestic Wastewater:

As in the case of urban domestic wastewater, information reported by the Census of India 2011 and 2001 has been used to arrive at the degree of utilization rates for rural domestic wastewater. The Census household survey through its dataset on the 'availability of diverse types of latrine facilities'[74] provides state-wise information on the use of different wastewater treatment/discharge systems by rural households (see Table 45 for sample data for Andhra Pradesh).

In Andhra Pradesh, the 'piped sewer system' category in the Census survey dataset refers to sewerage network to collect faecal sludge and wastewater as given in Table 45. Thus, it is inferred that 2.3% of rural households were connected to sewer network in 2011 and represent the collected portion of rural domestic wastewater. However, given that wastewater treatment facilities are largely absent in rural areas, the rural wastewater that is collected through the sewer network largely does not undergo any treatment downstream of the sewer network. Therefore, the portion of rural domestic wastewater that is collected and conveyed through the sewer network is assumed to not undergo any treatment and decomposes under aerobic conditions, thereby not leading to CH_4 emission – unlike the urban domestic wastewater wherein wastewater discharged through sewer network is a source of emission. The remaining portion of rural domestic wastewater (that is not collected through the sewer network) is either treated on-site through systems such septic tanks and latrines or discharged without any kind of treatment (see Figure 19).

Table 45: Latrine facility types as reported in Census of India for Urban Households in Andhra Pradesh

Census of India – 2001		Census of India – 2011		Remarks on CH_4 emission generation
Classification of latrine facility	**Percent of Rural Households connected**	**Classification of latrine facility**	**Percent of Rural Households connected**	
Water Closet	8.6%	Water Closet	25.7%	
		- Piped sewer system	2.3%	Does not generates CH_4 emission as there is no treatment downstream and decomposes under aerobic condition
		- Septic tank	22.6%	Generates CH_4 emission
		- Other system	0.80%	Does not generate CH_4 emissions as Census of India defines these as latrine systems which discharge wastewater to open areas such as streets, yards, drainage ditch, which will therefore lead to wastewater decomposition in aerobic condition
Pit Latrine	6.4%	**Pit Latrine**	6%	
		- With slab/ ventilated improved pit	5.4%	Generates CH_4 emission
		- Without Slab/ Open pit	0.6%	Generates CH_4 emission
Other Latrine	3.1%	Other Latrine	0.4%	
		- Night soil disposed into open drain	0.2%	Does not generate CH_4 emission as the wastewater is disposed into open drain, which will therefore lead to wastewater or septage decomposition under aerobic conditions
		- Night soil removed by humans	0.0%	Does not generate CH_4 emissions as Census of India indicates that these systems will discharge wastewater/ septage into open areas which will therefore lead to wastewater decomposition in aerobic condition
		-Night soil serviced by animals	0.2%	Does not generate CH_4 emissions as Census of India indicates that these systems will discharge wastewater/ septage into open areas which will therefore lead to wastewater decomposition in aerobic condition

CENSUS OF INDIA – 2001		CENSUS OF INDIA – 2011		REMARKS ON CH_4 EMISSION GENERATION
CLASSIFICATION OF LATRINE FACILITY	PERCENT OF RURAL HOUSEHOLDS CONNECTED	CLASSIFICATION OF LATRINE FACILITY	PERCENT OF RURAL HOUSEHOLDS CONNECTED	
No latrine within premises	81.9%	No latrine within premises	67.8%	
		- Public latrine	2.7%	Generates CH_4 emission
		- Open Defecation	65.1%	Does not generate CH_4 emission as decomposition under aerobic conditions

Note: Discharge or treatment systems which generate CH_4 emission in rural areas are indicated in bold in the table

For 2011, the degree of utilization for septic tank and latrine systems (including public, other latrine system) can be estimated directly based on the Census of India 2011 data (see Table 46 and Figure 19). However, the classification of septic tank and latrine systems in the Census of India 2001 is not as detailed as that in Census 2011, thereby presenting challenges in estimating corresponding degree of utilization. For instance, based on the Census 2001 data it is not possible to infer how many of the 8.6% rural households in Andhra Pradesh connected to 'Water closet' facility is using septic tanks. In such cases, corresponding proportions of these systems which are available in the Census 2011 data have been used to estimate the percentage distribution of these systems in year 2001. This approach is similar to that followed in the case of urban domestic wastewater.

For example, from the Census 2011 data, the percentage contribution of Septic tank in 'Water closet' latrine facility works out to 87.94% (i.e.22.6% ÷ (2.3%+22.6%+0.8%)). This proportion has been applied to the total percentage of households connected to 'Water closet' in 2001, to further work out the percentage of households connected to septic tanks in 2001 as 7.56% i.e. 87.94% of 8.6% (see Table 47). The proportion of 'piped sewer systems' in 2001 under the 'Water closet' category has been estimated similarly. Public latrines in the 'No latrine within premises' category in 2011 (i.e. 3.98%) has been used to estimate the proportion of public latrines in 2001 as 3.26% (i.e. 3.98% of 81.90%). Figure 21 in the Annexure depicts the classification of wastewater discharge/treatment systems and corresponding degree of utilization rates estimated for the rural population in 2001.

The state-wise degree of utilization values considered for rural domestic wastewater in this assessment, based on Census of India 2011 and 2001 data are listed in Table 48 and Table 49.

Assumption: Since only decadal information on the use of different wastewater treatment/discharge pathways by the rural population is available from the Census of India, the corresponding degree of utilization estimated for the rural population as per Census of India 2001 and Census of India 2011 data is assumed to be applicable for the two time-periods 2005-2010 and 2011-2014 respectively across the reporting years in the emission estimates.

Figure 19: Classification of Wastewater Treatment Systems and Estimated Degree of Utilization for Rural Andhra Pradesh, 2011

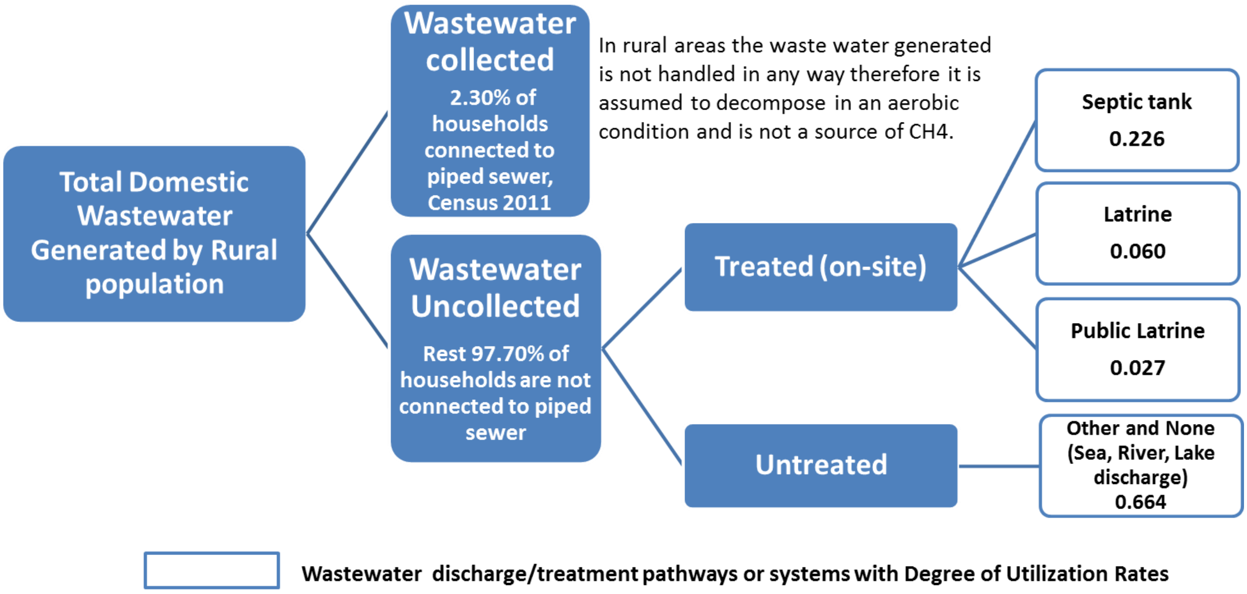


Table 46: Estimated degree of utilization of treatment/ Discharge pathway or system j, for Andhra Pradesh State Rural group fraction i (Ti,j), 2011 based on Census of India data

Classification of wastewater treatment/discharge system based on Census data[74]	Applicable Treatment/Discharge pathway or system (j) selected from Table 38 as per 2006 IPCC Guidelines[76]	Estimated degree of utilization of treatment/ Discharge pathway or system j, for Rural group fraction i (Ti,j) - 2011	Remarks
Piped sewer systems	Sewer (Collected and No Treatment)	0.023	2.3% of rural households connected to sewer network as per Census 2011
Septic tank (under Water Closet)	Septic tank (Uncollected and Treatment on-site)	0.226	22.6% of rural households connected to septic tanks as per Census 2011
Pit Latrine	Latrine (Uncollected and Treatment on-site)	0.06	6% of rural households connected to pit latrines as per Census 2011
Public Latrine (under No latrine within premises	Latrine (Uncollected and Treatment on-site)	0.027	2.7% of rural households using public latrines as per Census 2011
Pathway for rest of wastewater that is uncollected and untreated	Others and None (Uncollected and No Treatment)	100% - 2.30% - 22.6% - 6% - 2.7% = 66.4% i.e. 0.664	The remaining proportion of the rural wastewater is estimated by deducting proportions of the 4 systems listed above in this table. This proportion represents wastewater that is neither collected nor treated. As per 2006 IPCC guidelines, the wastewater discharge/treatment pathways for uncollected and untreated wastewater are categorized as 'Others' and 'None'. The distribution of rural wastewater handled between these two categories cannot be estimated based on available information for India and hence the 'Others' and 'None' categories are clubbed together in the degree of utilization estimation.

Note: Percentage values given in the Census data have been converted into fractions to express the degree of utilization rates

Table 47: Estimated Degree of utilization of treatment/ Discharge pathway or system j, for Andhra Pradesh Rural group fraction i (Ti,j), 2001 based on Census of India data

Classification of wastewater treatment/discharge system based on Census data[74]	Applicable Treatment/Discharge pathway or system (j) selected from Table 38 as per 2006 IPCC Guidelines[76]	Estimated degree of utilization of treatment/ Discharge pathway or system j, for Rural group fraction i ($T_{i,j}$) - 2001	Remarks
Piped sewer system	Sewer (Collected and No Treatment)	(2.3% ÷ 25.7%)x 8.6% = 0.77% i.e 0.077	Piped sewer system accounts for 8.95% (i.e. 2.3% ÷ 25.7%) of 'Water closet' latrine facility as per Census 2011. This percentage is applied to the percentage of households connected to 'Water closet' (i.e. 8.6%) as per Census 2001 in order to estimate the corresponding proportion of households connected to septic tanks in 2001.
Septic tank (under Water Closet)	Septic tank (Uncollected and Treatment on-site)	(22.6 ÷ 25.7%) x 8.6% = 7.56% i.e. 0.0756	Septic tanks account for 87.94% (i.e. 22.6 ÷25.7%) of 'Water closet' latrine facility as per Census 2011. This percentage is applied to the percentage of households connected to 'Water closet' (i.e. 8.6%) as per Census 2001 in order to estimate the corresponding proportion of households connected to septic tanks in 2001.
Pit Latrine	Latrine (Uncollected and Treatment on-site)	0.064	6.4% of rural households connected to pit latrines as per Census 2001
Public Latrine (under No latrine within premises)	Latrine (Uncollected and Treatment on-site)	(2.70% ÷ 67.8%) x 81.9% = 3.26% i.e. 0.0326	Census 2001 does not include information for public latrines separately. Public latrines account for 3.98% (i.e. 2.70% ÷ 67.8%) of 'No latrine within premises' category as per Census 2011. This percentage is applied to the percentage of households having 'No latrine within premises' (i.e. 81.9%) as per Census 2001 to estimate the corresponding proportion of households using public latrines in 2001.
Pathway for rest of wastewater that is uncollected and untreated	Others and None (Uncollected and No Treatment)	100%-0.77%-7.56%-6.40%-3.26% = 82.01% i.e. 0.820	The remaining proportion of the rural wastewater is estimated by deducting proportions of the 4 systems listed above in this table. This proportion represents wastewater that is neither collected nor treated. As per 2006 IPCC guidelines, the wastewater discharge/treatment pathways for uncollected and untreated wastewater are categorized as 'Others' and 'None'. The distribution of rural wastewater handled between these two categories cannot be estimated based on available information for Andhra Pradesh and Other States of India and hence the 'Others' and 'None' categories are clubbed together in the degree of utilization estimation.

Table 48: State-wise Degree of utilization considered in the estimates- Rural, 2011

State/Union Territory	Piped sewer system	Septic tank	Pit Latrine	Public Latrine	Others/None
Andaman and Nicobar Islands	2.30%	50.40%	4.50%	0.90%	41.90%
Andhra Pradesh	2.30%	22.60%	6.00%	2.70%	66.40%

State/Union Territory	Piped sewer system	Septic tank	Pit Latrine	Public Latrine	Others/None
Arunachal Pradesh	3.30%	11.90%	20.40%	3.00%	61.40%
Assam	3.30%	8.30%	37.20%	2.00%	49.20%
Bihar	1.20%	11.60%	2.20%	1.00%	84.00%
Chandigarh	83.00%	4.70%	0.10%	6.30%	5.90%
Chhattisgarh	0.60%	7.60%	4.10%	0.30%	87.40%
Dadra and Nagar Haveli	1.60%	23.10%	0.80%	2.80%	71.70%
Daman and Diu	1.70%	48.60%	0.40%	14.40%	34.90%
Delhi	10.40%	58.60%	5.20%	10.20%	15.60%
Goa	7.80%	51.90%	5.80%	1.70%	32.80%
Gujarat	3.90%	21.60%	6.30%	1.20%	67.00%
Haryana	2.50%	26.40%	23.10%	1.60%	46.40%
Himachal Pradesh	3.20%	52.40%	9.00%	0.90%	34.50%
Jammu and Kashmir	4.70%	10.80%	5.80%	3.10%	75.60%
Jharkhand	0.40%	5.00%	1.20%	0.70%	92.70%
Karnataka	2.00%	10.20%	14.60%	3.50%	69.70%
Kerala	9.90%	44.60%	34.00%	1.20%	10.30%
Lakshadweep	0.70%	97.10%	0.00%	0.30%	1.90%
Madhya Pradesh	0.80%	8.30%	2.60%	0.50%	87.80%
Maharashtra	2.20%	19.20%	14.10%	6.20%	58.30%
Manipur	5.40%	15.40%	40.50%	1.70%	37.00%
Meghalaya	4.70%	11.40%	26.40%	3.10%	54.40%
Mizoram	6.40%	23.00%	45.40%	2.50%	22.70%
Nagaland	2.80%	21.10%	32.80%	8.50%	34.80%
Odisha	0.90%	7.80%	3.30%	1.20%	86.80%
Puducherry	1.30%	36.20%	1.00%	1.40%	60.10%
Punjab	5.90%	32.60%	27.10%	1.50%	32.90%
Rajasthan	1.20%	9.80%	6.80%	0.50%	81.70%
Sikkim	3.00%	61.40%	15.40%	1.00%	19.20%
Tamil Nadu	2.20%	14.40%	5.10%	3.50%	74.80%
Tripura	2.30%	5.10%	65.30%	3.10%	24.20%
Uttar Pradesh	2.20%	12.00%	4.50%	1.10%	80.20%
Uttarakhand	3.40%	34.50%	14.20%	0.90%	47.00%
West Bengal	1.80%	9.30%	26.90%	2.00%	60.00%

Table 49: State-wise Degree of utilization considered in the estimates- Rural, 2001

State/Union Territory	Piped sewer system	Septic tank	Pit Latrine	Public Latrine	Others/None
Andaman and Nicobar Islands	0.76%	16.74%	12.40%	1.30%	68.79%
Andhra Pradesh	0.77%	7.56%	6.40%	3.26%	82.01%
Arunachal Pradesh	0.76%	2.74%	24.00%	3.34%	69.16%
Assam	1.38%	3.48%	46.90%	2.00%	46.24%
Bihar	0.34%	3.25%	6.00%	1.04%	89.37%
Chandigarh	44.90%	2.54%	6.40%	16.54%	29.62%
Chhattisgarh	0.10%	1.33%	1.80%	0.33%	96.43%

STATE/UNION TERRITORY	PIPED SEWER SYSTEM	SEPTIC TANK	PIT LATRINE	PUBLIC LATRINE	OTHERS/NONE
Dadra and Nagar Haveli	1.06%	15.37%	0.20%	3.15%	80.22%
Daman and Diu	0.67%	19.29%	9.40%	20.15%	50.49%
Delhi	2.82%	15.91%	32.90%	15.97%	32.40%
Goa	2.54%	16.89%	18.90%	3.03%	58.64%
Gujarat	1.66%	9.21%	8.10%	1.40%	79.62%
Haryana	0.16%	1.70%	20.50%	2.60%	75.04%
Himachal Pradesh	0.36%	5.84%	15.00%	1.95%	76.85%
Jammu and Kashmir	0.66%	1.51%	16.40%	2.94%	78.50%
Jharkhand	0.14%	1.77%	2.10%	0.71%	95.28%
Karnataka	0.70%	3.58%	9.50%	4.04%	82.18%
Kerala	10.39%	46.79%	12.80%	3.30%	26.73%
Lakshadweep	0.65%	90.36%	0.40%	1.04%	7.55%
Madhya Pradesh	0.20%	2.08%	3.90%	0.52%	93.30%
Maharashtra	0.49%	4.29%	10.20%	8.18%	76.83%
Manipur	0.65%	1.86%	66.80%	2.73%	27.95%
Meghalaya	0.67%	1.63%	29.80%	4.02%	63.88%
Mizoram	0.68%	2.45%	70.20%	3.30%	23.37%
Nagaland	0.47%	3.56%	47.30%	9.77%	38.90%
Odisha	0.29%	2.55%	3.10%	1.29%	92.77%
Puducherry	0.68%	18.96%	1.00%	1.80%	77.55%
Punjab	0.88%	4.89%	26.40%	2.99%	64.83%
Rajasthan	0.30%	2.47%	8.10%	0.53%	88.60%
Sikkim	1.07%	21.81%	29.80%	2.55%	44.77%
Tamil Nadu	0.92%	6.02%	4.60%	3.90%	84.56%
Tripura	0.70%	1.55%	66.00%	3.70%	28.04%
Uttar Pradesh	0.26%	1.43%	8.30%	1.14%	88.87%
Uttarakhand	0.62%	6.30%	16.10%	1.34%	75.63%
West Bengal	0.69%	3.58%	15.30%	2.74%	77.69%

4. Methane Correction Factor (MCF_j)

Methane Correction Factor (MCF) is an indication of the degree to which the wastewater treatment system is anaerobic (and thereby generates GHG emission) and this parameter varies with the type of treatment or discharge pathway. The emission factor EF_j for a given type of treatment system or discharge pathway is a product of the maximum CH_4 producing potential (Bo) (default value of 0.6 kg of CH_4/kg BOD as per 2006 IPCC Guidelines[77]) and the respective MCF value for that particular wastewater treatment and discharge system. In the emission estimates, corresponding default MCF values as per the 2006 IPCC Guidelines[78] (given in Table 38) have been used based on the applicable treatment/discharge pathways or systems for urban and rural population.

Table 50: MCF values considered for various treatment types for Urban and Rural Population

[77] The 2006 IPCC Guidelines define BOD and COD based default values for Bo. Since the data point for organic content of domestic wastewater is measured in BOD terms, the BOD based default value of 0.6 kg of CH4/kg BOD is used in the assessment. As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.2.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[78] Based on 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater treatment and discharge, Table 6.3
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

TREATMENT/ DISCHARGE PATHWAY OR SYSTEM (J)	CLASSIFICATION OF THE SYSTEM (COLLECTED/ UNCOLLECTED AND TREATMENT)	SPECIFIC TREATMENT/DISCHARGE PATHWAY OR SYSTEM (J) SELECTED FROM TABLE 38[76]	MCF_J
Urban Population			
Sewer	Collected (Anaerobic treatment)	Anaerobic reactor/Anaerobic digester for sludge	0.80
	Collected (Aerobic treatment)	Centralized, aerobic treatment plant (not well managed, overloaded)	0.30
	Collected (No Treatment)	Stagnant Sewer	0.50
Other	Uncollected (No Treatment)	Sea Lake or river discharge	0.10
None	Uncollected (No Treatment)	Sea Lake or river discharge	0.10
Septic Tank	Uncollected (Treatment on-site)	Septic system	0.50
Latrine	Uncollected (Treatment on-site)	Latrine (Dry climate, ground water table lower than latrine, small family (3-5 members))	0.10
Rural Population			
Sewer	Collected (treated/untreated)	Flowing sewer (Open/Closed)	0
Other	Uncollected (No Treatment)	Sea Lake or river discharge	0.10
None	Uncollected (No Treatment)	Sea Lake or river discharge	0.10
Septic Tank	Uncollected (Treatment on-site)	Septic system	0.50
Latrine	Uncollected (Treatment on-site)	Latrine (Dry climate, ground water table lower than latrine, small family (3-5 members))	0.10
Latrine (Public)	Uncollected (Treatment on-site)	Latrine - Dry climate, ground water table lower than latrine, communal (many users)	0.50

Assumptions:

- The portion of urban wastewater that is collected in sewers but is untreated can be handled through 'stagnant sewers' or be discharged into water bodies such as 'sea, lake or river'. The corresponding value of MCF of 'sea, lake or river discharge' is 0,1 and the MCF value of 'stagnant sewer' is 0.5. The quantity of this untreated wastewater that is discharged into water bodies is unknown and therefore the entire portion of collected and untreated urban wastewater is accounted under 'stagnant sewer' (MCF of 0.5). This assumption is based on the largely prevalent condition of untreated wastewater being discharged through sewers in urban areas.
- As reported in India's Second National Communication[6], wastewater generated in rural areas is not handled or treated in any way and decomposes under aerobic conditions. Using this basis, the proportion of rural wastewater that is collected and conveyed through sewer systems is also assumed to not undergo any treatment downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions. Thus, the 'flowing sewer' system having a MCF value of '0' and leading to no GHG emissions is selected as the corresponding treatment system for the proportion of rural wastewater collected through sewer.
- Rural wastewater that is uncollected and untreated can be either discharged into 'sea, lake or river' or 'to ground'. However, the quantity of wastewater that is discharged 'to ground' is unknown and therefore the entire portion of uncollected and untreated rural wastewater is accounted under 'sea, lake or river discharge' which has a MCF of 0.1.

5. Biochemical oxygen demand (BOD)

The primary factor in determining the CH_4 generation potential of wastewater is the amount of degradable organic material in the wastewater. BOD is a common parameter used to measure the organic component of domestic wastewater. Under the same ambient conditions, wastewater with higher BOD concentration will generally yield more CH_4 than wastewater with lower BOD concentration. The BOD concentration indicates only the amount of carbon that is aerobically biodegradable.

The 2006 IPCC Guidelines gives the default value of BOD generated per person for India which is about 34 gm/person/day[79]. An average national value for BOD of 40.5 gm/person/day is used for India in the Second National Communication[80]. State-specific BOD values available for some of the states have been used (see Table 51). For states, wherein state-level BOD value is not available, the average national value of 40.5 gm/person/day is used.

[79] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.4. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[80] Inventorization of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

Table 51: State level average per capita BOD

State/Union Territory	**Average per capita BOD (gm BOD/day)[80]**
Bihar	27.00
Chandigarh	61.86
Delhi	46.80
Gujarat	38.90
Haryana	38.00
Himachal Pradesh	19.60
Jharkhand	27.00
Karnataka	38.00
Madhya Pradesh	34.00
Maharashtra	38.00
Punjab	46.90
Uttar Pradesh	39.00
Uttarakhand	39.00
West Bengal	38.90

Assumption: Given that updated year-wise values of BOD generated per person are not available for the states, constant values as reported above are used across the reporting period.

6. Correction factor for additional Industrial BOD discharged into sewers (I)

Effluent from industries and commercial establishments is often co-discharged in sewers and mixes with domestic wastewater. As indicated previously the total organics in wastewater (TOW) is directly proportional to BOD value and BOD is the principal factor determining the CH_4 generation potential of domestic wastewater. Wastewater with higher BOD concentrations will generally yield more CH_4 than wastewater with lower BOD concentrations. Both the type of wastewater and the type of bacteria present in the wastewater influence the BOD concentration of the wastewater.

This correction factor I accounts for additional BOD from mixing of such industrial and commercial effluent with domestic wastewater. Based on the Second National Communication for India[6] and the 2006 IPCC Guidelines, the default values of 1.25 for 'I' for collected wastewater and 1 for uncollected wastewater respectively are used in this assessment[81].

1.16.2.2 N_2O Emissions from Domestic Wastewater

N_2O emissions can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea.

As per the 2006 IPCC Guidelines and India's Second National Communication, the following equation is used to estimate N_2O emissions from domestic wastewater treatment and discharge[82]

$$N_2O\ Emissions = N_{EFFLUENT} * EF_{EFFLUENT} * 44/28$$

Where,

N_2O emissions = N_2O emissions in inventory year, kg N_2O/yr

$N_{EFFLUENT}$ = nitrogen in the effluent discharged to aquatic environments, kg N/yr

$EF_{EFFLUENT}$ = emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N

The factor 44/28 is used for conversion of kg N_2O-N into kg N_2O.

The activity data that is needed for estimating N_2O emissions is nitrogen content in the wastewater effluent, state population, and the average annual per capita protein consumption (kg/person/yr).

The total nitrogen in the effluent is estimated as follows[83]:

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON-CON} * F_{IND-COM}) - N_{SLUDGE}$$

[81] Bas
Availa

[82] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.7. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

Where,

$N_{EFFLUENT}$	= total annual amount of nitrogen in the wastewater effluent, kg N/yr
P	= human population
Protein	= annual per capita protein consumption, kg/person/yr
F_{NPR}	= fraction of nitrogen in protein, kg N/kg protein (default value of 1.1 used as per 2006 IPCC Guidelines[83])
$F_{NON-CON}$	= factor for non-consumed protein added to the wastewater (default value of 1.1 used as per 2006 IPCC Guidelines[84])
$F_{IND-COM}$	= factor for industrial and commercial co-discharged protein into the sewer system, (default value of 1.25 used as per 2006 IPCC Guidelines[84])
N_{SLUDGE}	= nitrogen removed with sludge, kg N/yr (default value of 0 used as per 2006 IPCC Guidelines[83])

Data Sources and Assumptions

1. Human Population

The state-wise urban and rural population for the emission estimation period of 2005-2014[85] is estimated on the basis of population data and decadal population growth trends as per the Census of India, 2001 and Census of India, 2011. The state of Telangana was separated from Andhra Pradesh in year 2014. The population of Telangana state is referred from the Telangana State portal[38] and has been subtracted from the estimated population of Andhra Pradesh based on Census 2011 data (to obtain the updated population for bifurcated Andhra Pradesh for year 2014).

2. Annual per capita protein consumption (Protein)

State-wise protein consumption values are available from the NSSO reports. As per data available in NSSO report on Nutritional Intake 2004-05, the state-wise protein consumption is considered for the period 2005 to 2008. Based on NSSO surveys conducted subsequently, the updated per capita protein consumption values for urban and rural population have been used in this assessment as shown in the Table 52. Based on the daily protein consumption, annual protein consumption values have been calculated for urban and rural population and used in the equation to estimate N_2O emissions.

Assumption: Updated year-wise values of per capita protein consumption are not available for urban and population. Therefore, the available values based on NSSO surveys in 2004-05, 2009-10 and 2011-12 are used across the emission reporting period for 2005 to 2008, 2009 to 2010, and 2011 to 2014 respectively as indicated in Table 52.

Table 52: State-wise Daily Per Capita Protein Consumption considered for Urban and Rural Population

STATE/UNION TERRITORY	PROTEIN INTAKE (KG/CAPITA/DAY) 2004-05, NSSO REPORT [86]	PROTEIN INTAKE (KG/CAPITA/DAY) 2009-10, NSSO REPORT [87]	PROTEIN INTAKE (KG/CAPITA/DAY) 2011-12, NSSO REPORT [88]

[83] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.8. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

[84] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Section 6.3.1.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

[85] For '4D1 Domestic wastewater treatment and discharge', the emission estimation has been undertaken for year 2014 as well since relevant data is available for this source category. However, to maintain consistency with regards to the emission accounting and reporting period across the Waste sector, the overall emissions reported in this document are limited to the period 2005-2013.

[86] NSSO (2007): Nutritional Intake in India 2004-05, Table 3R for Rural protein intake and Table 3U for Urban protein intake. Available at http://mospi.nic.in/sites/default/files/publication_reports/513_final.pdf

[87] NSSO (2012): Nutritional Intake in India 2009-10. The NSSO survey was conducted over two rounds (or schedules). Values used are average values based on findings across the two schedules in the NSSO survey 2009-10 as indicated in Table 3A-R

	URBAN	RURAL	URBAN	RURAL	URBAN	RURAL
Andaman and Nicobar Islands	57.7	53.4	60	60.75	67.65	63.6
Andhra Pradesh	50.9	49.8	54.8	53.8	56.75	56.75
Arunachal Pradesh	93.3	67.7	57.3	59.1	57.25	51.65
Assam	55.9	52.7	55.7	51.55	53.5	52.2
Bihar	62.2	57.8	59.45	55.6	59.65	60.1
Chandigarh	65.5	60.3	64.5	62.8	60.1	61.55
Chhatisgarh	53.9	47.4	52.05	46.75	53.45	49.65
Dadra and Nagar Haveli	51.9	41.3	52.1	44.95	51.95	41.05
Daman and Diu	47.6	49.6	53.35	52.6	52.05	55.3
Delhi	61.3	56.9	53.5	57	59.35	59.8
Goa	47	47.5	58.35	54.1	60.15	54.15
Gujarat	57.3	53.3	54.85	55	55.2	52.25
Haryana	60.5	69.6	61.05	68.85	65.1	70.35
Himachal Pradesh	67.5	68.4	66.4	70.2	72.35	73.45
Jammu and Kashmir	61.2	63.6	62.65	64.05	64.95	65.7
Jharkhand	69.5	51.2	58.95	51.05	59	53.05
Karnataka	52.2	48.8	54.05	51.2	55.5	53.2
Kerala	56.7	55.4	56.95	55.85	59.75	57.8
Lakshadweep	71.6	71.2	68.65	71.05	69.5	73.3
Madhya Pradesh	58.2	58.8	56.55	60.55	60.55	63.4
Maharashtra	52.1	55.7	55.75	58.2	58.2	58.35
Manipur	52.5	59.6	46.45	48.4	46.85	49.25
Meghalaya	50.6	50.8	42.65	44.4	47.85	43.8
Mizoram	67.6	77.2	56.2	52.5	56.65	52.3
Nagaland	73.9	65.7	58.7	57.65	57	56.4
Odisha	55.2	48.3	55.25	52.1	54.35	51.65
Puducherry	52.1	47.8	61.05	57.75	62.65	57.55
Punjab	63.4	66.7	62.4	66.3	63.45	68.2
Rajasthan	64	69.6	62.1	69.6	64.7	70.15
Sikkim	51.5	49.9	56.75	52.35	51.75	52.5
Tamil Nadu	49.2	44.9	52.85	49.65	53.4	51.05
Telangana	NA	NA	NA	NA	NA	NA
Tripura	56.9	47.1	63	59.75	59.5	57
Uttar Pradesh	65.1	65.9	58.15	61.65	59.15	61.35
Uttarakhand	62.8	61.6	57.4	60.05	66.3	69.6
West Bengal	55.1	52	52.25	50.6	55.85	53.65

1.16.3 Uncertainties

Uncertainties in the emission estimates for this source category result from the following factors

- **Distribution of wastewater discharge pathways and treatment systems:** Updated year-on-year data on wastewater generation and the distribution of different treatment systems is lacking for the urban and rural areas across the states. Given this data constraint, constant values for the distribution of discharge/treatment systems, based on the Census of India 2011 and 2001 survey on household amenities and assets) have been used for the urban and rural populations in the states across the period from 2005-2014. The degree of utilization rates based on Census 2001 and 2011 data available for the states have been applied for the two-time periods of 2005-2010 and 2011-2014 respectively. Given the lack of updated information, on-ground developments in the states with regards to deployment wastewater treatment systems and any ensuing impacts on emissions may not be accurately captured in the state-level estimates.

& Table 3C-R for Rural and Table 3A-U & Table 3C-U for Urban. Available at http://www.indiaenvironmentportal.org.in/files/file/nutrition%20intake%20in%20india.pdf

[88] NSSO (2014): Nutritional Intake in India 2011-12. The NSSO survey was conducted over two rounds (or schedules). Values used are average values based on findings across the two schedules in the NSSO survey 2011-12 as indicated in Table 3A & Table 3B. Available at http://www.indiaenvironmentportal.org.in/files/file/nutritional%20intake%20in%20India%202011-12.pdf

- **MCF based on discharge pathway or treatment system classification:** The MCF represents the degree to which the wastewater treatment system is anaerobic and thereby generates GHG emission. IPCC defined MCF values[78] depending on the type of discharge pathway or treatment systems are used in the assessment. Due to lack of relevant information, the following assumptions have been made in the emission estimates which contribute to uncertainty.
  - The portion of urban wastewater that is collected in sewers but is untreated can be handled either through 'stagnant sewers' or be discharged into water bodies such as 'sea, lake or river'. The corresponding MCF value of 'sea, lake or river discharge' is 0.1 and the MCF value of 'stagnant sewer' is 0.5. The quantity of this untreated wastewater that is discharged into water bodies is unknown and therefore the entire portion of collected and untreated urban wastewater is accounted under 'stagnant sewer' for all the states.
  - Considering the relative lack of infrastructure for wastewater treatment in rural areas, it is assumed that the proportion of rural wastewater that is collected and conveyed through sewer systems does not undergo any treatment downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions. Thus, the 'flowing sewer' system having a MCF value of '0' and leading to no GHG emissions is selected as the corresponding treatment system for the proportion of rural wastewater collected through sewer in all the states.
  - Rural wastewater that is uncollected and untreated can be either discharged into 'sea, lake or river' or 'to ground'. However, the quantity of wastewater that is discharged 'to ground' is unknown and therefore the entire portion of uncollected and untreated rural wastewater for all states is accounted under 'sea, lake or river discharge' which has a MCF value of 0.1.
- **Availability of state-wise data on sewage treatment plants:** The performance of existing STPs that handle collected wastewater is observed to unsatisfactory across the states. Several these plants are not operating to their full capacities and do not conform to the CPCB'/SPCB's environmental standards for discharge of treated wastewater into streams. Hence domestic and industrial wastewater going to the treatment plants is discharged without treatment in some cases. Untreated discharge and mixing of industrial and domestic wastewater will impact the emission generation potential from such wastewater streams. State-level data on STPs is reported intermittently (reported in the years 1999, 2008 and 2014 as indicated in earlier sections). Furthermore, data is reported inconsistently across the states and is not available for some states at all. Given the data gaps, suitable assumptions have been used to assess how wastewater is handled in STPs in the states across the emission estimation period. Due to the lack of reliable and regularly reported data on the status of wastewater treatment plants, it is difficult to factor in these considerations in the state emission estimates.
- **Urban-Rural population and its distribution:** Decadal information on the urban and rural population available from the Census of India 2001 and Census of India 2011 has been used and population for the intermediate years has been estimated for the states based on corresponding decadal growth rate. Decadal information on the proportion of urban and rural population from the Census of India 2001 and 2011 has been applied across the emission estimation years. These estimates on urban and rural population may vary from the actual distribution existing in the states over the emission estimation period.
- **Biological Oxygen Demand values**: State specific BOD values are available only for 14 states. For the remaining states, national level average per capita BOD values are used in the CH_4 emission estimation. Since updated BOD values are not available on yearly basis, constant BOD values that are available are used across all the years.

As per 2006 IPCC Guidelines[89], the following conclusions may be drawn regarding uncertainty of GHG emissions from the treatment and disposal of domestic wastewater:

[89] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.7. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

Activity data:

- Uncertainty resulting from values considered for Degree of utilization of treatment/discharge pathway or system for each income group (Ti,j): ±50% for each individual pathway/system
- Uncertainty resulting from values considered for Fraction of population income group (U), particularly for urban high income and low-income group: ±15%
- Uncertainty resulting from values of Human population (P): ±5%
- Uncertainty related to BOD per person: ±30%
- Uncertainty resulting from Correction factor for additional industrial BOD discharged into sewers (I): ±20% for the collected portion of wastewater

Emission factor:

- Uncertainty related to the values of the Fraction treated anaerobically (MCF), depending on the type of technology: Untreated systems and latrines, ± 50%; Lagoons, poorly managed treatment plants± 30%; Centralized well managed plant, digester, reactor, ± 10%
- Uncertainty related to the Maximum CH_4 producing capacity (Bo): ±30%

Sensitivity Analysis for considered MCF values

Information on the exact wastewater treatment or discharge pathway for a part of domestic wastewater is not available in some cases. The MCF values[78] considered in the GHG estimates in such instances and possible alternate scenarios are given in the Table 53 below. Three possible alternate scenarios are proposed as follows based on conditions that may exist on the ground (at least partially) and corresponding deviation from the emission estimates has been assessed for each scenario.

- Scenario 1: The estimates consider that the uncollected and untreated portion of urban and rural wastewater is discharged to water bodies. The alternate scenario 1 considers that this portion of wastewater is instead discharged to the ground/open land and decomposes under aerobic condition, leading to no GHG emissions.
- Scenario 2: The estimates consider that the portion of urban wastewater collected through the sewer network but not undergoing any treatment downstream is in stagnant condition in the sewers based on the prevalent condition in urban areas. The alternate scenario 2 considers that this portion of wastewater is instead discharged to water bodies without any stagnation taking place in sewer.
- Scenario 3: The 'flowing sewer' type of discharge pathway having MCF value of '0' is considered for the portion of rural wastewater collected through the sewer network since this wastewater does not undergo any treatment downstream due to lack of facilities. The alternate scenario 3 considers that this portion of wastewater instead stagnates in the sewer.

Table 53: Alternate Scenarios for MCF values in the Domestic Wastewater Emission Estimates

Income Group	Treatment/ discharge pathway or system (j)	Corresponding Treatment/Discharge pathway or system (j) selected from from IPCC Classification for MCF[90]	MCF_j
Scenario 1:			
Consideration in GHG Platform India Final Emission Estimates			
Urban	Other (Uncollected and No Treatment)	Sea Lake or river discharge	0.10
	None (Uncollected and No Treatment)	Sea Lake or river discharge	0.10
Rural	Other (Uncollected and No Treatment)	Sea Lake or river discharge	0.10
	None (Uncollected and No Treatment)	Sea Lake or river discharge	0.10
Consideration in Scenario 1			
Urban	Other (Uncollected and No Treatment)	Discharge to ground/open land (aerobic decomposition; no emission)	0
	None (Uncollected and No Treatment)	Discharge to ground/open land (aerobic	0

[90] Based on India's Second National Communication. Available at http://unfccc.int/resource/docs/natc/indnc2.pdf and 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

INCOME GROUP	TREATMENT/ DISCHARGE PATHWAY OR SYSTEM (J)	CORRESPONDING TREATMENT/DISCHARGE PATHWAY OR SYSTEM (J) SELECTED FROM FROM IPCC CLASSIFICATION FOR MCF[90]	MCF_J
		decomposition; no emission)	
Rural	Other (Uncollected and No Treatment)	Discharge to ground/open land (aerobic decomposition; no emission)	0
	None (Uncollected and No Treatment)	Discharge to ground/open land (aerobic decomposition; no emission)	0
SCENARIO 2:			
Consideration in GHG Platform India Final Emission Estimates			
Urban	Sewer (Collected and No Treatment)	Stagnant Sewer	0.50
Consideration in Scenario 2			
Urban	Sewer (Collected and No Treatment)	Sea Lake or river discharge	0.10
SCENARIO 3:			
Consideration in GHG Platform India Final Emission Estimates			
Rural	Sewer (Collected)	Flowing sewer (Open/Closed)	0
Consideration in Scenario 3			
Rural	Sewer (Collected)	Stagnant Sewer	0.50

Table 54: Deviation in State-Aggregate Urban Domestic Wastewater CH_4 emission results based on Sensitivity Analysis for MCF values

YEAR	GHG PLATFORM INDIA FINAL STATE-AGGREGATE EMISSION ESTIMATES (MIL. TONNES OF CO_2e)	PERCENT DEVIATION W.R.T. GHG PLATFORM INDIA FINAL EMISSION ESTIMATES	
		SCENARIO 1	SCENARIO 2
2005	10.68	-13.2%	-4.6%
2006	10.85	-13.3%	-4.6%
2007	11.02	-13.3%	-4.6%
2008	11.14	-13.3%	-0.1%
2009	11.31	-13.3%	-0.1%
2010	11.47	-13.4%	-0.1%
2011	16.22	-4.7%	-1.7%
2012	16.49	-4.8%	-1.7%
2013	16.77	-4.8%	-1.7%
2014	17.19	-4.7%	-1.7%

Table 55: Deviation in State-Aggregate Rural Domestic Wastewater CH4 emission results based on Sensitivity Analysis for MCF values

YEAR	GHG PLATFORM INDIA FINAL STATE-AGGREGATE EMISSION ESTIMATES (MIL. TONNES OF CO_2e)	PERCENT DEVIATION W.R.T. GHG PLATFORM INDIA FINAL EMISSION ESTIMATES	
		SCENARIO 1	SCENARIO 3
2005	17.49	-63.1%	3.5%
2006	17.76	-63.1%	3.4%
2007	18.04	-63.2%	3.4%
2008	18.31	-63.3%	3.4%
2009	18.59	-63.3%	3.4%
2010	18.86	-63.4%	3.4%
2011	23.06	-43.7%	7.0%

YEAR	GHG PLATFORM INDIA FINAL STATE-AGGREGATE EMISSION ESTIMATES (MIL. TONNES OF CO_2e)	PERCENT DEVIATION W.R.T. GHG PLATFORM INDIA FINAL EMISSION ESTIMATES	
		SCENARIO 1	SCENARIO 3
2012	23.46	-43.8%	7.0%
2013	23.87	-43.8%	7.0%
2014	24.20	-43.9%	7.0%

Scenario 4: An alternate scenario is also assessed with regard to the BOD value used in the state-level emission estimation. State-specific per capita BOD values are available for 14 states and are used in the emission estimation. For states, wherein state-specific BOD values are not available, a national-level average BOD value of 40.5 g/capita/day is used. In the alternate scenario 4, sensitivity of emission results is assessed by using national-average per capita BOD values for all the states.

Table 56: Alternate Scenario for BOD values in the Domestic Wastewater Emission Estimates

INCOME GROUP	STATES FOR WHICH STATE SPECIFIC PER CAPITA BOD VALUES ARE AVAILABLE	PER CAPITA BOD (GM BOD/DAY)
Consideration in Emission estimates: Per capita BOD (gm BOD/day)		
Urban and Rural	Bihar	27.00
	Chandigarh	61.86
	Delhi	46.80
	Gujarat	38.90
	Haryana	38.00
	Himachal Pradesh	19.60
	Jharkhand	27.00
	Karnataka	38.00
	Madhya Pradesh	34.00
	Maharashtra	38.00
	Punjab	46.90
	Uttar Pradesh	39.00
	Uttrakhand	39.00
	West Bengal	38.90
Consideration in Scenario 4: Per capita BOD (gBOD/day)		
Urban and Rural	Bihar, Chandigarh, Delhi, Gujarat, Haryana, Himachal Pradesh, Jharkhand, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Uttar Pradesh, Uttrakhand and West Bengal	40.5

Table 57: Deviation in Domestic Wastewater CH_4 emission results based on Sensitivity Analysis for BOD values

STATE/UNION TERRITORY	GHG PLATFORM INDIA STATE-LEVEL CONSIDERED CH_4 EMISSION ESTIMATES (MIL. TONNES OF CO_2e)				SCENARIO 4- PERCENT DEVIATION W.R.T. GHG PLATFORM INDIA FINAL CH_4 EMISSION ESTIMATES	
	URBAN (2013)	URBAN (2014)	RURAL (2013)	RURAL (2014)	URBAN	RURAL

State/Union Territory	GHG Platform India State-Level Considered CH_4 Emission Estimates (Mil. Tonnes of CO_2e)				Scenario 4- Percent Deviation w.r.t. GHG Platform India Final CH_4 emission estimates	
	Urban (2013)	Urban (2014)	Rural (2013)	Rural (2014)	Urban	Rural
Bihar	0.45	0.46	1.79	1.83	50.0%	50.0%
Chandigarh	0.22	0.22	0.0001	0.0001	-34.5%	-34.5%
Delhi	0.75	0.76	0.03	0.03	-13.5%	-13.5%
Gujarat	1.22	1.25	1.18	1.20	4.1%	4.1%
Haryana	0.40	0.40	0.62	0.63	6.6%	6.6%
Himachal Pradesh	0.01	0.02	0.17	0.17	106.3%	106.6%
Jharkhand	0.26	0.27	0.40	0.41	50.0%	50.0%
Karnataka	0.78	0.79	1.02	1.04	6.6%	6.6%
Madhya Pradesh	0.83	0.85	1.15	1.17	19.1%	19.1%
Maharashtra	2.01	2.04	2.18	2.21	6.6%	6.6%
Punjab	0.77	0.78	0.84	0.85	-13.6%	-13.6%
Uttar Pradesh	2.03	2.07	4.31	4.39	3.8%	3.8%
Uttrakhand	0.13	0.14	0.30	0.31	3.8%	3.8%
West Bengal	1.35	1.37	1.62	1.64	4.1%	4.1%
State-aggregate CH_4 emission	16.77	17.19	23.87	24.20	3.9%	8.0%

Note: The percent deviation remains the same over the period 2005-2013 since constant values of BOD are used across this period in the estimation.

1.16.4 Source Category specific QA/QC

The internal QC procedures outlined previously in 'GHG estimation preparation, data collection, process and storage' in section 1.3 are carried out for this source category. Discussions were conducted with experts from CPCB and NEERI over datasets on wastewater generation, wastewater treatment in STPs and rural areas in particular, and for state-wise BOD values. These discussions contributed towards selection of relevant datasets and assumptions to address data gaps in relation to this information.
Specific considerations for the domestic wastewater treatment and discharge category, in view of the emission estimation approach, are indicated below.

The CH_4 and N_2O emissions have been estimated separately for the urban and rural population in the states and therefore, it is checked that the corresponding activity data and assumptions relating to the population, distribution of wastewater discharge/treatment pathways, and per capita protein consumption is appropriately applied for urban and rural areas and for the states.

For state-level CH_4 emission estimates relating to urban and rural domestic wastewater, the distribution of different wastewater discharge/treatment systems for the urban and rural population have been worked out based on state-specific data reported in Census of India 2001 and 2011 as indicated in section 3.5.2 of this document. The reported data on connectivity to sewer network in urban areas has been further broken down to estimate detailed degree of utilization rates using state specific data available on the extent and type of treatment in urban areas. The degree of utilization rates which indicate the distribution of wastewater flows through different treatment/discharge pathways, sums up to 100 percent for both urban and rural domestic wastewater respectively in all the states, thereby indicating that collected and uncollected as well as treated and untreated wastewater for urban and rural areas has been accounted for in the state emission estimates. Limited availability of published and updated data on the distribution of domestic treatment facilities which can be correlated with the IPCC treatment/discharge pathway classification is a challenge in the source specific QA/QC for this category.

1.16.5 Recalculation

No recalculations have been done since this is the first instance of estimating state-level emissions under the GHG Platform-India.

1.16.6 Verification

An external verification of the state emission estimates for this source category has not been undertaken at present. However, relevant QA/QC procedures have been applied internally to ensure reliability of calculations, processing of data, consistency, and transparent and clear documentation of methodology, assumptions and results. The state-level emission estimates have also undergone a peer review process and have been finalized subsequently.

The aggregated state emissions estimated under this assessment for domestic wastewater treatment and discharge have also been compared with the estimates reported for year 2007 and 2010 in India's National communication documents – the Second National Communication 2012[91] and the First Biennial Update Report 2015[92]. It is to be noted that the comparison considers the aggregate of the estimated state emissions from urban domestic wastewater treatment and discharge only since the scope of the National communication documents is limited to urban areas only for this sub-sector. The aggregate state-level GHG emission estimates from urban domestic wastewater for 2007 and 2010 show an under estimation as compared to the National reporting estimates, with a deviation of 31.0% and 43.5% respectively as compared to Nationally reported emissions. State aggregate emissions of CH_4 are underestimated by 39.1% and 27.6% for the year 2007 and 2010 respectively. State aggregate N_2O emissions are underestimated by 1.4% for the year 2007 and by 62.1% for the year 2010 as compared to the official estimates reported by India for domestic wastewater treatment and discharge (see Table 58)

Table 58: Comparison of the Aggregate State GHG emission estimates for Urban Domestic Wastewater Treatment and Discharge with Nationally Reported Values

YEAR	GHG PLATFORM INDIA EMISSION ESTIMATES FOR URBAN DOMESTIC WASTEWATER TREATMENT AND DISCHARGE	OFFICIAL EMISSION ESTIMATES FOR DOMESTIC WASTEWATER TREATMENT AND DISCHARGE AS PER SECOND NATIONAL COMMUNICATION (2007) AND BIENNIAL UPDATE REPORT (2010)	PERCENT DEVIATION W.R.T. OFFICIAL EMISSION ESTIMATES
CH_4 emissions (Mil. tonnes of CH_4)			
2007	0.524	0.861	-39.1%
2010	0.546	0.754	-27.6%
N2O emissions (Mil. tonnes of N_2O)			
2007	0.156	0.158	-1.4%
2010	0.166	0.437	-62.1%
Cumulative GHG emissions (Mil. tonnes of CO_2e)			
2007	15.85	22.98	-31.0%
2010	16.61	29.38	-43.5%

The possible reasons for deviation from the officially reported emissions are discussed below:

- **Distribution of Urban Population into income-groups:** The IPCC Guidelines provide default values at the national level on the distribution of urban population into two income groups - urban high income and urban low income- and indicate of degree of utilization rates (indicating usage of different treatment systems by the population) for each of these two income groups. India's National Communication documents follow the same approach and use the IPCC defined degree of utilization rates for urban high income and urban low income population in the emission estimation. However, reliable state-level information in terms of urban high-income and urban low-income population is not available in country-specific datasets such as the Census of India. Therefore, for the state-level emission estimation in this assessment, the urban population is not split into two income groups and the estimation is instead done on the basis of wastewater treatment/discharge related information for the overall urban population in each state. This difference in the approach and relevant datasets results in deviation in the aggregate of state-level urban emission estimates and the official estimates reported for India.
- **Proportion of treated and untreated wastewater:** To estimate CH_4 emissions, the extent of wastewater treated aerobically, anaerobically or not treated at all and the type of treatment system used is critical since this impacts the degree of utilization of the wastewater treatment system and the corresponding emission factor – input parameters which subsequently impact the GHG emission resulting from each system. Limited clarity and details are provided in the Second National Communication Report

[91] Available at http://unfccc.int/resource/docs/natc/indnc2.pdf
[92] Available at http://unfccc.int/resource/docs/natc/indbur1.pdf

and the Biennial Update Report on the breakup of degree of utilization, assumptions and specific data sources used- specifically for the portion of the domestic wastewater that is collected and conveyed through sewer networks. The variation in the datasets and assumptions used in the state-level assessment and National Communication has led to deviation in estimates, however given the limited information on activity data and assumptions reported in the National Communication documents, it is difficult to completely understand the underlying reasons.

- **Variation in BOD values:** India's Second National Communication uses a national average BOD value of 40.5 gm/capita/day. Under this assessment, state-specific BOD values available for 14 states have been used in the CH_4 emission estimation for the states, which contributes to deviation in the emission results.
- **Variation in protein intake values**: For the estimation of N_2O emissions for year 2007 under India's Second National Communication, the protein consumption in urban India is assumed to be 57 gm/capita/day as per the NSSO survey in 2004-05 on nutritional Intake in India 2004-05. Under this state-level assessment, state-specific protein intake values reported by NSSO surveys in 2004-05 and 2009-10 have been used to estimate emissions in year 2007 and 2010 respectively. The mathematical average of the state-wise protein intake values considered comes to 59.25 gm/capita/day for 2007 and 57.2 for 2010. The variation in this parameter with respect to the national-level value used in the National Communication documents contributes to variation in emission results.
- **Urban Population:** The state population used to calculate the CH_4 and N_2O emissions in this assessment has been interpolated for the reporting period based on Census of India 2001 and 2011 data and decadal population growth rates therein. The Second National Communication and the Biennial Update Report do not provide details of the country population (i.e. aggregate of states) that is used for the estimations. Possible variation in the methods used to arrive at state-urban population can be a likely source of deviation.

1.16.7 Planned improvements

Updated year-on-year data on wastewater generation in urban and rural areas and use of distribution of different treatment systems by households within states is lacking. In the absence of information, constant values for distribution of discharge/treatment systems (i.e. degree of utilization based on Census 2001 and 2011 data have been used for the urban and rural population in the states across the reporting period. Updated and reliable information is sought on deployment of improved wastewater treatment systems, coverage of sewer networks, proportion of untreated wastewater and its method of disposal in order to accurately capture impacts on emission that programmes or interventions for improved sanitation and wastewater management may have in each state.

Reliable information on STPs with regard to volumes treated, underutilization of treatment capacity or any overutilization due to mixing of domestic and industrial wastewater, quality of treatment, and recovery of methane is lacking at the state-level. Updated information on the same will improve accuracy of the state emission estimates.

Updated socio-economic information such as household income levels, actual population distribution by income groups - particularly in line with the IPCC defined income group categorization for urban areas (high-income and low-income) - will help to better capture and report the disaggregated emissions for these income-categories within states and subsequently inform targeted interventions.

Going forward, the GHG Platform India could look at including activities to collect primary state-level data on wastewater generation, its characteristics and treatment, to some extent, to improve reliability of the estimates. The Platform could help promote and provide technical inputs towards recording and reporting of relevant activity data in an accurate, consistent and transparent manner. The Platform could also engage further with the Ministry of Environment, Forests and Climate Change to gain access to the underlying datasets and assumptions used for the official National GHG emission estimates. This will greatly help in improving the accuracy of this assessment, enable better comparability, and help identify and address any limitations in the domestic wastewater estimates prepared under this assessment as well as official emission estimates

1.17 4D2 Industrial Wastewater Treatment and Discharge

1.17.1 Category Description

CH_4 is emitted from industrial wastewater when it is treated or disposed anaerobically. Wastewater from industrial sources may be treated on-site, transferred through a sewer to a centralized treatment plant or disposed of untreated in nearby areas or via an outfall.

The scope of the state-level GHG emissions assessment is limited to only those industry sectors which have substantial generation of wastewater containing organic matter, thereby leading to release of GHG emissions from treatment and/or discharge of such organic wastewater. 10 industry sectors have been included for estimating CH_4 from industrial wastewater in line with India's National Communications[6], related documentation from NEERI[93], and the 2006 IPCC guidelines for National GHG inventories[62]. While emissions from Beer and Soft drinks sector have been included in the national-level emission estimates under this Platform, these sectors have not been considered in the state-level emission estimates. This is due to the unavailability of relevant activity data at the state-level to enable emission estimation. Other reliable information related to industrial activity, economic output etc. at the state-level which can be used to as a basis for apportionment or approximations is also absent for these 2 sectors at the state-level. The product categories for the 10 industry sectors included in the estimates are indicated in Table 59.

Table 59: Industrial Sectors and products considered

Iron and Steel	Production of Pig Iron, Sponge Iron and Finished steel (alloy & Non-alloy)
Fertilizer	Production of Nitrogenous and Phosphatic Fertilizers (finished product for sale)
Meat	Finished Meat production from all the registered Slaughterhouses
Sugar	Finished Sugar production from cane
Coffee	Production of all types of coffee (Arabica, Robusta and varieties of these) in Indian states
Pulp & Paper	Production of paper[94] from all pulp and paper industries in Indian states
Petroleum	Refining and production of Petroleum, Oil and Lubricants[95]
Rubber	Production of Finished Natural and Synthetic Rubber
Dairy	Production of milk in the Dairy Sector in Indian states
Tannery	Production of Raw Bovine, Sheep, lamb, Goat and kid skins and hides

The other industrial sectors which consume and discharge chemicals or other inorganic matter that are not sources of significant GHG emission, such as Cement industry, Plastic industry, Pharmaceuticals, Automobile industry etc., are not included in the analysis. This assessment is applicable for all on-site generation and treatment of industrial wastewater for the industrial sectors listed above within all states in India. Assessment of CH_4 generation potential from industrial wastewater streams is based on the concentration of degradable organic matter in the wastewater, the volume of wastewater generated, and the type of prevalent wastewater treatment systems used by the respective industrial sector.

Due to the lack of documented information on the total volume of wastewater generated from industrial sectors across states, a tier I approach in which industrial production is used as a metric to estimate volume of wastewater generation is adopted in this assessment. It is found that reliable activity data on industrial production at the state-level that can be directly used in the emission calculation equation is not available for most of the sectors across the reporting period, either wholly or partly. Given these challenges in the availability of state-level data, apportionment has been used as an approach to address data gaps (to varying degrees) in 8 out of the 10 industry sectors considered in the assessment. Apportionment or approximations based on national level production data have been done based on relevant proxy data such as installed production capacity by state, no. of manufacturers or manufacturing facilities by state, gross economic value added by state, etc. Further details of the sector-wise approach and assumptions used for the activity data on

[93] Inventorization of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf; Impact of methane emissions from wastewater sector in India through a case study of an effluent treatment plant, NEERI, 2011. Available at: http://www.cseindia.org/userfiles/Karthik.pdf

[94] Paper produced from various raw materials – Wood, Agro and Recycled fiber based raw materials which is used for various purposes – writing, printing, newsprint and packaging are all included

[95] Industrial output/production data is considered from petroleum refining and not from crude oil extraction since water consumption and wastewater generation is significant in the refining process. International Petroleum Industry Environmental Conservation Association (IPIECA) (2010): Petroleum refining water/wastewater use and management- Operations Best Practice series

industrial production data are given in the subsequent section 3.6.2 on 'Data sources and Assumptions' in this chapter.

Secondary data on industrial production and industrial activity between the years 2005 – 2013 is sourced from multiple entities such as the Ministry of Steel, Indian Bureau of Mines, Directorate of Sugarcane Development, the Coffee Board, the Fertilizer Association of India, the Rubber Board, Food & Agriculture organization, and the Department of Animal Husbandry, Dairying & Fisheries, to name a few. Where the use of country-specific information is not feasible due to limitations in the data, IPCC defined default values have been used.

Table 60: Principal Sources and Quality of Data for Industrial Wastewater Treatment and Discharge Estimates

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
4D2	Industrial wastewater treatment and discharge	Secondary	Low-Medium	• Ministry of Steel • Indian Bureau of Mines • Department of Fertilizers, Ministry of Chemicals and Fertilizers • Directorate of Sugarcane Development, Ministry of Agriculture • Coffee Board, Ministry of Commerce and Industry • Petroleum Planning and Analysis Cell, Ministry of Petroleum & Natural Gas • Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture • Central Pulp & Paper Research Institute • Rubber Board, Ministry of Commerce and Industry • Food and Agriculture Organization (FAO) • Department of Industrial Policy and Promotion, Ministry of Commerce & Industry • NEERI • Centre for Science and Environment (CSE) • 2006 IPCC Guidelines on national emission inventories

Country specific wastewater generation rates are used for all 10 sectors based on NATCOM, NEERI and CSE data. Degradable organic concentration in the wastewater (kg COD/m^3) for 7 sectors is based on NATCOM & NEERI data and for 3 sectors is based on IPCC default data. Maximum CH_4 producing capacity, kg CH_4/kg COD (Bo) and MCF values are also based on IPCC default data. Due to lack of country-specific data on the emission factors for CH_4 emissions from industrial wastewater, default values of these emission factors as specified by the 2006 IPCC Guidelines[62] have been used in this assessment.

Industrial production data reported in potential single source datasets such as the ASI and industry associations is found to be in disparate units. The requisite guidance for normalization/conversion of the production data to a single unit (i.e. tonnes as required in the emission calculation) is absent and this has necessitated the use of multiple data sources for each of the industrial sectors under consideration. While data has been sourced from alternate published data sources, these data sources themselves collate data from a number of sources which has impacted quality and reliability of the data. Further, as indicated earlier, the availability of activity data on industrial production at the state-level and for all years of the reporting period is a challenge and therefore national- level data has been apportioned for most of the sectors. Due to the lack of updated year-on-year information on the changes in volume of wastewater generated per tonne of product - a parameter that should vary given the improvements in production technologies - constant values have been used for this parameter across the reporting period for all industry sectors, with the exception of the Pulp and Paper sector where such information was available for a few years. State-wise information for this parameter is not available and thereby corresponding national-level value has been used for the industry sectors.

Activity data and related information for the industrial sectors has been largely sourced from official publications from government departments and nodal institutions/associations. However, given the unavailability of data (across the states and for particular years) and the need for apportionment/ approximations to address data gaps, the data is assessed to range from low to medium quality across the industry sectors (see section 3.6.2 on Methodology for further details on assumptions and emission factors used)[96].

An assessment of the quality of activity data and emission factors used in the estimation across industry sectors is indicated in the Table 61 below. The quality has been assessed based on the source of the data[97] and its availability. Published data sourced from government institutions and agencies is deemed to be of 'high' quality for the years where such published data is available. Data from peer reviewed literature and studies undertaken by research and academic institutions with experience of working in the waste sector is deemed to be of 'medium' quality. Data sourced from private organizations, online databases, and individual researchers is deemed to be of 'low' quality. Further, for years wherein no data has been published for the parameter, the quality is assigned as 'low', with suitable assumptions used to address data gaps in such cases. Emission factors and default values sourced from the 2006 IPCC Guidelines[62] have been assessed to be of 'high' quality.

- Data and trends from Annual Reports, Status Papers, Statistical records of line ministries such as Ministry of Agriculture, Ministry of Commerce and Industry, Ministry of Chemicals and Fertilizers of Government of India, have been used for data on state-wise 'Industrial production (Pi)' for the industry sectors considered in estimates. Therefore, the quality of data is considered as 'high' for the years wherein published state-level industrial production datasets from such government institutions are available while 'low' quality is assigned for years wherein reliable data is not available. Issues were found with quality and availability of state-level industrial production data for the Dairy, Rubber, Tannery, and Petroleum sectors, thereby requiring use of proxy data such as gross value added, production capacity and no. of manufacturers in the emission estimation and therefore 'low' quality has been assigned across the estimation period for these sectors.
- Information on' volume of wastewater generated per tonne of product' has been sourced from published data from NEERI and India's Second National Communication for year 2007 for 9 sectors and is deemed to be of 'high' quality for this year. For the Pulp and Paper sector, this information is based on a study undertaken by CSE which provides values for years 2011 and 2012 and is therefore gauged to be of 'medium' quality for these two years.
- The values for 'Degradable organic component in industrial wastewater (CODi)' used for Sugar, Dairy, Tannery and Pulp & Paper sectors are sourced from NEERI's published document on India's National Communication for year 2007 and are thus assessed to be of ' high' quality for this year. The COD values for Iron & Steel, Fertilizers and Rubber sectors is based on a NEERI study but pertain to year 2003 which falls outside the emission estimation period and therefore quality is assessed to be 'low' for these sectors. The COD values for Coffee, Petroleum and Meat sectors is sourced from the 2006 IPCC Guidelines and are thereby gauged to be of 'high' quality.
- 'Methane correction factor (MCFj)' value is based on the prevalent wastewater treatment system used in the respective industrial sector (see Table 63 in section 3.6.2). While the MCF values for corresponding treatment technologies has been sourced from the 2006 IPCC Guidelines, information on prevalent treatment system used is based on National Communication documents, 2006 IPCC Guidelines, and sector specific publications and the quality is assessed accordingly. MCF for Coffee and Meat are based on the 2006 IPCC Guidelines and thus assessed to be of 'high' quality. Information for this parameter for Fertilizer, Dairy, Sugar, Pulp & Paper, Tannery is sourced from India's Second National Communication and is thus assessed to be of 'high' quality for year 2007. MCF for Iron & Steel and Petroleum is based on private organization and independent research based publications and is thus assessed to be of 'low' quality. Information sourced for the Tannery sector pre-dates the estimation period 2005-2014 and is therefore assessed to be of 'low' quality.

[96] It is difficult to assess the quality of activity data by state since industrial activity for a particular sector is non-existent in some states. Therefore, a qualitative assessment has been done for each industry sector, since this is largely applicable across all states for a particular sector.
[97] Data sources for all parameters for industrial wastewater are indicated further in section 3.6.2 of this note.

- Values for the following parameters and emission factors for all industry sectors are sourced from the 2006 IPCC Guidelines[62]. Therefore, the quality is assessed to be 'high' across the emission estimation period.
    - Organic component removed as sludge (Si)
    - Amount of CH_4 recovered (Ri)
    - Maximum CH_4 producing capacity (Bo)

Table 61: Qualitative Assessment of Year-wise Activity and Emission Factor Data used in the Industrial Wastewater Treatment and Discharge Estimates

S. No.	Activity Data/Emission Factor	Quality									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
1	**Activity Data**										
(a)	Industrial Production (Pi)										
	Iron & Steel	L	L	L	L	L	L	H	H	H	H
	Fertilizers	L	H	H	H	H	H	H	H	H	H
	Sugar	H	H	H	H	H	H	H	L	L	H
	Coffee	H	H	H	H	H	H	H	H	H	H
	Petroleum	L	L	L	L	L	L	L	L	L	L
	Dairy	L	L	L	L	L	L	L	L	L	L
	Meat	H	H	H	H	H	H	H	H	H	H
	Pulp & Paper	L	L	L	L	L	L	H	H	H	H
	Rubber	L	L	L	L	L	L	L	L	L	L
	Tannery	L	L	L	L	L	L	L	L	L	L
(b)	Wastewater generated, m3 /t product (Wi)										
	Iron & Steel	L	L	H	L	L	L	L	L	L	L
	Fertilizers	L	L	H	L	L	L	L	L	L	L
	Sugar	L	L	H	L	L	L	L	L	L	L
	Coffee	L	L	H	L	L	L	L	L	L	L
	Petroleum	L	L	H	L	L	L	L	L	L	L
	Dairy	L	L	H	L	L	L	L	L	L	L
	Meat	L	L	H	L	L	L	L	L	L	L
	Pulp & Paper	L	L	L	L	L	L	M	M	L	L
	Rubber	L	L	H	L	L	L	L	L	L	L
	Tannery	L	L	H	L	L	L	L	L	L	L
(c)	Chemical oxygen demand (CODi)										
	Iron & Steel	L	L	L	L	L	L	L	L	L	L
	Fertilizers	L	L	L	L	L	L	L	L	L	L
	Sugar	L	L	H	L	L	L	L	L	L	L
	Coffee	H	H	H	H	H	H	H	H	H	H
	Petroleum	H	H	H	H	H	H	H	H	H	H
	Dairy	L	L	H	L	L	L	L	L	L	L
	Meat	H	H	H	H	H	H	H	H	H	H
	Pulp & Paper	L	L	H	L	L	L	L	L	L	L
	Rubber	L	L	L	L	L	L	L	L	L	L
	Tannery	L	L	H	L	L	L	L	L	L	L
(d)	Organic component removed as sludge (Si)	H	H	H	H	H	H	H	H	H	H
(e)	Amount of CH_4 recovered (Ri)	H	H	H	H	H	H	H	H	H	H
2	**Emission Factors**										
(a)	Methane correction factor (MCFj)										
	Iron & Steel	L	L	L	L	L	L	L	L	L	L
	Fertilizers	L	L	H	L	L	L	L	L	L	L
	Sugar	L	L	H	L	L	L	L	L	L	L
	Coffee	H	H	H	H	H	H	H	H	H	H
	Petroleum	L	L	L	L	L	L	L	L	L	L
	Dairy	L	L	H	L	L	L	L	L	L	L
	Meat	H	H	H	H	H	H	H	H	H	H
	Pulp & Paper	L	L	H	L	L	L	L	L	L	L

S. No.	Activity Data/Emission Factor	Quality									
		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
	Rubber	L	L	L	L	L	L	L	L	L	L
	Tannery	L	L	H	L	L	L	L	L	L	L
(b)	Maximum CH_4 producing capacity(Bo)	H	H	H	H	H	H	H	H	H	H

H-high, M-medium, L-low

1.17.2 Methodology

A Tier I approach has been followed to estimate CH_4 emissions from industrial wastewater since neither state-specific nor country-specific data on volumes of industrial wastewater generated is available. 10 industrial sectors with substantial organic wastewater generation are considered in the state-level emission estimation. Emission estimation for each sector is based on the following parameters:

- Industrial production in tonnes
- Wastewater generated per tonne of product
- Organic concentration (i.e. characteristic of wastewater)
- MCF based on broad treatment technology used by sector
- Methane recovery (if any)

A top-down approach has been followed and a combination of country-specific and state specific (where available) activity data has been sourced for most of the industry sectors, with IPCC default values used where such data is unavailable. Default values of the emission factors as per the 2006 IPCC Guidelines[62] have been used in the calculations. In some industries, CH_4 is recovered from industrial wastewater, and in the present calculations, CH_4 recovered for energy purposes in sugarand dairy industries has been subtracted from the total CH_4 estimated to be emitted from these industries (recovery rate was 70%, 75% and 75% respectively[98]).

Table 62: Type of Emission Factor and Level of Methodological Tier adopted for Industrial Wastewater Treatment and Discharge Estimates

IPCC ID	GHG Source & Sink Categories	CH_4	
		Method Applied	Emission Factor
4D1	**Industrial wastewater treatment and discharge**	**T1**	**D**

Notes: T1: Tier 1; D: IPCC default

As per the 2006 IPCC Guidelines and India's National Communication, the following equation is used to estimate CH_4 emissions from industrial wastewater treatment[99].

$$CH_4\ Emissions = \sum_i \left[\left(TOW_i - S_i \right) EF_i - R_i \right]$$

Where:

CH_4 Emissions	= CH_4 emissions in inventory year, kg CH_4/yr
TOW_i	= state-wise total organically degradable material in wastewater from industry i in inventory year, kg COD/yr
i	= industrial sector
S_i	= organic component removed as sludge in inventory year, kg COD/yr (Default value 0.35 as per 2006 IPCC Guidelines[100] and India's Second National Communication report[6])
EF_i	= emission factor for industry i,kg CH_4/kg COD for treatment/discharge pathway or system(s) used in inventory year
R_i	= amount of CH_4 recovered in inventory year, kg CH_4/yr

[98] Based on India's Second National Communication. Available at http://unfccc.int/resource/docs/natc/indnc2.pdf
[99] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.4. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[100] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

The activity data for this source category is the amount of organically degradable material in the wastewater (TOW), which is a function of industrial output (product) P (tonnes/year), wastewater generation W (m^3/ton of product), and degradable organics concentration in the wastewater COD (kg COD/m^3) as given in the equation[101]:

$$TOWi = Pi \cdot Wi \cdot CODi$$

Where:

TOWi = total organically degradable material in wastewater for industry i, kg COD/yr
i = industrial sector
P_i = state-wise total industrial product for industrial sector i, t/yr
W_i = wastewater generated, m3/t product
COD_i = chemical oxygen demand (industrial degradable organic component in wastewater), kg COD/m^3

For each industrial sector, the emission factor is estimated using the maximum methane producing capacity and the average methane correction factor (MCF) based on the type of treatment method used by the industry. The MCF indicates the extent to which the CH_4 producing potential (B_o) is released in each type of treatment method and thereby it is an indication of the degree to which the system is anaerobic.

$$CH_4 \text{ EMISSION FACTOR } EFj = B_o \cdot MCFj$$

Where:

EF_j = emission factor for each treatment/discharge pathway or system used by the industry, kg CH_4/kg COD
j = each treatment/discharge pathway or system
B_o = maximum CH_4 producing capacity, kg CH_4/kg COD (Default value 0.25[102])
MCF_j = methane correction factor (fraction)

Table 63: Default MCF values based on treatment type and discharge pathway or system for Industrial Wastewater

TYPE OF TREATMENT AND DISCHARGE PATHWAY OR SYSTEM	DETAILS	MCF
Untreated		
Sea, river and lake discharge	Rivers with high organics loadings may turn anaerobic, however this is not considered here	0.1
Treated		
Aerobic treatment plant	Well managed	0
Aerobic treatment plant	Not well managed. Overloaded	0.3
Anaerobic digester for sludge	CH4 recovery not considered	0.8
Anaerobic reactor (e.g., UASB, Fixed Film Reactor)	CH4 recovery not considered	0.8
Anaerobic shallow lagoon	Depth less than 2 metres	0.2
Anaerobic deep lagoon	Depth more than 2 metres	0.8

(Source: 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.8)

Data Sources and Assumptions

1. Industrial Production (P_i)

As indicated earlier, the unavailability of reliable data on industrial production is a key challenge encountered in the state-level emission estimates. In some cases, industrial production data is not available at the state-level at all. Data is also found to be partly missing for some years in the reporting period or is not reported in a disaggregated manner for some states. To address these data gaps, national level production data has been apportioned to the state-level for 8 out of 10 sectors, either across all years and all states or partially for some of the years. Information such as installed production capacity by state, no. of manufacturers or manufacturing facilities by state, and gross economic value added by state, which can be correlated with industrial production has been used to scale down national-level data to the state-level.

[101] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.5. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[102] As per 2006 IPCC Guidelines, Vol.5, Chapter 6: Wastewater Treatment and Discharge and NEERI document on Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

The following sources have been used to obtain the production data or correlated information on industrial activity for the industry sectors under consideration. The assumptions used to address data gaps for the industry sectors are listed below the Table 64. State-wise industrial production data considered in the emission estimates for each industry sector is given in Tables 75 to 84 in the Annexure.

Table 64: Data sources for Industrial Production data

SECTOR	DATA POINT	DATA SOURCE
Iron & Steel	• Installed capacity of Pig Iron production for private sector plants and their location • Production of Pig iron by public sector plants and their location • National-level Pig iron production	Indian Bureau of Mines- The Indian Minerals Yearbook 2012 (Part- II: Metals & Alloys – Iron & Steel and Scrap), Table 8[103] Ministry of Steel - Annual Report 2007-08, Annexure VII[104] Ministry of Steel, Government of India- Annual Report 2012-13, Annexure VII[103] Ministry of Steel, Government of India -Annual Report 2014-15, Annexure VII[103]
	• Installed capacity of Sponge plants and their location • National-level Sponge iron production	Ministry of Steel, Government of India- Annual Report 2008-09, Annexure VII[103] Indian Bureau of Mines- The Indian Minerals Yearbook 2012 (Part- II: Metals & Alloys – Iron & Steel and Scrap), Table 9[102] Indian Bureau of Mines- The Indian Minerals Yearbook 2015 (Part- II : Metals & Alloys – Iron & Steel and Scrap), Table 9[102]
	• Installed capacity of Steel Production by plants and their location • National-level Steel Production	Report of the Working Group on Steel Industry for 12th FYP (2012-2017), Ministry of Steel 2011, Table 3.7[105] Ministry of Steel, Government of India- Annual Report 2008-09, Annexure VII[103] Indian Bureau of Mines- The Indian Minerals Yearbook 2012 (Part- II: Metals & Alloys – Iron & Steel and Scrap), Table 3[102] Indian Bureau of Mines- The Indian Minerals Yearbook 2015 (Part- II: Metals & Alloys – Iron & Steel and Scrap), Table 3[105]
Fertilizer	Plant-wise production of nitrogen and phosphate fertilizer and their location	Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, Annual Report 2012-13, Annexure IV[106] Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, Annual Report 2010-11, Annexure IV[107] Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, Annual Report 2008-09, Annexure IV[108] Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, Annual Report 2006-07, Annexure IV[109] Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India, Annual Report 2004-05, Annexure IV[110]
Sugar	State-wise production of Sugar	Annexure XXIX, Status Paper on Sugarcane, Directorate of Sugarcane Development, Ministry of Agriculture[111]
Coffee	State-wise production of Coffee	Quarterly Publications on Database on Coffee - Part I, Table 1.6 Production of Coffee in Major States/Districts of India, Coffee Board, Ministry of Commerce and Industry, Government of India[112] Data for the years 2004-05 to 2007-08 has been received over telephone from Dy. Director (Market Research), Coffee Board
Petroleum	• Volume of Crude Oil processed by refineries and their location • National-level production of Petroleum, Oil and	Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum & Natural Gas – Crude Processing[113] Petroleum Planning and Analysis Cell (PPAC), Ministry of Petroleum & Natural Gas – Production of Petroleum Products[114]

103 Available at http://ibm.nic.in/index.php?c=pages&m=index&id=107
104 Available at http://steel.gov.in/annual-reports
105 Available at http://planningcommission.gov.in/aboutus/committee/wrkgrp12/wg_steel2212.pdf
106 Available at http://chemicals.nic.in/document-report/annual-report
107 Available at http://fert.nic.in/sites/default/files/Annual_Report_English_2011_0.pdf
108 Available at http://fert.nic.in/sites/default/files/Annual-Report-2008-2009-english.pdf
109 Available at http://fert.nic.in/sites/default/files/Annual-Report-2006-2007-english.pdf
110 Available at http://fert.nic.in/sites/default/files/Annual-Report-2004-2005-english.pdf
111 Available at http://www.nfsm.gov.in/Publicity/2014-15/Books/Status%20Paper%20of%20Sugarcane_Final_New.pdf
112 Available at http://www.indiacoffee.org/database-coffee.html
113 Available at http://www.ppac.org.in/WriteReadData/userfiles/file/PT_crude_H.xls
114 Available at http://www.ppac.org.in/WriteReadData/userfiles/file/PT_production_source_H.xls

SECTOR	DATA POINT	DATA SOURCE
	Lubricants	
Dairy	• No. of registered dairy plants and their installed capacity by state • National-level milk production	Basic Animal Husbandry Statistics 2012 - PART VIII- Dairying Statistics, Table 74, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture[115] Basic Animal Husbandry & Fisheries Statistics- 2015, Table 1, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture[116]
Meat	State-wise Meat production	Basic Animal Husbandry & Fisheries Statistics- 2015, Table 19, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture[114] Basic Animal Husbandry and Fisheries Statistics, 2012, Part III: Meat and Wool, Table 22, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture[117] Basic Animal Husbandry Statistics, 2010, Table 21, Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture[118]
Pulp and Paper	State-wise Paper production	Compendium of Census Survey of Indian Paper Industry, Central Pulp & Paper Research Institute, 2015 (print version)
Rubber	• No. of licensed rubber manufacturers by state • Rubber cultivation in Meghalaya and Nagaland • National-level production of rubber	Statistics & Planning Department, Rubber Board- Rubber Statistical Monthly News -June 2006, Page 2 – Production and Consumption of NR & SR[119] Statistics & Planning Department, Rubber Board – Indian Rubber Statistics, Table 6 and Table 18[120] Statistics & Planning Department, Rubber Board- Rubber Statistical Monthly News –July 2011, Page 2 – Production and Consumption of NR & SR [121] Statistics & Planning Department, Rubber Board- Rubber Statistical Monthly News –May 2013, Page 2 – Production and Consumption of NR & SR [122] Statistics & Planning Department, Rubber Board- Rubber Statistical Monthly News –September 2014, Page 2 – Production and Consumption of NR & SR [123] Website of Rubber Board- Manufacturer License List[124] Website of Rubber Board, Development Activities- Scheme in Operation- North Eastern States[125]
Tannery	• Gross value added for leather and related products • National level production of Bovine, Sheep, lamb, Goat and kid skins and hides	Handbook of Industrial Policy and Statistics 2008-09, Table 14.2-Table 14.36, Department of Industrial Policy and Promotion, Ministry of Commerce & Industry[126] Food and Agriculture Organization (FAO)- World Statistical Compendium for raw hides and skins, leather and leather footwear 1998-2015, Table 5, Table 7, Table 9[127]

Assumptions:

115 Available at http://dahd.nic.in/sites/default/files/11.%20Part%20VIII%20Dairying%20%20Statistics%20BAHS%202012.pdf
116 Available at http://dahd.nic.in/sites/default/files/BAH_%26_FS_Book.pdf
117 Available at http://dahd.nic.in/sites/default/files/wool.pdf
118 Available at http://www.nadrs.gov.in/SitePages/~/_layouts/images//BAHS_2010.pdf
119 Available at http://www.rubberboard.org.in/RSN/RSN_June06.pdf
120 Available at http://rubberboard.org.in/IRS_Vol33.pdf
121 Available at http://www.rubberboard.org.in/RSN/RSN_July2011.pdf
122 Available at http://www.rubberboard.org.in/RSN/RS_News_May2013(annual).pdf
123 Available at http://www.rubberboard.org.in/RSN/rsnewssep2014.pdf
124 Available at http://rubberboard.org.in/displaymanufacturers.asp
125 Available at http://rubberboard.org.in/ManageScheme.asp?Id=59
126 Available at http://eaindustry.nic.in/industrial_handbook_200809.pdf
127 Available at http://www.fao.org/3/a-i5599e.pdf

- To ensure consistency with India's Second National Communication Report[6] and the First Biennial Update Report[7], the GHG emission inventory is to be prepared on a calendar year basis. For all the industrial sectors included in this assessment except Tannery sector, production data is available on a financial year basis has been apportioned on a calendar year basis. Production datasets available on financial year basis have been converted to calendar year datasets for a given calendar year by considering 3/4th of the value from the previous financial year (corresponding to 9 months from April to December out of 12 months in a year) and 1/4th from the next financial year (corresponding to 3 months from January to March out of 12 months in a year). For example, 3/4th of the production data from the financial year 2004-05 and 1/4th of the production data from the financial year 2005-06 has been considered and added together to estimate the production data for the calendar year 2005, and so on. Production data for Tannery sector was already reported for the calendar year and thus no further estimation was required to convert this data to calendar year basis.
- Iron & Steel Sector assumption and apportionments:
  (a) State-wise total Pig Iron production is not available directly from the data sources for all years of the emission estimation period. Therefore, state-wise Pig Iron production has been consolidated based on reported data for public and private sector plants. Production data considered for public sector plants has been aggregated for relevant states based on reported production data and location of the plant. With regard to private sector plants, only aggregated all-India level production of Pig Iron by private sector plants from 2004-05 to 2013-14 is available and state-wise production is not reported. Further, data on 'installed capacities' is only reported for these plants for year 2011-12 and data on production of Pig Iron by these plants is not reported. Given the lack of time-series data, the state-wise proportion of 'installed capacity' of Pig Iron plants, as available for year 2011-12, is assumed to be applicable across the emission estimation period. The state-wise production has been estimated based on the corresponding share of installed capacity of the private sector plants (as available for year 2011-12).
  (b) State-wise data on production of Sponge Iron is not available across the emission estimation period. Data on 'installed capacity' for Sponge Iron plants by their location is available for the period 2011-12 to 2013-14 and production data for each of these plants is not available. To address the unavailability of state-level production data, aggregated national-level data available on Sponge Iron production from 2004-05 to 2013-14 has been apportioned to each of the states based on corresponding proportions of 'installed capacity' of Sponge Iron plants by their location. Given the lack of time-series data, the state-wise proportion of 'installed capacity' of Sponge Iron plants, as available for 2011-12 to 2013-14, is assumed to be applicable across the emission estimation period.
  (c) State-wise data on production of Steel is not available across the emission estimation period. Data on 'installed capacity' for Steel plants by their location is available for the period 2010-11 to 2013-14 and production data for each of these plants is not available. To address the unavailability of state-level production data, aggregated national-level data available on Steel production from 2004-05 to 2013-14 has been apportioned to each of the states based on corresponding proportions of 'installed capacity' of Steel plants by their location. Given the lack of time-series data, the state-wise proportion of 'installed capacity' of Steel plants, as available for 2010-11 to 2013-14, is assumed to be applicable across the emission estimation period.
  (d) With regard to Steel, aggregated data reported for Steel Authority of India Limited (SAIL) steel plants producing finished steel[128] has been apportioned among 3 states based on the plant location and their respective 'installed capacities'. Further in the Steel dataset, location of some plants is reported as 'Multi location' and the specific state is not indicated. The 'Multi location' category includes the following five states: Maharashtra, West Bengal, Andhra Pradesh, Chattishgarh, and Karnataka. Therefore, in this case the 'installed capacity' reported under 'Multi location' has been split equally in these 5 states, given the lack of information.
- Fertilizer Sector data assumption and apportionments:

[128] (a) The three SAIL steel plants include- (1) Alloy Steels Plant, Durgapur, West Bengal with 184,000 tonnes per annum production capacity in 2015 (2) Salem Steel Plant (SSP), Tamil Nadu with 339,000 tonnes per annum production capacity in 2015 (3) Visvesvaraya Iron and Steel Limited (VISL), at Bhadravathi, Karnataka with 216,000 tonnes per annum production capacity

(a) Reported data on plant-wise production of Nitrogen and phosphate fertilizer for 2004-05 to 2013-14 has been aggregated to the state-level based on plant location.

(b) Nitrogen fertilizer production data for plants located in Andhra Pradesh, Goa, Karnataka, Odisha, Rajasthan, Tamil Nadu and West Bengal is not reported for year 2004-05 and has been estimated based on the corresponding annual growth rate in nitrogen fertilizer production for these states from 2003-04 to 2005-06.

(c) Phosphate fertilizer production data for plants located in Odisha and West Bengal is not reported for year 2004-05 and has been estimated based on the corresponding annual growth rate in phosphate fertilizer production for these states from 2003-04 to 2005-06.

- Coffee Sector data assumption and apportionments:
  (a) Coffee production for the states of Andhra Pradesh and Odisha is clubbed together in the source document and is not reported separately. Similarly, coffee production in North East region is not reported separately for each of the constituent states. Therefore, for these states the following assumptions have been considered to estimate coffee production for these states across the reporting period as per communication with Deputy Director (Market Research), Coffee Board -
    - In the Andhra Pradesh & Odisha cluster, Andhra Pradesh and Odisha has a respective share of 95% and 5% approximately in the coffee production
    - In the North-East region, the states of Assam and Meghalaya have an approximate share of 20% each and the rest of the five states (Arunachal Pradesh, Manipur, Mizoram, Nagaland, Tripura) have a share of approximately 12% each in the North East region's total Coffee Production
- Petroleum Sector data assumption and apportionments:
  (a) State-wise data on production of Petroleum products (petroleum, oil and lubricants) is not available. Reported data on the 'volume of crude oil processed' is available for different refineries along with their location for the period 2004-05 to 2013-14. National-level data available on cumulative production of Petroleum products for 2004-05 to 2013-14 has been apportioned to each of the states that house refineries based on corresponding proportion of 'volume of crude oil processed' by each refinery to the 'total volume of Crude Oil processed' by all refineries.
- Milk Sector data assumption and apportionments:
  (a) State-wise data on Milk processed by dairies is not available across the emission estimation period. State-wise data on 'cumulative installed capacity' of registered dairies is available for year 2011. To address the unavailability of state-level production data, aggregated national-level data available on Milk production from 2004-05 to 2013-14 has been apportioned to each of the states based on corresponding proportions of 'installed capacity' of dairies by State. Given the lack of time-series data, the state-wise proportion of 'installed capacity' of dairies, as available for year 2011, is assumed to be applicable across the emission estimation period.
- Pulp & Paper Sector data assumption and apportionments:
  (a) State-wise paper production is available only for the time period 2010-11 to 2013-14 and is not available for the period from 2004-05 to 2009-10. The total National-level production has been estimated for these years by applying an average annual growth rate of 6% to the available data from 2010-11 to 2013-14 as per inputs received from the Central Pulp & Paper Research Institute (CPPRI). The paper production for relevant states has subsequently been estimated for the period from 2004-05 to 2009-10 based on the corresponding average share of each state in the production as per reported data from 2011-12 to 2013-14.
- Rubber sector data assumption and apportionments:
  (a) State-wise data on Natural and Synthetic Rubber processed by states is not available across the emission estimation period. National-level data on cumulative production of Natural and Synthetic Rubber has been apportioned to each of the corresponding states based on the available data on state-wise no. of licensed rubber manufacturers across the period between 2004-05 and 2013-14. Information on the 'installed production capacity' for the licensed rubber manufacturers is not available and thus given the lack of alternate production related data, apportionment has been done solely on the basis of the number of licensed manufacturers.

  (b) Data on no. of rubber manufacturers for the union territories of Chandigarh, Dadra & Nagar Haveli, and Daman & Diu is not reported separately in the data sources. Reported data on state-wise no. of manufacturers that is available for year 2017 has been used accordingly for these 3 union territories.

(c) Data on no. of rubber manufacturers for the states of Jammu and Kashmir, Meghalaya, Nagaland, Puducherry and Tripura is not reported separately in the data sources and is clubbed under 'Others' across the emission reporting period. Reported data on state-wise no. of manufacturers for year 2017 has been used for Puducherry, Tripura, and Jammu & Kashmir. Segregated data on no. of manufacturers in Meghalaya and Nagaland is not available and therefore information on corresponding share of rubber cultivation in these two states, available for year 2004-05 only, has been used as a basis for apportionment.

- Tannery sector data assumption and apportionments:
  (a) State-wise data on leather processed by states not available for the emission estimation period. State-wise data on corresponding 'Gross Value Added' by Tannery sector is available for year 2005-06. Data on no. of tannery factories is also available however data on 'production or installed capacities' is not known for the tanneries. Hence, 'Gross Value Added' is gauged to be a more appropriate metric to represent the manufacturing activity in tannery sector for each state and has been used as a basis for apportionment. National-level data available on cumulative production of tannery products (total of Bovine, Sheep, lamb, Goat and kid skins and hides) has been apportioned to each of the states based on the corresponding share of 'Gross Value Added' for each state to total state-aggregate 'Gross Value Added' for the sector. Given the lack of time-series data, the state-wise proportion of 'Gross Value Added' by the Tannery sector, as available for year 205-06, is assumed to be applicable across the emission estimation period.

2. Wastewater generated per tonne of product (W_i)

A combination of country specific and default values available at the national level have been used for this coefficient since state-level values are not available. The following data sources are used, in the order of preference to prioritize the use of country specific values for this coefficient (based on the availability of information)

1. India's Second National Communication to the UNFCCC
2. related NEERI[129] documentation (indicated in the following Table)
3. 2006 IPCC Guidelines (Vol. 5, Chapter 6: Wastewater Treatment and Discharge)

The values for wastewater generation per tonne of production and respective data sources are indicated in the Table 65 below.

Table 65: Industry-wise Wastewater generation per tonne of Product

INDUSTRY	WASTEWATER GENERATION (M^3/TONNE OF PRODUCT)	REFERENCE
Iron & Steel	60	India's Second National Communication to the UNFCCC, 2012[6]
Fertilizer	8	India's Second National Communication to the UNFCCC, 2012
Sugar	1	India's Second National Communication to the UNFCCC, 2012
Coffee	5	India's Second National Communication to the UNFCCC, 2012
Petroleum	0.7	India's Second National Communication to the UNFCCC, 2012
Dairy	3	India's Second National Communication to the UNFCCC, 2012
Meat	11.7	India's Second National Communication to the UNFCCC, 2012
Pulp & Paper	60 (2011) & 57 (2012)	CSE Paper Industry Report, 2013. Available at http://ipma.co.in/wp-content/uploads/2015/11/CSE-Paper-Industry-Report-2013.pdf
Rubber	26.3	India's Second National Communication to the UNFCCC, 2012
Tannery	32	Inventorization of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

[129] NEERI was the lead institution involved in the estimation of GHG emissions from industrial wastewater for the Waste sector. NEERI has been contacted for details on the methodology and information for this assessment and in case of data gaps or limited availability of information in the National Communication reports, preference has been given to relevant NEERI documents.

Assumptions:

- Wastewater generation per tonne of product would likely vary over the years, with improvements in production processes and technologies leading to reduction in wastewater generation. However, due to the lack of such updated information in the 2006 IPCC Guidelines[62] and the National Communication[6], and in the absence of other published literature, constant values of wastewater generated per tonne of product have been used for all the years (2005-2013) in this assessment for 9 industry sectors, except for the Pulp and paper sector.
- A study conducted by CSE in 2012-13 for the sector indicates that wastewater generation has reduced to 60 m^3 per tonne in 2011-12 and 57 m^3 per tonne in 2012-13 due to improvements in technology, with an average annual reduction of 7.4% since 1995-96[130]. Field studies conducted by the National Productivity Council in 10 pulp and paper mills in 2005-06[131], in consultation with the CPCB, indicate that the wastewater discharge per tonne of product ranges from 65-100 m^3 and thereby validates the findings of the CSE study. Wastewater generation for the rest of the years in the reporting period has been estimated using the average annual reduction rate of 7.4%.

3. Degradable organic component in industrial wastewater (COD_i)

The following data sources are used, in the order of preference to prioritize the use of country specific values for this coefficient (based on the availability of information)

1. NEERI documentation on India's official National Inventory (indicated in the following Table)
2. NEERI documentation on Methane Emissions from wastewater in India (indicated in the following Table)
3. 2006 IPCC Guidelines (Vol. 5, Chapter 6: Wastewater Treatment and Discharge)

Specific values of degradable organic concentration in the wastewater (kg COD/m^3) used in the India's National Communications are not indicated in the National Communication reports. State-wise values for this coefficient are not available. Therefore, default and country specific national level values are used for this coefficient in this assessment are indicated in the Table 66 below.

Table 66: Industry-wise degradable organic concentration in the Wastewater

INDUSTRY	COD (KG COD/M³)	REFERENCE
Iron & Steel	0.55	NEERI (2010): Status of Methane Emissions from Wastewater and Role of Clean Development Mechanisms in India. Published in the TERI Information Digest on Energy and Environment, [S.l.], p. 155-166, June. 2010. ISSN 0972-6721. Available at: http://www.i-scholar.in/index.php/tidee/article/view/89982
Fertilizer	3.0	NEERI (2010): Status of Methane Emissions from Wastewater and Role of Clean Development Mechanisms in India. TERI Information Digest on Energy and Environment, [S.l.], p. 155-166, June 2010. ISSN 0972-6721. Available at: http://www.i-scholar.in/index.php/tidee/article/view/89982
Sugar	2.5	Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf
Coffee	9	2006 IPCC guidelines for National Greenhouse Gas Inventories, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.9. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
Petroleum Refineries	1	2006 IPCC guidelines for National Greenhouse Gas Inventories, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.9. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
Dairy	2.24	Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

[130] The CSE study includes a sample survey of twelve pulp and paper mills accounting for 21 per cent of the total production of the industry and spread over 10 states. CSE (2013): Paper Through Time – Tracking the Industry's Progress. Available at http://ipma.co.in/wp-content/uploads/2015/11/CSE-Paper-Industry-Report-2013.pdf

[131] National Productivity Council and CPCB (2006): Final Report on Development of Guidelines for Water Conservation in Pulp and Paper Sector. Available at http://cpcb.nic.in/newitems/45.pdf

Industry	COD (kg COD/m³)	Reference
Meat	4.1	2006 IPCC guidelines for National Greenhouse Gas Inventories, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.9
Pulp & Paper	5.9	Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf
Rubber	6.12	NEERI (2010): Status of Methane Emissions from Wastewater and Role of Clean Development Mechanisms in India. Published in TERI Information Digest on Energy and Environment, [S.l.], p. 155-166, jun. 2010. ISSN 0972-6721. Available at: http://www.i-scholar.in/index.php/tidee/article/view/89982
Tannery	3.1	Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, NEERI, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

4. Methane Correction Factor and Emission Factor (EF_i) for the industry

The value of the MCF is based on the prevalent wastewater treatment system used in the respective industrial sector (see Table 63). The following data sources are used, in the order of preference (based on the availability of information) for consistency with India's National Communication and the IPCC guidelines

1. India's Second National Communication to the UNFCCC
2. 2006 IPCC Guidelines (Vol. 5, Chapter 6: Wastewater Treatment and Discharge)
3. Sector-specific documents and studies (used where information is not available from NEERI and IPCC guidelines)

The data sources to identify the prevalent wastewater treatment technologies for the industrial sectors and the corresponding emission factor used are indicated in Table 67. State-level information for the emission factor related parameters is not available. The 2006 IPCC Guidelines and other reference documents define values for the emission factors and coefficients at the national level only. Therefore, the national level values listed for each industry sector are used in the emission estimation across all states.

Table 67: Industry-wise Methane Correction Factor based on the prevalent treatment system

Industry	Bo (kg CH4/kg COD)[132]	MCF [133]	EF= Bo x MCF (kg CH4/kg COD)	Reference for Prevalent Treatment Technology
Iron & Steel	0.25	0	0	Sirajuddin, Ahmed, Umesh Chandra, R. K. Rathi, (2010) "Waste water treatment technologies Commonly practiced in Major Steel Industries of India" In 16th Annual International Sustainable Development Research Conference 2010, 30 May – 1 June, 2010 The University of Hong Kong, Hong Kong. Available at: http://www.kadinst.hku.hk/sdconf10/Papers_PDF/p537.pdf
Fertilizer	0.25	0.2	0.05	India's Second National Communication to the UNFCCC, 2012. Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf
Sugar	0.25	0.8	0.2	• India's Second National Communication to the UNFCCC, 2012 • Methane extraction from Organic wastewater, at Mandya District, Karnataka< India by M/s Sri Chamundeswari Sugars Ltd. Available at: https://cdm.unfccc.int/Projects/DB/DNV-CUK1176804855.99/view
Coffee	0.25	0.8	0.2	2006 IPCC guidelines for National Greenhouse Gas Inventories, Vol. 5, Chapter 6: Wastewater Treatment and

132 Bo value is taken as default value as per 2006 IPCC Guidelines, Vol. 5, Chapter 6. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
133 MCF value is taken based on treatment systems listed in 2006 IPCC Guidelines, Vol. 5, Chapter 6, Table 6.8 (see Table 63 in this document). Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

INDUSTRY	BO (KG CH4/KG COD)[132]	MCF [133]	EF= BO x MCF (KG CH4/KG COD)	REFERENCE FOR PREVALENT TREATMENT TECHNOLOGY
				Discharge. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
Petroleum Refineries	0.25	0	0	Technical EIA Guidance Manual for Petroleum Refining Industry prepared by IL&FS Ecosmart Limited for MoEF, 2010. Available at: http://envfor.nic.in/sites/default/files/TGM_Petroleum_Refineries_010910.pdf
Dairy	0.25	0.8	0.2	India's Second National Communication to the UNFCCC, 2012. Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf
Meat	0.25	0.8	0.2	2006 IPCC guidelines for National Greenhouse Gas Inventories, Vol. 5, Chapter 6: Wastewater Treatment and Discharge. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
Pulp & Paper	0.25	0.8	0.2	• India's Second National Communication to the UNFCCC, 2012. Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf • Methane recovery from wastewater generated at Paper manufacturing unit of Sree Sakthi Paper Mills Ltd., Kerala, India. Available at https://cdm.unfccc.int/Projects/DB/SGS-UKL1236761076.31
Rubber	0.25	0	0	• Central Pollution Control Board (CPCB), Pollution Control Implementation Division – III report on 'Pollution Control in Natural Rubber Processing Industry'. Available at: http://cpcb.nic.in/divisionsofheadoffice/pci3/pciiiidivrubber.pdf • Woodard, F. (2001). Industrial waste treatment handbook. Available at: http://neerienvis.nic.in/pdf/publications/e-book/Industrial%20Waste%20Treatment%20Handbook.pdf
Tannery	0.25	0.2	0.05	India's Second National Communication to UNFCCC, 2012. Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf

5. Methane Recovery Rates

CH_4 is recovered in some of the industries such as sugar and dairy for energy purposes. In such cases, the methane recovered is to be subtracted from the total CH_4 estimated to be emitted from wastewater treatment in these industries. Since, state-level information on methane recovery rates is not available, national-level values as per GHG estimates prepared for year 2007 for India's Second National Communication[6]have used across the states:

- Sugar: 70% methane recovery rate
- Dairy: 75% methane recovery rate

1.17.3 Uncertainties

Emission estimate uncertainties are considerable in the case industrial wastewater. Key factors that result in such significant uncertainties include:

- **Unavailability of reliable state-level production data across the years for each industry type**: Since data on industrial wastewater generation is unavailable, industrial production is a crucial starting point in the activity dataset to estimate the total wastewater generation for each industrial sector as per the tier I approach adopted. Reliable state-level data on industrial production is not available for most of the industry sectors across the emission estimation period. In some cases, industrial production data is not available at the state-level at all. Data is also found to be partly missing for some years in the reporting period or is not reported in disaggregated manner for some states. To address these data gaps, apportionment has been done for 8 out of 10 sectors based on national level production data and relevant proxy data such as installed production capacity, no. of manufacturers, etc. at the state level. Given that the activity data estimated using such approximations may not accurately reflect the prevalent industry environment in the reporting period and therefore this unavailability of activity data has impacted reliability. Further, the data is sourced from multiple data sources, which in turn report data that is collated from numerous sources, leading to the errors in reporting from the universe of respondents being carried over into the emission estimates.

- **The operational status of industrial wastewater treatment:** The type of wastewater treatment considered in the estimates is based primarily on information from NATCOM reports, IPCC guidelines and, NEERI publications. However, the status of the treatment plants that exist in the states, in terms of whether these are fully functional or not, is not recorded for any of the considered years. The amount of total degradable organic carbon (TOW) in industrial wastewater that is discharged into open or closed domestic sewers is very difficult to quantify, since information regarding the functional status of on-site treatment plants is not available.
- **Wastewater generation per unit product:** In the case of industrial wastewater, it is likely that wastewater generation per tonne of product and therefore wastewater generation may vary over the years with changes in production processes and technologies. However, due to the lack of such updated information, constant values of wastewater generated per tonne of product have been used for all the years (2005-2013) in the state-level emission estimates, except for Pulp & Paper sector.

As per 2006 IPCC Guidelines[134], the following conclusions may be drawn regarding uncertainty of GHG emissions from the treatment and disposal of industrial wastewater:

- Uncertainty resulting from values considered for Maximum CH_4 producing capacity (Bo): ±30%
- Uncertainty resulting from values considered for Industrial Production: ±25%
- Uncertainty resulting from kg COD per unit of produced product: -50%, +100% (a factor of 2)

Sensitivity Analysis for considered MCF values

The MCF considered in the GHG estimates and possible alternate scenarios are given in the Table 68 below. Alternate scenarios are proposed based on potential alternate treatment methods that may exist on ground. Given that the exact treatment process, even at the national-level, is not validated in the National Communication reports and is not available in other literature, the following two scenarios are considered to assess the percentage of deviation from the considered estimates.

Scenario 1 assumes that in Iron & Steel, Petroleum refineries, and Rubber industries the aerobic treatment plants for wastewater are not well managed, thereby, the MCF is changed from 0 to 0.3. In scenario 2, the impact of using anaerobic reactors instead of anaerobic shallow lagoons is considered for Tannery and Fertilizer industries.

Table 68: Alternate Scenarios for MCF values in the Industrial Wastewater Emission Estimates

Industry Sector	Treatment type considered in GHG Platform India Final estimates	MCF	Treatment type: Alternate Scenario - 1	MCF - Scenario 1	Treatment type: Alternate Scenario - 2	MCF - Scenario 2
Iron & Steel	Aerobic well-managed	0	Aerobic not-well managed	0.3	Aerobic well-managed	0
Fertilizer	Anaerobic shallow lagoon	0.2	Anaerobic shallow lagoon	0.2	Anaerobic reactor	0.8
Petroleum Refineries	Aerobic well-managed	0	Aerobic not-well managed	0.3	Aerobic well-managed	0
Rubber	Aerobic well-managed	0	Aerobic not-well managed	0.3	Aerobic well-managed	0
Tannery	Anaerobic shallow lagoon	0.2	Anaerobic shallow lagoon	0.2	Anaerobic reactor	0.8

[134] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.10. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

Table 69: Deviation in Aggregated State Industrial Wastewater GHG emission results based on Sensitivity Analysis

Year	GHG Platform India Final Aggregated State-Level Considered Emission Estimates (Mil. Tonnes of CO_2e)	Scenario 1		Scenario 2	
		Estimated Aggregated State-Level Emission (Mil. Tonnes of CO_2e)	Percent Deviation w.r.t. GHG Platform India Final emission estimates	Estimated Aggregated State-Level Emission (Mil. Tonnes of CO_2e)	Percent Deviation w.r.t. considered GHG emission estimates
2005	23.75	27.13	14.2%	24.96	5.1%
2006	23.64	27.59	16.7%	24.97	5.6%
2007	23.71	28.05	18.3%	24.97	5.3%
2008	23.62	28.15	19.2%	24.84	5.2%
2009	23.54	28.38	20.6%	24.86	5.6%
2010	23.47	28.75	22.5%	24.84	5.9%
2011	23.31	28.94	24.2%	24.68	5.9%
2012	24.20	30.23	24.9%	25.57	5.7%
2013	23.99	30.31	26.4%	25.38	5.8%

1.17.4 Source Category specific QA/QC

The internal QC procedures outlined previously in 'GHG estimation preparation, data collection, process and storage' in section 1.3 are carried out for this source category. Inputs were also received from experts from NEERI and CPCB on prevalent wastewater treatment technologies for industry sectors such as Iron & Steel, Rubber, Petroleum, Dairy, Coffee, Meat that are considered in this assessment. Discussions were also held with representatives from industrial departments and associations including the Ministry of Statistics and Programme Implementation, Central Board of Excise and Customs - Central Excise, the Central Pulp & Paper Research Institute, the Indian Paper Manufacturers Association, the Coffee Board of India, All India Brewers Association, the Rubber Board on industrial production datasets. Inputs received helped to ascertain the status of available state-level industrial production data and gaps therein and identify potential data sources for Beer, Soft drinks, Pulp & Paper, Coffee and Rubber sectors in particular. Specific considerations for the industrial wastewater treatment and discharge category, in view of the emission estimation approach, are indicated below.

The emission estimates for industrial wastewater are based on a tier 1 approach and cover 10 industry sectors. Activity data on industrial production and correlated proxy data has been sourced from official publications from government departments, nodal agencies, and industry associations. In cases where information on industrial production for a sector has been reported in multiple datasets, the datasets have been compared and data has been sourced to minimize reliability related issues such as consistency in time-series trends, errors in conversion and reporting of units, etc. Country specific wastewater generation rates have been used for all 10 sectors. Country specific values of Degradable organic concentration in the wastewater (kg COD/m^3) have been used for 7 sectors, with IPCC default values used otherwise. Limited availability of published data on facility-specific industrial wastewater generation and characteristics technology is a challenge in the source specific QA/QC for this category.

1.17.5 Recalculation

No recalculations have been done since this is the first instance of estimating state-level emissions under the GHG Platform-India.

1.17.6 Verification

An external verification of the state emission estimates for this source category has not been undertaken at present. However, relevant QA/QC procedures have been applied internally to ensure reliability of calculations, processing of data, consistency, and transparent and clear documentation of methodology, assumptions and results. The state-level emission estimates have undergone a peer review process and have been finalized subsequently.

The cumulative state estimates for industrial wastewater treatment and discharge under this assessment have also been compared with the emissions reported for year 2007 and 2010 in India's National communication documents – the Second National Communication, 2012[6] and the First Biennial Update Report, 2015[7]. The estimates show an over-estimation, with a deviation of 7.3% and 8.1% respectively for year 2007 and 2010 as compared to the official estimates reported by India for solid waste disposal (see Table 70).

Table 70: Comparison of the Aggregate State GHG emission estimates for Industrial Wastewater Treatment and Discharge with Nationally Reported Values

Year	GHG Platform India Emission Estimates for Industrial Wastewater Treatment and Discharge (Mil. Tonnes of CO_2e)	Official Emission Estimates for Industrial Wastewater Treatment and Discharge As per Second National Communication (2007) and Biennial Update Report (2010) (Mil. Tonnes of CO_2e)	Percent deviation w.r.t. Official Emission Estimates
2007	23.71	22.10	7.3%
2010	23.47	21.70	8.1%

The deviation in the estimates for this source category can be attributed largely to ambiguity over the values of multiple parameters, assumptions data sources used in official national inventories for 2007 and 2010 across the industrial sectors and the broad approximations used at the state-level due to unavailability of reliable data. The possible reasons for the deviation are discussed further below:

- **Variation in Activity Data:** The Tier I methodology for GHG emission estimation from industrial wastewater is dependent on a number of input parameters/activity data such as sector-wise production data, wastewater generation per tonne of product, COD values, and the Methane Correction Factor (based on the prevalent treatment technologies in the industry). Limited clarity and information is provided in the National Communication Report and the Biennial Update Report on values and specific data sources used for these parameters in the preparation of the 2007 and 2010 national inventories. The lack of detail and clarity in the National Communication reports poses a challenge towards ensure consistency and comparability with the official National GHG estimates.
- **Data Sources:** It is not possible to use single source datasets such as the ASI in the state emission estimation, due to issues such as reporting of industrial production data in multiple units of measurement, inconsistent/unreliable data reported, and lack of requisite guidance in the ASI database for normalization/conversion of the data to a single unit (i.e. tonnes). This has necessitated use of multiple data sources for each of the industrial sectors under consideration. Reliable state-level data on industrial production is not available for most of the industry sectors across the emission estimation period. In some cases, industrial production data is not available at the state-level at all. Data is also found to be partly missing for some years in the reporting period or is not reported in disaggregated manner for some states. To address data gaps, apportionment or approximation has been undertaken in this assessment for 8 out of 10 sectors based on relevant proxy data such as installed production capacity, no. of manufacturers, etc. at the state level. While published data sources such as the Indian Bureau of Mines, Ministry of Agriculture, Rubber Board, and the FAO have been used to access industrial production data, the inherent inconsistencies and unavailability of state-level datasets has impacted the reliability of activity data and the state emission estimates.
- **Factoring in Technology and Process Improvements:** It is not known if the estimates reported in the National Communication reports took into consideration the technological and process improvements; likely to impact parameters such as W_i – Wastewater production per tonne of product and Methane correction factor, which in turn would reduce wastewater generation and overall associated GHG emissions. However, due to lack of such updated information at the state-level, constant values of

wastewater generated per tonne of product have been used across the states for all the years (2005-2013) in this assessment, with the exception of Pulp and Paper sector.

- **Treatment Technology:** In this assessment, the condition of aerobic treatment systems for Iron & Steel, Petroleum and Rubber industries is assumed to be well managed, and thereby these systems have MCF value as 0 and emission factor of 0 (see Table 63), leading to no CH_4 emissions from wastewater treatment in these sectors. The assumptions considered in the National Communication reports in this regard are not reported and this could possibly contribute to deviation in the aggregate state emission estimates as compared to estimates in the National Communication reports.

1.17.7 Planned improvements

Constant values of wastewater generated per tonne of product have been used for all the years (2005-2013) for 9 of the 10 industry sectors considered in the state-level emission estimates. In practice, the volume of wastewater generated per unit product should be expected to reduce given the improvements in technology and industrial processes. However, such information is not available for the industry sectors, except for the Pulp & Paper sector. Updated information on changes in wastewater generation due to improved technology is sought across the industry sectors and at the state-level to accurately capture any ensuing impacts on emission.

Updated sector-wise information for each state is also sought on the volume of industrial wastewater generated and its characteristics, prevalent treatment technologies, methane recovery to improve accuracy and better represent the on-ground situation in the states. Due to the lack of reported data on volume of industrial wastewater generated by each industry sector, a tier 1 approach which uses industrial production as a metric to estimate volume of wastewater generation has been adopted in the emission estimation. However, several issues exist in availability, reliability, quality and of reported activity data on state-level industrial production. Lack of reliable state-level data has necessitated undertaking approximations in 8 of the 10 industry sectors. In some cases, state-level production data is not available in the public domain at all. Access to better quality and reliable industry related data that is representative of the industrial activity in each state will contribute to improving reliability of the estimates.

Going forward, the GHG Platform India could look at including activities, to some extent, to collect primary state-level data on industrial wastewater generation, its characteristics and treatment technology used by different industry sectors in order to improve reliability of the estimates. The Platform could help promote and provide technical inputs towards recording and reporting of relevant activity data in an accurate, consistent and transparent manner. The Platform could also engage further with the Ministry of Environment, Forests and Climate Change to gain access to the underlying datasets and assumptions used for the official National GHG emission estimates. This will greatly help in improving the accuracy of this assessment, enable better comparability, and help identify and address any limitations in the industrial wastewater estimates prepared under this assessment as well as official emission estimates.

Public Consultation & Outreach

ICLEI South Asia participated in participated in the regional roundtable meetings organised in Bangalore, Mumbai and Delhi, to reach out to potential users of the Platform's outputs such as policymakers, research institutions, experts and the media. The round tables also aimed to capture feedback on the methodology, suitability of data sets, analyses undertaken and emission estimation results based on phase-I emission estimates. The roundtable discussions were intended to contribute to ongoing work under phase-II. Suggestions received with regard to the methodology, scope and datasets from the round tables along with relevant responses are indicated in following table. Based on feedback received from the roundtables, it was decided to expand the scope of assessment to cover rural areas as well in the state-level domestic wastewater emission estimation under phase-II.

S. No	Comment	Received from		Response
		Name	e-mail ID	
1	Atleast 5-10% of primary data can be collected in the	Mr. Tapas Ghatak, Independent Waste sector Consultant	tk.ghatak@gmail.com	While collection of primary data sources can be useful, the scope of this assessment and its activities is limited to use of

S. No	COMMENT	RECEIVED FROM		RESPONSE
		NAME	E-MAIL ID	
	phase II			existing secondary data sources
2	Models such as LandGEM model could be explored for GHG emission estimation for solid waste disposal	Prof. Amit Dutta, Jadhavpur University	Amittt555@gmail.com	The emission estimation is sought to be consistent with the IPCC methodology. Therefore the First Order Decay (FOD) model as defined in the 2006 IPCC Guidelines and used in India's National Communication reports is followed in this assessment.
3	Emissions from solid waste processing plants and reduction due to recycling should be included	- Kankana Das, Legal Initiative for Environment and Forest - Amrita Ganguly, Ernst & Young	kankana@lifeindia.org.net -	The source category '4B Biological treatment of solid waste' has not been included in the assessment to the lack of reliable state-level data observed and the limited number of waste incineration and composting facilities for a large part of the reporting period, especially pre-2010. Recycling related emission reductions cannot be factored in since this requires detailed and reliable product life cycle related data which is unavailable for India.
4	Emissions from industrial solid waste may also be accounted	Dr. Ashim Bhattacharya, Bengal National Chamber of Commerce and Industry	Ashimk.bhattacharya@gmail.com	The assessment is limited to disposal of municipal solid waste. Industrial solid waste is not considered in the emission estimation, given the lack of reliable state-level information for this waste stream.
5	Domestic wastewater estimates can cover rural population	- Mr. Tapas Ghatak, Independent Waste sector Consultant - Mr. Joydeep Gupta, Third Pole	tk.ghatak@gmail.com; joydeep.gupta@thethirdpole.net	This suggestion has been considered and the scope of the state level estimation in phase-II has been expanded to include domestic wastewater for the rural population as well.
6	Emissions from fertilizers and pesticides which are flowing in the wastewater stream can be considered.	Kankana Das, Legal Initiative for Environment and Forest	kankana@lifeindia.org.net	Direct emissions from fertilizers and pesticides application are accounted under AFOLU sector. The 2006 IPCC Guidelines**Error! Bookmark not defined.** indicate that indirect N_2O emissions are largely from covered by wastewater treatment effluent, associated with domestic sources (and any industrial wastewater co-discharged), that is discharged into water bodies. Emissions from fertilizers/pesticides are not indicated as major sources of wastewater related emission in the IPCC Guidelines.
7	Wastewater generated from Thermal Power plants can be considered in the assessment	- Dr. Ashim Bhattacharya, Bengal National Chamber of Commerce and Industry - Kankana Das, Legal Initiative for Environment and Forest	Ashimk.bhattacharya@gmail.com; kankana@lifeindia.org.net	While thermal power plants do discharge significant volumes of wastewater, this primarily contains metals (lead, mercury, cadmium and chromium) and does not contain much organic content, which contributes to GHG emission. Therefore, this industry sector is not considered
8	Resources such as Toxic Links website can be referred to for information	Prof. Sadhan Ghosh, Jadhavpur University	sadhankghosh@gmail.com	The Toxic links website is a good resource for information and case studies mainly on hazardous waste, bio-medical waste, electronic waste, plastic waste. However, while these wastes are toxic, they do not contribute to GHG emissions.
9	State Pollution Control Board data can be referred for domestic wastewater	Prof. Sadhan Ghosh, Jadhavpur University	sadhankghosh@gmail.com	SPCB reports have been looked for state-level information, especially to check capacities and technologies used in sewage treatment plants.
10	Environment	Manas Dey,	Mdey09@gmail.com	Limited information is available on SPCB

S. No	Comment	Received from		Response
		Name	e-mail ID	
	clearances issued to industries should be referred to as data source for industrial wastewater	Greentech Management Pvt. Ltd.		websites related to environmental clearances for separate product categories. The information indicated relates to cumulative wastewater generation for a mix of industries/product and it is difficult to correlate this to a per unit product basis for each product type.

Recommendation

The unavailability of published state-specific and regularly updated information on the activity data, emission factors and related coefficients has been a challenge in the state emission estimation process for all 3 source-categories in the Waste sector. The limited availability of reliable state-level data has necessitated the use of national average values or IPCC default values in the emission estimates. Further, information reported at the state-level is found to not match with national-level information.

For instance, year-on-year information on the distribution of domestic wastewater treatment facilities within states is lacking which presented a challenge in accurately capturing any impacts on emission due to on-ground deployment of such systems in urban and rural areas of states. Furthermore, annually reported and comprehensive information on the status and performance of all STPs in the states is also lacking. This makes it difficult to factor in considerations on volumes treated, underutilization of treatment capacity, quality of treatment, and recovery of methane in the state emission estimates for domestic wastewater treatment and discharge.

With regard to industrial wastewater, state-level information on volume and characteristics of industrial wastewater generated by industry sectors along with treatment technologies used and their performance is lacking. A number of issues exist with regard to availability, reliability and quality of state-level activity data related to industrial production data. For sectors such as Beer and Soft drinks state-level data on industrial production is not available at all in some cases.

There is scope to improve consistency of industry production numbers reported by primary data sources. There is scope to improve consistency of industry production numbers reported by primary data sources. The ASI is one of India's largest, and the most comprehensive survey system established by the MOSPI for the manufacturing sector. However, industrial output/production data collated and reported under the ASI is represented in disparate units such as tonnes, cubic meter, nos., liters, bags, pairs, rolls, bottles etc. This diversity in reported metrics makes it challenging to convert such industrial production data into the single metric of 'tonnes' that is required to calculate GHG emissions from industrial wastewater. Information on changes in specific wastewater generation per unit industrial product due to expected improvements in technology is not recorded and therefore ensuing impacts do not reflect in the state emission estimates. Updated and reliable state-level data on solid waste generation, changes in composition, operational status of processing/treatment facilities is not available, leading to approximations that impact accuracy of the emission estimates. Inconsistencies are observed in year-on-year information on solid waste generation and waste processing/treatment that is being reported by states.

There is therefore a need for periodic reporting of state-wise information related to the data points indicated above. Transparent and robust data management systems can improve accuracy of state-level emission estimation and capture emission reduction because of policy and programme initiatives. To optimize efforts, specific data gathering and data disaggregating processes may be integrated within existing and ongoing processes that may need further strengthening.

- For example, the annual reporting by SPCBs and under the Swachh Bharat Mission needs to be strengthened and expanded to include accurate information on solid waste composition along with updated status of operational and non-operational solid waste processing plants. This will help to accurately assess the waste going to disposal sites and generating GHG emissions within each state.
- In addition, wastewater treatment status reports by the CPCB and SPCBs should include information on the operational status and type of wastewater treatment technologies being used. This will help to capture updated status of technological improvements and functionality and thereby improve accuracy of the state emission estimates. Reporting on associated activities that is collated by Ministries, such as the information

on wastewater collection and treatment facilities collated under the AMRUT scheme could also be considered to capture accurate state level activity data.

- A few revisions in the ASI methodology and subsequent assimilation of its information in inventory calculations could even help the MOEFCC moving up in the tier ladder. The merit in the use of ASI data sets has already been already demonstrated in the emission estimates prepared for the manufacturing sector under the GHG Platform – India. The ASI could prove to be a useful information source for industrial wastewater generation, and hence, estimation of associated GHG emission. However, this is restricted by industrial output data in the ASI datasets not being in the requisite metric (i.e. tonnes) to help compute accurate emissions from industrial wastewater. The ASI can promote reporting in metrics that better conform to accurate GHG emission estimation. For example, production of beverages is better reported in volume basis (liters/kiloliters) instead of 'no. of bottles' or production of fertilizers can be reported on mass basis (kg/tonnes) instead of 'no. of bags'. It is also prudent to tap into the knowledge-base and networks of technical institutes and industry associations such as the Central Food Technological Research Institute, the Central Leather Research Institute, the Fertilizer Association of India, and the Indian Beverage Association by involving them in development of technical guidance and resources for standardization and conversion of reported metrics for products of industry sectors such as Tannery, Leather, Fertilizers, Soft Drinks, Beer etc.
- In addition, the SPCBs could also make available the data on volume of wastewater generated, its physio-chemical characteristics such as COD, and treatment processes used that they collect from all the registered industries within their jurisdiction, particularly for industry sectors such as Pulp & paper, Coffee, Soft drink, Beer, Meat, Tannery that generate substantial volumes of organic wastewater. It is also critical to enhance reliability and consistency of such data in terms of time-series trends and reported metrics, and providing sufficiently disaggregated data that enables identification of product sub-classes, technology variations, and scale of operation across the industry sectors.

Annexures

1.18 4A2 Unmanaged Waste Disposal Sites

Table 71: State wise Reported Population from Census of India, 1951-2011

STATE/UNION TERRITORY	1951	1961	1971	1981	1991	2001	2011
Andaman & Nicobar	7,789	14,075	26,218	49,634	74,955	116,198	143,488
Andhra Pradesh	5,420,325	6,274,508	8,402,527	12,487,576	17,887,126	20,808,940	28,219,075
Arunachal Pradesh	-	-	17,288	41,428	110,628	227,881	317,369
Assam	344,831	781,288	1,289,222	1,782,376	2,487,795	3,439,240	4,398,542
Bihar	2,626,261	3,913,920	5,633,966	8,718,990	11,353,012	8,681,800	11,758,016
Chandigarh	-	99,262	232,940	422,841	575,829	808,514	1,026,459
Chhattisgarh	-	-	-	-	-	4,185,747	5,937,237
Dadra & Nagar Haveli	-	-	-	6,914	11,725	50,463	160,595
Daman & Diu	-	-	-	29,023	47,543	57,348	1,82,851
Delhi	1,437,134	2,359,408	3,647,023	5,768,200	8,471,625	12,905,780	16,368,899
Goa		106,664	226,774	351,808	479,752	670,577	906,814
Gujarat	4,427,896	53,16,624	74,96,500	1,06,01,653	1,42,46,061	1,89,30,250	2,57,45,083
Haryana	9,68,494	13,07,680	17,72,959	28,27,287	40,54,744	61,15,304	88,42,103
Himachal Pradesh	1,53,827	1,78,275	2,41,890	3,25,971	4,49,196	5,95,581	6,88,552
Jammu & Kashmir	4,57,213	5,93,315	8,58,221	12,60,403	18,39,400	25,16,638	34,33,242
Jharkhand	-	-	-	-	-	59,93,741	79,33,061
Karnataka	44,53,480	52,66,493	71,22,093	1,07,29,606	1,39,07,788	1,79,61,529	2,36,25,962
Kerala	18,25,832	25,54,141	34,66,449	47,71,275	76,80,294	82,66,925	1,59,34,926
Lakshadweep	-	-	-	18,629	29,114	26,967	50,332
Madhya Pradesh	31,32,937	46,27,234	67,84,767	1,05,86,459	1,53,38,837	1,59,67,145	2,00,69,405
Maharashtra	92,01,013	1,11,62,561	1,57,11,211	2,19,93,594	3,05,41,586	4,11,00,980	5,08,18,259
Manipur	2,862	67,717	1,41,492	3,75,460	5,05,645	5,75,968	8,34,154
Meghalaya	58,512	1,17,483	1,47,170	2,41,333	3,30,047	4,54,111	5,95,450
Mizoram	6,950	14,257	37,759	1,21,814	3,17,946	4,41,006	5,71,771
Nagaland	4,125	19,157	51,394	1,20,234	2,08,223	3,42,787	5,70,966
Odisha	5,94,070	11,09,650	18,45,395	31,10,287	42,34,983	55,17,238	70,03,656
Puducherry	-	-	1,98,288	3,16,047	5,16,985	6,48,619	8,52,753
Punjab	19,89,267	25,67,306	32,16,179	46,47,757	59,93,225	82,62,511	1,03,99,146
Rajasthan	29,55,275	32,81,478	45,43,761	72,10,508	1,00,67,113	1,32,14,375	1,70,48,085
Sikkim	2,744	6,848	19,668	51,084	37,006	59,870	1,53,578
Tamil Nadu	73,33,525	89,90,528	1,24,64,834	1,59,51,875	1,90,77,592	2,74,83,998	3,49,17,440
Telangana	-	-	-	-	-	-	-
Tripura	42,595	1,02,997	1,62,360	2,25,568	4,21,721	5,45,750	9,61,453
Uttar Pradesh	86,25,699	94,79,895	1,23,88,596	1,98,99,115	2,76,05,915	3,45,39,582	4,44,95,063
Uttarakhand	-	-	-	-	-	21,79,074	30,49,338
West Bengal	62,81,642	85,40,842	1,09,67,033	1,44,46,721	1,87,07,601	2,24,27,251	2,90,93,002

Note: States for which no population has been reported for some years were formed subsequently. The historic data on the population has been acquired by visiting the Census office in Delhi, except for 2001 and 2011.

Table 72: State wise GHG emission from Solid Waste Disposal, 2005-2014

State/Union Territory	Estimated GHG emission from Solid waste disposal (tonnes of CO_2e)									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Andaman & Nicobar	5,049.36	5,595.85	6,102.23	6,575.48	7,021.47	7,445.17	7,850.77	8,241.78	8,629.88	9,016.46
Andhra Pradesh	677,159.06	739,780.93	799,984.66	858,276.37	915,083.10	970,765.10	1,025,626.34	1,079,923.25	1,136,086.90	1,116,170.08
Arunachal Pradesh	4,316.08	4,805.95	5,273.44	5,723.04	6,158.50	6,582.99	6,999.20	7,409.38	7,833.58	7,610.14
Assam	40,408.91	44,667.92	48,658.80	52,429.95	56,022.18	59,469.93	62,802.28	66,043.73	69,306.47	72,596.08
Bihar	208,934.03	210,072.83	212,507.71	216,061.65	220,585.32	225,952.73	232,057.57	238,810.17	246,575.35	255,232.02
Chandigarh	18,930.03	20,217.62	21,460.34	22,667.73	23,847.82	25,007.41	26,152.22	24,445.56	23,099.71	23,311.01
Chhattisgarh	43,523.45	54,315.06	64,272.77	73,542.32	82,246.69	90,489.59	98,358.57	105,927.47	113,564.91	121,283.61
Dadra & Nagar Haveli	1,008.30	1,301.89	1,608.30	1,926.81	2,256.83	2,597.82	2,949.36	3,311.09	3,808.06	4,423.52
Daman & Diu	1,544.90	1,717.33	1,921.48	2,153.71	2,410.90	2,690.45	2,990.15	3,308.16	3,794.60	4,428.18
Delhi	424,452.14	458,669.34	491,231.39	522,456.50	552,613.11	581,927.71	610,591.40	638,765.39	667,401.12	680,500.49
Goa	21,289.86	23,734.78	26,048.36	28,255.50	30,377.17	32,431.09	34,432.20	36,393.11	38,398.92	40,266.96
Gujarat	334,227.16	345,897.14	358,558.52	372,105.41	386,448.46	401,512.29	417,233.31	433,557.86	451,296.89	470,300.91
Haryana	151,036.50	163,403.38	175,653.99	187,839.71	200,003.90	212,183.15	224,408.33	236,705.47	249,796.59	263,609.15
Himachal Pradesh	9,408.76	10,468.46	11,431.01	12,312.50	13,126.52	13,884.52	14,596.16	13,298.75	12,231.71	11,605.41
Jammu & Kashmir	79,056.63	87,369.03	95,299.35	102,923.35	110,304.96	117,498.10	124,548.25	131,493.82	138,649.73	146,006.59
Jharkhand	71,599.56	86,170.36	99,524.83	111,871.11	123,384.82	134,214.12	144,483.99	154,299.90	164,037.86	173,735.63
Karnataka	418,466.89	458,328.84	496,228.06	532,543.31	567,594.12	601,650.08	634,938.66	667,651.74	701,073.64	735,195.10
Kerala	241,855.73	277,613.83	313,717.40	350,233.87	387,220.15	424,724.23	462,786.60	501,441.43	545,829.13	595,304.73
Lakshadweep	536.58	598.20	661.44	726.28	792.68	860.65	930.15	1,001.19	1,082.74	1,173.62
Madhya Pradesh	353,325.39	372,054.57	390,502.46	408,755.08	426,885.01	444,953.46	463,012.08	481,104.47	499,825.10	519,132.49
Maharashtra	815,495.16	881,071.76	942,973.49	1,001,876.57	1,058,351.48	1,112,879.54	1,165,866.83	1,217,655.96	1,269,805.38	1,322,393.80
Manipur	6,762.44	7,499.42	8,212.11	8,905.98	9,585.62	10,254.92	10,917.17	11,575.14	12,266.38	12,988.29
Meghalaya	9,103.52	10,123.40	11,082.10	11,990.84	12,859.06	13,694.76	14,504.67	14,594.59	14,773.47	15,246.63
Mizoram	6,421.14	7,075.57	7,692.42	8,278.63	8,840.08	9,381.70	9,907.66	10,421.48	10,942.06	11,469.82
Nagaland	3,442.86	3,962.91	4,470.88	4,970.02	5,463.07	5,952.34	6,439.78	6,927.02	7,456.98	8,025.41
Odisha	117,800.34	123,557.49	129,304.61	135,057.62	140,829.93	146,632.89	152,476.03	158,367.43	164,511.19	170,887.40
Puducherry	22,859.53	25,066.35	27,162.27	29,168.56	31,103.17	32,981.26	34,815.60	36,616.97	38,455.89	40,332.03
Punjab	237,872.30	259,110.48	279,127.30	298,147.10	316,359.14	333,923.09	350,973.68	367,624.55	384,416.94	401,373.85
Rajasthan	305,736.97	316,269.50	327,401.81	339,077.16	351,247.63	363,872.84	376,918.69	390,356.42	404,701.15	419,862.32
Sikkim	1,719.46	2,022.79	2,341.42	2,674.31	3,020.57	3,379.45	3,750.33	3,937.22	4,226.82	4,868.92
Tamil Nadu	798,476.49	849,073.74	898,235.12	946,289.52	993,514.46	1,040,144.06	1,086,375.85	1,132,376.47	1,179,727.76	1,228,361.02
Telangana	-	-	-	-	-	-	-	-	-	-

State/Union Territory	Estimated GHG emission from Solid waste disposal (tonnes of CO_2e)									
	2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Tripura	13,493.61	14,990.18	16,509.88	18,054.24	19,624.54	21,221.87	22,847.13	24,501.09	26,363.14	28,410.45
Uttar Pradesh	885,157.54	923,221.90	962,103.80	1,001,786.72	1,042,256.69	1,083,501.93	1,125,512.51	1,168,280.05	1,213,411.21	1,260,690.32
Uttarakhand	23,341.44	29,623.22	35,390.32	40,731.54	45,721.80	50,424.31	54,892.39	59,171.03	63,457.56	67,763.27
West Bengal	691,917.93	726,101.90	760,506.15	795,188.51	830,197.76	865,575.06	901,355.14	937,567.31	975,607.84	1,015,319.36
Total emissions (tonnes of CO2e)	**7,045,730**	**7,545,554**	**8,033,160**	**8,511,577**	**8,983,359**	**9,450,661**	**9,915,301**	**10,373,106**	**10,852,447**	**11,258,895**

1.19 4D1 Domestic Wastewater Treatment and Discharge

Figure 20: Classification of Wastewater Treatment Systems and Estimated Degree of Utilization for Urban population, Andhra Pradesh, 2001

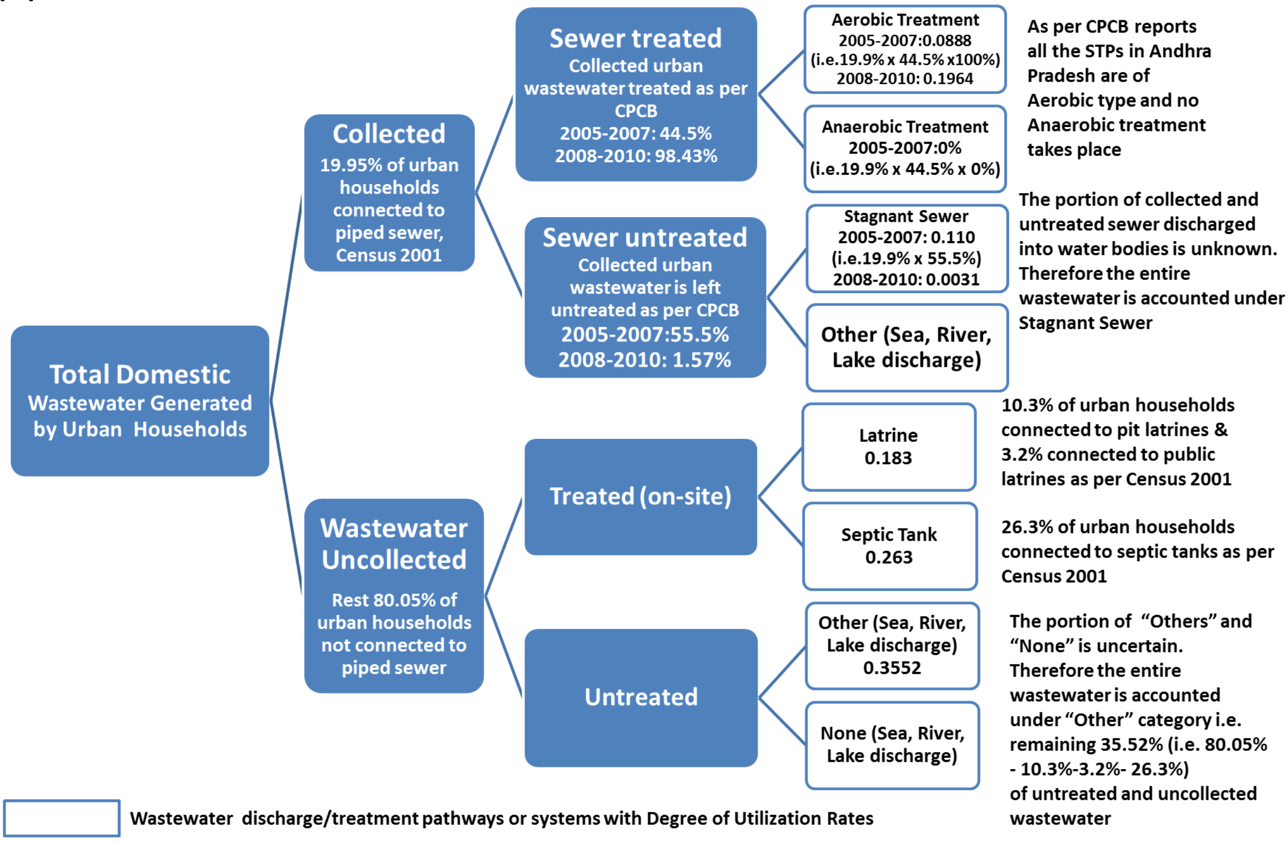


Figure 21: Classification of Wastewater Treatment Systems and Estimated Degree of Utilization for Rural Andhra Pradesh, 2001

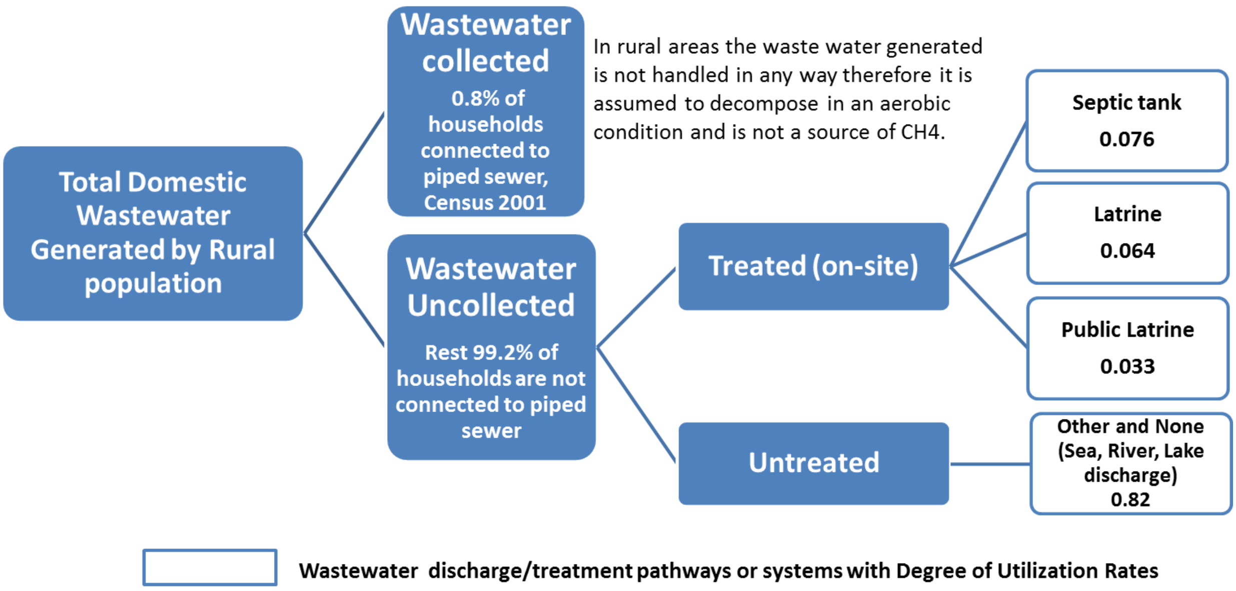


Table 73: State-wise share of Urban and Rural Population for 2001 and 2011

State/Union Territory	Rural-Urban population share (2011)		Rural-Urban population share (2001)	
	Rural	Urban	Rural	Urban
Andaman and Nicobar Islands	62.30%	37.70%	67.37%	32.63%
Andhra Pradesh	66.64%	33.36%	72.70%	27.30%
Arunachal Pradesh	77.06%	22.94%	79.25%	20.75%
Assam	85.90%	14.10%	87.10%	12.90%
Bihar	88.71%	11.29%	89.54%	10.46%
Chandigarh	2.75%	97.25%	10.23%	89.77%
Chhatisgarh	76.76%	23.24%	79.91%	20.09%
Dadra and Nagar Haveli	53.28%	46.72%	77.11%	22.89%
Daman and Diu	24.83%	75.17%	63.75%	36.25%
National Capital Territory of Delhi	2.50%	97.50%	6.82%	93.18%
Goa	37.83%	62.17%	50.24%	49.76%
Gujarat	57.40%	42.60%	62.64%	37.36%
Haryana	65.12%	34.88%	71.08%	28.92%
Himachal Pradesh	89.97%	10.03%	90.20%	9.80%
Jammu and Kashmir	72.62%	27.38%	75.19%	24.81%
Jharkhand	75.95%	24.05%	77.76%	22.24%
Karnataka	61.33%	38.67%	66.01%	33.99%
Kerala	52.30%	47.70%	74.04%	25.96%
Lakshadweep	21.93%	78.07%	55.54%	44.46%
Madhya Pradesh	72.37%	27.63%	73.54%	26.46%
Maharashtra	54.78%	45.22%	57.57%	42.43%
Manipur	67.55%	32.45%	74.89%	25.11%
Meghalaya	79.93%	20.07%	80.42%	19.58%
Mizoram	47.89%	52.11%	50.37%	49.63%
Nagaland	71.14%	28.86%	82.77%	17.23%
Odisha	83.31%	16.69%	85.01%	14.99%
Puducherry	31.67%	68.33%	33.43%	66.57%
Punjab	62.52%	37.48%	66.08%	33.92%
Rajasthan	75.13%	24.87%	76.61%	23.39%
Sikkim	74.85%	25.15%	88.93%	11.07%
Tamil Nadu	51.60%	48.40%	55.96%	44.04%
Telangana	61.33%	38.64%	61.33%	38.64%
Tripura	73.83%	26.17%	82.94%	17.06%
Uttar Pradesh	77.73%	22.27%	79.22%	20.78%
Uttarakhand	69.77%	30.23%	74.33%	25.67%
West Bengal	68.13%	31.87%	72.03%	27.97%

Table 74: State-wise Proportion of Sewage Treatment and Type of Technology used based on Reported Data on Sewage Treatment Plants

SEWAGE TREATMENT PLANTS	1999[135]			2008-09[136]			2014-15[137]		
STATE/UNION TERRITORY	SHARE OF TREATMENT TYPE, AEROBIC	SHARE OF TREATMENT TYPE, ANAEROBIC	SHARE OF SEWER COLLECTED AND NOT TREATED	SHARE OF TREATMENT TYPE, AEROBIC	SHARE OF TREATMENT TYPE, ANAEROBIC	SHARE OF SEWER COLLECTED AND NOT TREATED	SHARE OF TREATMENT TYPE, AEROBIC	SHARE OF TREATMENT TYPE, ANAEROBIC	SHARE OF SEWER COLLECTED AND NOT TREATED
Andaman and Nicobar Islands	-	-	100%	-	-	100%	-	-	100.00%
Andhra Pradesh	100.00%	0.00%	55.50%	100.00%	0.00%	1.57%	100.00%	0.00%	0.00%
Arunachal Pradesh	-	-	100%	-	-	100%	-	-	100.00%
Assam	-	-	-	100%	-	-	100.00%	0.00%	0.00%
Bihar	-	-	-	100.00%	0.00%	1.48%	100.00%	0.00%	20.07%
Chandigarh	100.00%	0.00%	13.38%	-	-	-	4.51%	95.49%	0.00%
Chhatisgarh	-	-	100%	-	-	100%	-	-	100.00%
Dadra and Nagar Haveli	-	-	100%	-	-	100%	-	-	100.00%
Daman and Diu	-	-	100%	-	-	100%	-	-	100.00%
Delhi	100%	0%	29%	98.81%	1.19%	-	100.00%	0.00%	0.84%
Goa	100.00%	0.00%	0.00%	100.00%	0.00%	-	100.00%	0.00%	0.00%
Gujarat	100.00%	-	17.81%	100.00%	0.00%	-	77.29%	22.71%	19.08%
Haryana	0.00%	100.00%	45.18%	71.13%	28.87%	-	63.66%	36.34%	0.33%
Himachal Pradesh	-	-	-	0.00%	0.00%	100.00%	64.14%	35.86%	30.69%
Jammu and Kashmir	-	-	-	0.00%	0.00%	100.00%	86.61%	13.39%	2.61%
Jharkhand	-	-	-	0.00%	0.00%	100.00%	98.64%	1.36%	0.00%
Karnataka	99.07%	0.93%	12.42%	100.00%	0.00%	-	91.57%	8.43%	0.00%
Kerala	100.00%	0.00%	0.00%	100.00%	0.00%	-	100.00%	0.00%	2.59%
Lakshadweep	-	-	100%	-	-	100%	-	-	100.00%
Madhya Pradesh	100.00%	0.00%	65.61%	-	-	-	81.07%	18.93%	1.40%
Maharashtra	100.00%	0.00%	43.09%	89.51%	10.49%	-	98.33%	1.67%	7.26%

[135] CPHEEO (2005): Status of Water Supply, Sanitation and Solid Waste Management in Urban Areas.
Estimated based on reported information referred from Appendix 2: Table B-2 and Table B-3. http://cpheeo.nic.in/status_watersupply.pdf
[136] CPCB (2010): Annual report 2009-10. Information referred from Table 6.2, Table 6.3, Chapter XiV.
Available at http://cpcb.nic.in/upload/AnnualReports/AnnualReport_40_Annual_Report_09-10.pdf
CPCB (2008): Evaluation of Operation and Maintenance of Sewage Treatment Plants in India-2007. Information referred from Table 2.1, Table 2.2 and Chapter 3.
Available at http://www.cpcb.nic.in/upload/NewItems/NewItem_99_NewItem_99_5.pdf
CPCB (2013): Performance Evaluation of STPs under NCRD. Information referred from Table 2, Table 3, Table 4, Table 5, Table 8, Table 14, Annexure – IV.
Available at http://cpcb.nic.in/upload/NewItems/NewItem_195_STP_REPORT.pdf
CPCB (2009): Status of Water Supply, Wastewater Generation and Treatment in Class-I Cities & Class-II Towns Of India. Information referred from Table 3.4, Table 3.5, Table 3.6, Table 3.11, Table 3.12, Table 3.18, Table 3.19. Available at http://cpcb.nic.in/upload/NewItems/NewItem_153_Foreword.pdf
[137] CPCB (2015): Inventorization of STPs. Information referred from Table 3 and Chapter 4. http://www.cpcb.nic.in/upload/NewItems/NewItem_210_Inventorization_of_Sewage-Treatment_Plant.pdf
CPCB (n.d.): Monitoring of STPs in Karnataka 2014-15. Information referred on STPs throughout the document. http://cpcb.nic.in/zonaloffice/banglore/STP_report_karnataka.pdf

Sewage Treatment Plants	1999[135]			2008-09[136]			2014-15[137]		
State/Union Territory	Share of Treatment type, Aerobic	Share of Treatment type, Anaerobic	Share of Sewer collected and not treated	Share of Treatment type, Aerobic	Share of Treatment type, Anaerobic	Share of Sewer collected and not treated	Share of Treatment type, Aerobic	Share of Treatment type, Anaerobic	Share of Sewer collected and not treated
Manipur	-	-	100%	-	-	100%	-	-	100.00%
Meghalaya	-	-	100%	-	-	100%	-	-	100.00%
Mizoram	-	-	100%	-	-	100%	-	-	100.00%
Nagaland	-	-	100%	-	-	100%	-	-	100.00%
Odisha	100.00%	0.00%	73.53%	-	-	-	100.00%	0.00%	0.00%
Puducherry	100.00%	0.00%	0.00%	-	-	-	71.43%	28.57%	0.00%
Punjab	0%	0%	100%	-	-	-	45.63%	54.37%	1.09%
Rajasthan	100.00%	0.00%	50.00%	-	-	-	90.22%	9.78%	0.00%
Sikkim	-	-	-	0.00%	0.00%	100.00%	100.00%	0.00%	38.46%
Tamil Nadu	99.38%	0.62%	31.44%	100.00%	0.00%	-	100.00%	0.00%	3.83%
Telangana	-	-	-	-	-	-	55.56%	44.44%	0.00%
Tripura	-	-	-	0.00%	0.00%	100.00%	100.00%	0.00%	10.00%
Uttar Pradesh	74.70%	25.30%	10.83%	47.63%	52.37%	-	55.26%	44.74%	3.09%
Uttarakhand	-	-	-	25.00%	75.00%	-	98.62%	1.38%	0.00%
West Bengal	100.00%	0.00%	0.17%	100.00%	0.00%	-	100.00%	0.00%	43.55%

1.20 4D2 Industrial Wastewater Treatment and Discharge

Table 75: State-wise Iron & Steel Industrial Production data, 2005-2013 (Tonnes)

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Pig Iron									
Andhra Pradesh	595,914	607,297	709,928	673,491	692,491	637,606	661,910	809,043	780,659
Chhattisgarh	529,085	569,461	656,952	749,839	765,947	717,882	641,836	752,561	899,498
Goa	192,663	226,778	243,412	299,307	297,121	288,494	277,865	330,672	400,213
Jharkhand	206,262	235,964	193,426	181,280	200,312	229,729	146,489	178,079	182,413
Karnataka	772,673	926,771	985,170	1,182,242	1,164,467	1,128,808	1,091,588	1,303,615	1,568,926
Maharashtra	1,503,347	1,769,543	1,899,341	2,335,484	2,318,435	2,251,116	2,168,177	2,580,231	3,122,852
Odisha	111,269	151,831	154,023	159,137	163,028	161,650	151,506	170,054	268,343
West Bengal	417,035	430,854	391,497	402,220	362,698	317,965	309,629	370,995	457,096
Pig Iron-India-State-total	**4,328,250**	**4,918,500**	**5,233,750**	**5,983,000**	**5,964,500**	**5,733,250**	**5,449,000**	**6,495,250**	**7,680,000**
Sponge Iron									
Andhra Pradesh	125,657	176,232	206,958	217,846	244,983	261,338	261,090	244,775	238,610
Chhattisgarh	3,480,127	4,880,834	5,731,788	6,033,351	6,784,914	7,237,872	7,231,020	6,779,144	6,608,420
Goa	130,226	182,641	214,483	225,768	253,891	270,841	270,585	253,676	247,287
Gujarat	4,041,015	5,667,471	6,655,572	7,005,737	7,878,429	8,404,389	8,396,433	7,871,729	7,673,489
Jharkhand	188,485	264,348	310,437	326,769	367,474	392,007	391,636	367,162	357,915
Karnataka	162,783	228,301	268,104	282,210	317,364	338,551	338,231	317,094	309,109
Maharashtra	2,181,862	3,060,034	3,593,539	3,782,603	4,253,795	4,537,776	4,533,480	4,250,177	4,143,142
Odisha	1,566,714	2,197,296	2,580,386	2,716,147	3,054,492	3,258,408	3,255,324	3,051,894	2,975,036
West Bengal	162,783	228,301	268,104	282,210	317,364	338,551	338,231	317,094	309,109
Sponge Iron-India-State total	**12,039,653**	**16,885,458**	**19,829,371**	**20,872,642**	**23,472,708**	**25,039,734**	**25,016,029**	**23,452,746**	**22,862,116**
Finished Steel (Alloy/Non-Alloy)									
Andhra Pradesh	5,644,664	6,289,879	6,801,350	7,011,256	7,364,612	8,210,367	8,647,195	10,149,285	10,344,234
Chhattisgarh	5,574,252	6,211,419	6,716,510	6,923,797	7,272,745	8,107,951	8,620,822	10,149,285	10,344,234
Gujarat	2,699,112	3,007,635	3,252,205	3,352,576	3,521,540	3,925,955	5,107,891	6,323,848	6,292,681
Jharkhand	3,989,991	4,446,068	4,807,607	4,955,981	5,205,755	5,803,586	6,449,793	8,021,612	8,782,966
Karnataka	10,182,183	11,346,061	12,268,682	12,647,323	13,284,727	14,810,351	16,791,206	17,234,313	17,484,222
Maharashtra	5,926,310	6,603,719	7,140,710	7,361,090	7,732,077	8,620,032	9,064,833	8,678,378	8,345,383
Odisha	1,877,643	2,092,267	2,262,403	2,332,226	2,449,767	2,731,099	3,694,687	5,547,017	7,957,965
Tamil Nadu	4,042,628	4,504,723	4,871,031	5,021,362	5,274,431	5,880,149	6,042,320	6,178,466	7,297,899
West Bengal	5,865,967	6,536,479	7,068,002	7,286,138	7,653,347	8,532,261	9,001,262	8,957,681	9,462,051
Steel - India- State-total	**45,802,750**	**51,038,250**	**55,188,500**	**56,891,750**	**59,759,000**	**66,621,750**	**73,420,009**	**81,239,886**	**86,311,634**

Notes: Data is shown only for states where industrial activity (i.e. production data) is reported for the sectors

Table 76: State-wise Production data for Fertilizer Sector, 2005-2013 (Tonnes)

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013

Nitrogenous Fertilizer (N)									
Andhra Pradesh	985,985	998,825	952,275	947,950	1,054,575	1,120,350	1,103,725	1,094,925	1,095,825
Assam	110,550	135,000	148,975	103,125	128,550	133,925	128,925	168,175	221,325
Goa	298,131	302,150	294,250	274,250	279,525	269,025	248,175	233,350	286,900
Gujarat	1,824,350	2,186,550	2,083,125	1,971,575	2,116,750	2,150,575	2,033,050	2,245,125	2,265,150
Haryana	234,875	233,425	234,975	227,350	233,100	221,125	226,625	209,850	227,250
Karnataka	213,332	218,000	218,925	218,200	224,700	218,525	208,425	204,875	217,925
Kerala	178,375	182,575	114,025	133,950	177,725	171,775	159,750	158,850	170,325
Madhya Pradesh	850,225	849,975	822,150	825,425	838,100	858,150	876,275	863,525	927,350
Maharashtra	904,300	937,225	931,300	950,950	1,035,125	1,093,225	1,113,950	1,202,100	1,137,700
Odisha	263,775	347,425	378,475	403,950	477,225	513,700	524,825	474,850	543,075
Punjab	462,900	457,325	455,725	476,700	462,050	469,575	458,825	437,475	449,575
Rajasthan	1,041,056	1,051,175	1,084,375	1,071,950	1,098,550	1,141,275	1,161,450	1,120,750	1,003,800
Tamil Nadu	628,639	644,825	352,750	222,300	255,050	398,175	584,575	600,675	752,175
Uttar Pradesh	2,256,200	2,813,150	2,872,800	2,952,925	3,166,650	3,239,300	3,304,575	3,266,825	3,231,550
West Bengal	97,936	140,625	102,825	73,900	72,325	71,225	77,425	68,675	107,375
Nitrogenous Fertilizer - India-State total	**10,350,628**	**11,498,250**	**11,046,950**	**10,854,500**	**11,620,000**	**12,069,925**	**12,210,575**	**12,350,**	**12,637,300**
Phosphatic Fertilizer (P2O5)									
Andhra Pradesh	552,050	678,475	600,125	571,800	695,125	673,225	622,275	578,100	618,000
Goa	196,225	208,525	208,050	196,550	246,100	220,075	192,900	139,050	130,675
Gujarat	1,428,000	1,478,525	1,256,375	1,054,350	1,294,700	1,272,325	1,167,025	1,113,100	988,950
Karnataka	82,800	98,875	104,400	91,875	102,850	93,950	73,325	75,500	65,775
Kerala	140,550	144,600	99,600	112,100	144,050	134,525	124,675	126,300	130,825
Maharashtra	117,275	101,425	85,100	83,525	95,475	132,375	146,325	154,425	147,275
Odisha	558,648	704,825	808,825	754,425	827,150	948,625	990,825	924,950	904,825
Tamil Nadu	267,525	222,000	109,325	42,875	65,975	174,675	187,150	205,775	160,350
West Bengal	270,540	388,575	283,925	210,775	203,550	230,100	216,750	183,300	175,650
Phosphate Fertilizer - India- State total	**3,613,613**	**4,025,825**	**3,555,725**	**3,118,275**	**3,674,975**	**3,879,875**	**3,721,250**	**3,500,500**	**3,322,325**

Table 77: State-wise Industrial Production data for Sugar Sector, 2005-2013 (Tonnes)

Industrial Production (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andhra Pradesh	1,172,500	1,569,000	1,421,250	778,500	534,500	883,250	1,102,750	1,096,158	1,046,142
Bihar	379,750	443,750	364,750	244,500	247,000	353,250	433,750	434,600	414,770
Chhattisgarh	16,000	22,500	34,500	19,250	10,000	19,500	32,750	34,768	33,182
Goa	10,250	17,000	16,000	10,500	8,250	11,750	10,750	9,658	9,217
Gujarat	1,075,250	1,360,750	1,380,750	1,100,500	1,144,750	1,223,500	1,058,750	965,778	921,711
Haryana	331,750	591,250	612,250	321,500	243,250	356,000	468,500	477,095	455,325
Karnataka	1,717,250	2,482,250	2,840,500	1,965,500	2,332,000	3,401,750	3,824,750	3,739,494	3,568,865

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Madhya Pradesh	88,500	158,500	175,500	85,500	74,000	143,750	160,500	153,559	146,552
Maharashtra	4,452,000	8,124,250	9,081,250	5,702,250	6,444,750	8,557,250	8,996,250	8,669,793	8,274,200
Odisha	41,000	55,750	62,500	39,000	25,000	39,500	60,000	62,776	59,911
Puducherry	25,500	52,000	53,250	25,500	18,500	40,000	59,750	61,810	58,990
Punjab	332,250	449,000	522,000	315,000	196,250	271,750	368,000	376,654	359,467
Rajasthan	5,500	6,750	6,250	4,500	4,000	4,000	2,500	1,932	1,843
Tamil Nadu	1,883,500	2,439,750	2,240,500	1,733,750	1,359,500	1,704,500	2,245,750	2,297,587	2,192,751
Uttar Pradesh	5,597,250	7,802,250	7,608,000	4,877,750	4,900,250	5,710,000	6,702,250	6,735,338	6,428,013
Uttrakhand	414,750	507,750	433,750	267,250	274,750	299,500	323,750	319,673	305,086
West Bengal	5,000	7,250	5,750	2,750	2,000	4,250	5,000	4,829	4,609
Sugar-India- State total	**17,548,000**	**26,089,750**	**26,858,750**	**17,493,500**	**17,818,750**	**23,023,500**	**25,855,750**	**25,441,500**	**24,280,634**

Table 78: State-wise Industrial Production data for Coffee Sector, 2005-2013 (Tonnes)

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andhra Pradesh	2,250	3,344	3,232	4,231	5,145	5,426	5,876	5,942	7,009
Arunachal Pradesh	32	25	19	16	15	19	25	22	22
Assam	53	41	32	26	26	32	42	37	37
Karnataka	196,856	203,588	195,188	208,521	219,649	215,704	219,195	227,919	215,881
Kerala	56,194	58,813	51,619	55,150	58,963	64,125	67,488	65,175	66,056
Manipur	32	25	19	16	15	19	25	22	22
Meghalaya	53	41	32	26	26	32	42	37	37
Mizoram	32	25	19	16	15	19	25	22	22
Nagaland	32	25	19	16	15	19	25	22	22
Odisha	118	176	170	223	271	286	309	313	369
Tamil Nadu	18,694	18,375	18,131	16,994	18,819	17,375	17,925	17,615	18,424
Tripura	32	25	19	16	15	19	25	22	22
Coffee-India- State total	**274,375**	**284,500**	**268,500**	**285,250**	**302,975**	**303,075**	**311,000**	**317,150**	**307,925**

Table 79: State-wise Industrial Production data for Petroleum Sector, 2005-2013 (Tonnes)

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013

Andhra Pradesh	7,569,251	8,797,385	9,203,897	8,145,463	8,350,831	8,299,118	8,616,538	8,159,603	7,829,448
Assam	5,856,233	5,904,445	5,896,052	5,339,450	5,985,111	6,078,563	6,512,950	6,445,059	6,514,295
Bihar	5,324,472	5,417,957	5,454,648	5,125,597	5,708,475	6,133,337	5,837,039	6,126,160	6,389,278
Gujarat	41,449,210	44,708,611	51,993,079	69,370,931	86,101,391	93,292,756	95,535,925	100,420,556	100,419,789
Haryana	6,345,067	8,596,012	11,667,125	11,380,311	12,565,633	13,498,681	15,004,933	15,062,743	14,974,547
Karnataka	11,719,785	12,244,219	12,219,140	10,996,040	11,656,897	12,483,059	12,737,290	13,863,412	14,419,896
Kerala	7,041,567	7,445,130	7,865,969	6,879,195	7,305,630	8,404,262	9,259,057	9,843,645	10,152,293
Madhya Pradesh	-	-	-	-	-	-	1,532,202	4,754,038	5,472,525
Maharashtra	15,881,699	18,490,072	19,443,787	16,816,840	18,005,565	19,083,668	20,135,351	20,274,807	20,260,418
Punjab	-	-	-	-	-	-	-	3,630,512	8,113,876
Tamil Nadu	9,796,661	10,255,115	10,044,174	8,896,255	9,403,559	10,704,111	10,659,929	9,842,011	10,315,976
Uttar Pradesh	7,393,730	8,535,623	8,045,833	7,391,126	7,655,237	8,596,402	,353,974	8,383,385	7,057,264
West Bengal	5,369,574	5,677,931	5,603,905	5,209,494	5,370,783	6,515,713	7,756,682	7,558,270	7,769,579
Petroleum-India-State total	**123,747,250**	**136,072,500**	**147,437,610**	**155,550,702**	**178,109,111**	**193,089,669**	**201,941,869**	**214,364,201**	**219,689,184**

Table 80: State-wise Industrial Production data for Dairy Sector, 2005-2013 (Tonnes)

Industrial Production (PI)	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**
Andhra Pradesh	6,242,624	6,585,822	6,933,900	7,229,928	7,504,812	7,836,624	8,222,112	8,540,912	8,872,724
Bihar	875,543	923,678	972,496	1,014,015	1,052,568	1,099,106	1,153,171	1,197,884	1,244,421
Chhattisgarh	79,595	83,971	88,409	92,183	95,688	99,919	104,834	108,899	113,129
Delhi	3,183,794	3,358,828	3,536,351	3,687,328	3,827,521	3,996,748	4,193,350	4,355,941	4,525,168
Goa	238,785	251,912	265,226	276,550	287,064	299,756	314,501	326,696	339,388
Gujarat	11,522,946	12,156,438	12,798,937	13,345,361	13,852,755	14,465,231	15,176,783	15,765,240	16,377,716
Haryana	2,345,660	2,474,617	2,605,406	2,716,639	2,819,926	2,944,604	3,089,451	3,209,240	3,333,918
Himachal Pradesh	481,549	508,023	534,873	557,708	578,913	604,508	634,244	658,836	684,432
Jammu & Kashmir	23,878	25,191	26,523	27,655	28,706	29,976	31,450	32,670	33,939
Karnataka	3,826,920	4,037,311	4,250,693	4,432,168	4,600,680	4,804,091	5,040,407	5,235,841	5,439,252
Kerala	1,269,936	1,339,753	1,410,562	1,470,783	1,526,702	1,594,203	1,672,623	1,737,476	1,804,977
Madhya Pradesh	3,989,692	4,209,031	4,431,489	4,620,683	4,796,362	5,008,425	5,254,792	5,458,539	5,670,602
Maharashtra	21,165,863	22,329,489	23,509,659	24,513,356	25,445,360	26,570,382	27,877,393	28,958,297	30,083,320
Odisha	475,977	502,145	528,684	551,256	572,214	597,514	626,906	651,213	676,513
Puducherry	39,797	41,985	44,204	46,092	47,844	49,959	52,417	54,449	56,565
Punjab	6,645,374	7,010,714	7,381,248	7,696,375	7,988,993	8,342,213	8,752,571	9,091,938	9,445,158
Rajasthan	4,601,378	4,854,346	5,110,911	5,329,111	5,531,725	5,776,300	6,060,440	6,295,424	6,540,000
Sikkim	19,899	20,993	22,102	23,046	23,922	24,980	26,208	27,225	28,282
Tamil Nadu	7,417,444	7,825,230	8,238,813	8,590,552	8,917,167	9,311,424	9,769,458	10,148,254	10,542,511
Tripura	7,959	8,397	8,841	9,218	9,569	9,992	10,483	10,890	11,313
Uttar Pradesh	19,934,530	21,030,462	22,141,976	23,087,282	23,965,066	25,024,640	26,255,615	27,273,637	28,333,211
West Bengal	1,560,855	1,646,665	1,733,696	1,807,712	1,876,442	1,959,406	2,055,790	2,135,500	2,218,464

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Dairy-India- State total	**95,950,000**	**101,225,000**	**106,575,000**	**111,125,000**	**115,350,000**	**120,450,000**	**126,375,000**	**131,275,000**	**136,375,000**

Table 81: State-wise Industrial Production data for Meat Sector, 2005-2013 (Tonnes)

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andaman & Nicobar	350	300	300	300	375	400	408	463	1,395
Andhra Pradesh	455,500	477,250	538,000	592,000	660,250	730,000	804,480	885,583	927,620
Arunachal Pradesh	17,000	20,750	20,250	20,000	20,750	21,000	19,628	18,023	17,940
Assam	26,500	28,500	29,750	30,750	31,750	33,500	34,150	36,000	37,875
Bihar	175,750	177,500	196,750	207,500	215,750	221,750	226,585	228,155	276,280
Chandigarh	1,000	1,000	1,000	1,000	1,000	1,000	948	893	903
Chhattisgarh	4,000	4,000	14,500	19,500	23,750	26,500	28,935	32,865	30,338
Dadra & Nagar Haveli	-	-	-	75	100	100	93	90	90
Daman & Diu	58	-	225	225	200	200	208	210	368
Delhi	31,000	32,500	32,250	27,500	26,000	38,000	44,250	71,933	78,038
Goa	-	1,500	4,250	5,750	6,000	6,750	9,310	8,738	5,913
Gujarat	16,750	18,000	17,250	18,500	20,500	21,750	31,960	34,695	33,510
Haryana	7,500	7,750	147,425	220,975	238,250	299,500	332,455	344,943	361,860
Himachal Pradesh	3,000	3,000	3,750	4,000	4,000	3,250	3,728	3,993	3,993
Jammu & Kashmir	20,250	27,000	27,750	28,000	29,500	30,750	32,088	33,665	33,290
Jharkhand	43,000	43,750	46,250	47,000	47,000	44,750	45,455	44,875	45,218
Karnataka	50	225	300	300	375	400	415	390	425
Kerala	99,750	105,250	109,250	113,750	118,000	122,750	135,685	159,440	168,918
Lakshadweep	63,750	71,000	115,000	125,000	119,500	122,500	350,178	407,135	412,293
Madhya Pradesh	18,250	19,750	32,000	34,500	35,500	37,500	39,043	42,015	46,475
Maharashtra	234,500	241,250	454,500	533,250	542,750	558,500	579,245	589,175	601,143
Manipur	23,000	23,000	23,450	23,225	23,775	24,000	24,323	24,873	25,013
Meghalaya	36,750	36,250	36,750	37,000	37,000	37,750	38,180	38,450	39,885
Mizoram	9,000	9,750	10,750	12,500	10,750	10,000	12,370	12,350	12,163
Nagaland	62,500	63,000	32,250	52,750	65,250	65,250	74,675	72,455	68,270
Odisha	51,750	54,250	96,250	116,000	125,500	135,500	137,918	140,110	150,503
Puducherry	6,000	8,500	8,250	8,750	10,500	12,500	13,443	13,913	14,238
Punjab	4,000	53,500	99,250	108,250	137,250	168,000	179,328	204,298	229,308
Rajasthan	67,000	68,750	77,250	83,000	90,000	103,250	118,415	144,345	169,098
Sikkim	51,000	17,000	1,500	1,250	2,500	3,000	3,000	3,000	3,000
Tamil Nadu	110,500	194,750	376,750	450,000	490,750	475,000	461,770	461,845	463,968
Tripura	11,250	12,750	13,750	17,750	20,500	22,500	24,500	30,093	32,165

Industrial Production (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Uttar Pradesh	196,000	199,500	572,000	749,250	791,750	833,750	927,950	1,091,538	1,200,150
Uttrakhand	6,000	6,750	8,500	9,750	10,000	13,000	15,313	20,115	23,123
West Bengal	484,000	293,500	436,000	513,250	537,000	568,750	602,538	639,033	648,825
Meat-India- State total	**2,336,708**	**2,321,525**	**3,583,450**	**4,212,600**	**4,493,825**	**4,793,100**	**5,352,963**	**5,839,690**	**6,163,585**

Table 82: State-wise Industrial Production data for Pulp & Paper Sector, 2005-2013 (Tonnes)

Industrial Production (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andhra Pradesh	953,975	1,009,843	1,074,301	1,142,874	1,215,823	1,266,268	1,311,980	1,536,123	1,632,904
Assam	152,069	157,646	167,709	178,413	189,802	188,485	197,119	238,151	271,618
Chhattisgarh	24,686	25,785	27,430	29,181	31,044	30,109	31,140	41,395	44,343
Gujarat	1,724,384	1,828,052	1,944,736	2,068,868	2,200,924	2,391,528	2,391,998	2,690,400	2,914,120
Haryana	116,776	127,683	135,833	144,503	153,727	174,035	183,596	187,412	182,271
Himachal Pradesh	101,008	109,090	116,054	123,461	131,342	143,946	154,935	159,653	162,197
Jammu & Kashmir	21,583	23,401	24,895	26,484	28,174	30,911	33,660	34,320	34,320
Karnataka	442,381	475,528	505,880	538,171	572,522	601,723	667,142	715,058	724,462
Kerala	153,637	166,592	177,226	188,538	200,572	228,521	233,872	241,114	244,156
Madhya Pradesh	132,049	141,939	150,999	160,637	170,891	184,467	197,035	210,625	215,736
Maharashtra	877,438	946,002	1,006,385	1,070,623	1,138,960	1,243,542	1,328,174	1,392,865	1,418,982
Odisha	246,275	266,137	283,124	301,196	320,421	357,302	379,752	383,290	392,893
Punjab	781,142	830,311	883,310	939,692	999,672	1,079,114	1,151,733	1,188,796	1,293,933
Rajasthan	43,025	42,315	45,016	47,890	50,946	48,818	52,800	54,450	81,450
Tamil Nadu	1,087,334	1,140,092	1,212,864	1,290,280	1,372,639	1,471,792	1,483,803	1,641,756	1,868,892
Uttar Pradesh	1,587,645	1,675,758	1,782,721	1,896,512	2,017,566	2,162,042	2,213,258	2,442,902	2,696,999
Uttrakhand	831,358	906,541	964,405	1,025,963	1,091,450	1,206,183	1,294,895	1,352,539	1,313,321
West Bengal	404,576	426,582	453,810	482,777	513,592	382,774	642,231	711,139	703,601
Paper-India- State total	**9,681,339**	**10,299,297**	**10,956,699**	**11,656,062**	**12,400,066**	**13,191,560**	**13,949,123**	**15,221,988**	**16,196,199**

Table 83: Indian State-wise Industrial Production data for Rubber Sector, 2005-2013 (Tonnes)

Industrial Production (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Natural and Synthetic Rubber									
Andhra Pradesh	29,350	31,558	31,998	32,345	32,516	34,385	35,114	34,796	32,894
Assam	1,372	1,708	1,809	1,542	1,452	1,504	380	-	1,318
Bihar	411	400	252	206	207	215	54	-	330
Chhattisgarh	2,524	2,955	2,864	2,416	2,126	1,986	489	-	1,154

INDUSTRIAL PRODUCTION (PI)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Delhi	34,515	34,917	31,517	30,072	28,784	27,479	28,128	27,811	25,357
Goa	4,630	5,003	4,874	4,789	4,616	5,216	1,359	-	4,779
Gujarat	69,861	78,641	76,431	78,678	81,055	84,603	92,701	98,424	94,924
Haryana	61,598	67,592	71,065	75,381	75,405	73,540	76,887	75,804	71,982
Himachal Pradesh	1,328	2,169	3,160	1,629	4,145	5,698	1,468	-	4,449
Jharkhand	4,446	4,956	4,574	4,533	4,253	4,134	1,033	-	3,790
Karnataka	37,480	40,609	42,987	46,014	44,343	44,305	46,699	48,122	44,224
Kerala	161,429	161,122	156,645	155,319	155,060	157,128	171,278	172,033	163,655
Madhya Pradesh	12,027	14,022	13,818	14,324	13,744	13,151	13,841	13,788	13,143
Maharashtra	99,980	109,416	109,020	111,323	109,220	107,428	112,651	116,196	112,906
Odisha	1,974	2,508	2,612	2,835	2,283	1,986	489	-	1,648
Punjab	87,683	89,203	84,169	84,791	82,305	82,594	84,417	84,911	82,863
Rajasthan	20,919	23,781	25,312	28,093	28,368	29,547	30,569	33,520	33,494
Tamil Nadu	92,924	99,941	103,512	107,720	104,451	104,339	109,799	111,552	102,381
Uttar Pradesh	77,865	82,237	82,684	86,665	85,105	85,439	90,501	92,719	90,800
Uttrakhand	1,790	2,155	3,109	3,347	3,474	3,979	1,033	-	3,955
West Bengal	74,343	76,638	73,310	73,139	73,226	68,997	71,192	76,304	70,158
Rubber - India -State total	**878,450**	**931,534**	**925,723**	**945,164**	**936,138**	**937,652**	**970,083**	**985,981**	**960,203**

Table 84: State-wise Industrial Production data for Tannery Sector, 2005-2013 (Tonnes)

Industrial Production (P_i)	2005	2006	2007	2008	2009	2010	2011	2012	2013
Andhra Pradesh	1,742	1,778	1,815	1,853	1,890	1,929	1,943	1,967	2,102
Bihar	2,078	2,121	2,164	2,210	2,254	2,301	2,318	2,346	2,508
Chhattisgarh	52	53	54	55	56	57	58	59	63
Gujarat	2,236	2,282	2,329	2,378	2,425	2,476	2,494	2,524	2,698
Haryana	42,161	43,030	43,916	44,845	45,731	46,685	47,029	47,606	50,882
Himachal Pradesh	9,202	9,391	9,585	9,787	9,981	10,189	10,264	10,390	11,105
Karnataka	9,447	9,642	9,840	10,049	10,247	10,461	10,538	10,667	11,402
Kerala	16,346	16,682	17,026	17,386	17,730	18,100	18,233	18,456	19,727
Madhya Pradesh	15,235	15,549	15,869	16,204	16,524	16,869	16,994	17,202	18,386
Maharashtra	15,298	15,613	15,934	16,271	16,593	16,939	17,064	17,273	18,462
Punjab	11,595	11,834	12,078	12,333	12,577	12,839	12,934	13,092	13,993
Rajasthan	10,784	11,006	11,232	11,470	11,697	11,941	12,029	12,176	13,014
Tamil Nadu	140,756	143,656	146,614	149,715	152,672	155,860	157,008	158,932	169,872
Uttar Pradesh	133,544	136,296	139,102	142,044	144,850	147,874	148,964	150,789	161,169
Uttrakhand	5,891	6,012	6,136	6,266	6,390	6,523	6,571	6,652	7,110
West Bengal	73,834	75,355	76,907	78,533	80,085	81,757	82,359	83,368	89,107
Tannery - State total	**490,200**	**500,300**	**510,600**	**521,400**	**531,700**	**542,800**	**546,800**	**553,500**	**591,600**

1.21 State-wise Data Quality Assessment for Select Parameters

Table 85: State-wise Qualitative Assessment of Activity Data on 'Mass of Waste Deposited' used in the Solid Waste Disposal Estimates

STATES AND UTs	QUALITY									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Mass of Waste Deposited (W)										
Andaman & Nicobar	L	L	L	L	L	L	H	L	H	H
Andhra Pradesh	H	L	L	L	L	L	H	L	H	H
Arunachal Pradesh	H	L	L	L	L	L	H	L	H	H
Assam	H	L	L	L	L	L	H	L	H	H
Bihar	H	L	L	L	L	L	H	L	H	H
Chandigarh	H	L	L	L	L	L	H	L	H	H
Chhattisgarh	H	L	L	L	L	L	H	L	H	H
Dadra & Nagar Haveli	H	L	L	L	L	L	H	L	H	H
Daman & Diu	H	L	L	L	L	L	H	L	H	H
Delhi	H	L	L	L	L	L	H	L	H	H
Goa	H	L	L	L	L	L	H	L	H	H
Gujarat	H	L	L	L	L	L	H	L	H	H
Haryana	H	L	L	L	L	L	H	L	H	H
Himachal Pradesh	H	L	L	L	L	L	H	L	H	H
Jammu & Kashmir	H	L	L	L	L	L	H	L	H	H
Jharkhand	H	L	L	L	L	L	H	L	H	H
Karnataka	H	L	L	L	L	L	H	L	H	H
Kerala	H	L	L	L	L	L	H	L	H	H
Lakshadweep	H	L	L	L	L	L	H	L	H	H
Madhya Pradesh	H	L	L	L	L	L	H	L	H	H
Maharashtra	H	L	L	L	L	L	H	L	H	H
Manipur	H	L	L	L	L	L	H	L	H	H
Meghalaya	H	L	L	L	L	L	H	L	H	H
Mizoram	H	L	L	L	L	L	H	L	H	H
Nagaland	H	L	L	L	L	L	H	L	H	H
Odisha	H	L	L	L	L	L	H	L	H	H
Puducherry	H	L	L	L	L	L	H	L	H	H
Punjab	H	L	L	L	L	L	H	L	H	H
Rajasthan	H	L	L	L	L	L	H	L	H	H
Sikkim	H	L	L	L	L	L	H	L	H	H
Tamil Nadu	H	L	L	L	L	L	H	L	H	H
Telangana	-	-	-	-	-	-	-	-	-	H
Tripura	H	L	L	L	L	L	H	L	H	H
Uttar Pradesh	H	L	L	L	L	L	H	L	H	H
Uttarakhand	H	L	L	L	L	L	H	L	H	H
West Bengal	H	L	L	L	L	L	H	L	H	H

Notes: H- high, L-low

Table 86 relates to information on wastewater collection through the sewer network and its treatment in STPs through anaerobic or aerobic treatment routes. The data determines the extent of domestic wastewater that is conveyed and treated through the 'sewer' pathway for each state.

Urban: When STP data/Sewer data is available for a particular year (indicated in Table 74 in Annexure 6.2) the data quality is considered 'high'. The data is sourced from CPCB/SPCB reports as indicated in section 3.5.2. Also, when there is evidence that there are no STPs for a specific year then the preceding year data quality is also considered as 'high' along with the year for which data is reported. For rest of the years where reliable data is not available from CPCB/SPCB reports, the data quality is termed 'low'.

Rural: The sewer data is based on Latrine facility data from Census of India, 2011. Therefore quality of data for the year 2011 is considered to be 'high'. For the rest of the years, data quality is assigned as 'low' since data is unavailable.

Table 86: State-wise Qualitative Assessment of Activity Data on 'Degree of Utilization' used in the Domestic Wastewater Estimates

STATES AND UTs	QUALITY																			
	2005		2006		2007		2008		2009		2010		2011		2012		2013		2014	
	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R
Degree of Utilization - Sewer																				
Andaman and Nicobar Islands	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Andhra Pradesh	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Arunachal Pradesh	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Assam	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Bihar	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Chandigarh	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L
Chhatisgarh	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Dadra and Nagar Haveli	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Daman and Diu	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
National Capital Territory of Delhi	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Goa	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Gujarat	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Haryana	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Himachal Pradesh	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L
Jammu and Kashmir	H	L	H	L	H	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Jharkhand	H	L	H	L	H	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Karnataka	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Kerala	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Lakshadweep	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Madhya Pradesh	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L
Maharashtra	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Manipur	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Meghalaya	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Mizoram	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Nagaland	H	L	H	L	H	L	H	L	H	L	H	L	H	H	H	L	H	L	H	L
Odisha	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L
Puducherry	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L

States and UTs	Quality																			
	2005		2006		2007		2008		2009		2010		2011		2012		2013		2014	
	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R	U	R
Punjab	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L
Rajasthan	L	L	L	L	L	L	L	L	L	L	L	L	L	H	L	L	L	L	H	L
Sikkim	H	L	H	L	H	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Tamil Nadu	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Telangana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	L	L
Tripura	H	L	H	L	H	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Uttar Pradesh	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
Uttarakhand	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L
West Bengal	L	L	L	L	L	L	H	L	L	L	L	L	L	H	L	L	L	L	H	L

Notes: U- Urban, R- Rural, H- high, L-low

Table 87: State-wise Qualitative Assessment of Activity Data on 'Per Capita BOD' value used in the Domestic Wastewater Estimates

State	Quality									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Per capita BOD										
Andaman and Nicobar Islands	L	L	L	L	L	L	L	L	L	L
Andhra Pradesh	L	L	L	L	L	L	L	L	L	L
Arunachal Pradesh	L	L	L	L	L	L	L	L	L	L
Assam	L	L	L	L	L	L	L	L	L	L
Bihar	L	L	H	L	L	L	L	L	L	L
Chandigarh	L	L	H	L	L	L	L	L	L	L
Chhatisgarh	L	L	L	L	L	L	L	L	L	L
Dadra and Nagar Haveli	L	L	L	L	L	L	L	L	L	L
Daman and Diu	L	L	L	L	L	L	L	L	L	L
National Capital Territory of Delhi	L	L	H	L	L	L	L	L	L	L
Goa	L	L	L	L	L	L	L	L	L	L
Gujarat	L	L	H	L	L	L	L	L	L	L
Haryana	L	L	H	L	L	L	L	L	L	L
Himachal Pradesh	L	L	H	L	L	L	L	L	L	L
Jammu and Kashmir	L	L	L	L	L	L	L	L	L	L
Jharkhand	L	L	H	L	L	L	L	L	L	L
Karnataka	L	L	H	L	L	L	L	L	L	L
Kerala	L	L	L	L	L	L	L	L	L	L
Lakshadweep	L	L	L	L	L	L	L	L	L	L
Madhya Pradesh	L	L	H	L	L	L	L	L	L	L
Maharashtra	L	L	H	L	L	L	L	L	L	L
Manipur	L	L	L	L	L	L	L	L	L	L
Meghalaya	L	L	L	L	L	L	L	L	L	L
Mizoram	L	L	L	L	L	L	L	L	L	L
Nagaland	L	L	L	L	L	L	L	L	L	L
Odisha	L	L	L	L	L	L	L	L	L	L
Puducherry	L	L	L	L	L	L	L	L	L	L
Punjab	L	L	H	L	L	L	L	L	L	L
Rajasthan	L	L	L	L	L	L	L	L	L	L
Sikkim	L	L	L	L	L	L	L	L	L	L
Tamil Nadu	L	L	L	L	L	L	L	L	L	L

STATE	QUALITY									
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Telangana	-	-	-	-	-	-	-	-	-	L
Tripura	L	L	L	L	L	L	L	L	L	L
Uttar Pradesh	L	L	H	L	L	L	L	L	L	L
Uttarakhand	L	L	H	L	L	L	L	L	L	L
West Bengal	L	L	H	L	L	L	L	L	L	L

Notes: H- high, L-low

1.22 Sample Calculations for Emission Estimation

1.22.1 Sample Emission Estimate Calculation for 4A2 Unmanaged Waste Disposal Sites for Andhra Pradesh for Year 2005

CH_4 Emission from Solid Waste Disposal Sites

CH_4 Emissions = $[\sum CH_{4\ generatedT} - R_T] \times (1 - OX_T)$ ----- *Equation 1*

Where,

CH_4 Emissions = CH_4 emitted in year T, Gg

T = inventory year

x = waste category or type/material

R_T = recovered CH_4 in year T, Gg (default value of 0[138])

OX_T = oxidation factor in year T, (fraction) (default value of 0[139])

CH_4 Generated from Decayed $DDOC_m$

$CH_{4generatedT} = DDOC_{mdecompT} \times F \times 16/12$ —*Equation 2*

Where,

$CH_{4generatedT}$ = amount of CH_4 generated from decomposable material

$DDOC_{m\ decompT}$ = Decomposable Degradable Organic Carbon decomposed in year T, Gg

F = fraction of CH_4, by volume, in generated landfill gas (fraction) (default value of 0.5[140])

16/12 = molecular weight ratio CH_4/C (ratio)

DECOMPOSABLE DOC FROM WASTE DISPOSAL DATA[141]

$DDOC_m = W \times DOC \times DOCf \times MCF$ —*Equation 3*

Where,

$DDOC_m$ = mass of decomposable DOC deposited, Gg

W = mass of waste deposited, Gg

DOC = degradable organic carbon in the year of deposition, fraction, Gg C/Gg waste

DOC_f = fraction of DOC that can decompose (fraction) (Default value of 0.5[140])

MCF = CH_4 correction factor for aerobic decomposition in the year of deposition (fraction) (default value of 0.4[142])

ESTIMATED DOC USING DEFAULT CARBON CONTENT VALUES[143]

$$DOC = \sum_i (DOCi * Wi)$$ —*Equation 4*

Where,

DOC = fraction of degradable organic carbon in bulk waste, Gg C/Gg waste

DOC_i = fraction of degradable organic carbon in waste type i[144]

W_i = fraction of waste type i by waste category

$DDOC_m$ ACCUMULATED IN THE SWDS AT THE END OF YEAR T[145]

$DDOC_{maT} = DDOC_{mdT} + (DDOC_{maT-1} \times e^{(-k)})$ —*Equation 5*

$DDOC_m$ DECOMPOSED AT THE END OF YEAR T[146]

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138 As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Section 3.2.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

139 As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.2. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

140 As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

141 As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.2. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

142 As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.1. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

143 As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.7. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

144 Default values given in 2006 IPCC Guidelines, Vol. 5, Chapter 2: Waste Generation, Composition and Management Data, Table 2.6. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

145 As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.4. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

146 As per IPCC 2006 Guidelines, Vol. 5, Chapter 3: Solid Waste disposal, Equation 3.5.

$$DDOC_{mdecompT} = DDOC_{maT-1} \times (1 - e^{(-k)})$$ ----*Equation 6*

Where,

T	= inventory year
$DDOC_{maT}$	= DDOCm accumulated in the SWDS at the end of year T, Gg
$DDOC_{maT-1}$	= DDOCm accumulated in the SWDS at the end of year (T-1), Gg
$DDOC_{mdT}$	= DDOCm deposited into the SWDS in year T, Gg
$DDOC_{m\ decompT}$	= DDOCm decomposed in the SWDS in year T, Gg
k	= reaction constant,

$k = \ln(2)/t_{1/2}$ (y-1) = 0.17[147]

$t_{1/2}$ = half-life time (y)[148]

Step 1: Calculation of per capita waste generation rates and mass of waste deposited (W)

Based on the 2006 IPCC Guidelines for National GHG Inventories**Error! Bookmark not defined.**, the FOD model is used to estimate emissions from decomposition of solid waste in waste disposal sites in this assessment. The FOD model considers that waste deposited in a disposal site at a point of time decomposes gradually over time and the residual waste (material that remains after the partial decomposition of waste during anaerobic digestion process) continues to undergo anaerobic digestion again and generate CH_4 over a subsequent period of time (around 50 years). The FOD model estimates the actual methane generation at a given point of time, accounting for the total methane generation over a preceding time period. Thereby it is necessary to estimate 50-year data on waste disposal prior to the base year 2005 i.e. from 1954-2004.

As time series data on mass of waste deposited (W) for the 50 year period before 2005 is not available at state-level, the quantum of waste deposited in disposal sites is estimated based on urban population, per capita waste generation, and the proportion of generated waste that reaches disposal sites and leads to CH_4 emission as shown in the sample calculation that follows.

Based on reported data on per capita waste generation rate for Andhra Pradesh in year 2005, the per capita waste generation for the preceding and subsequent years is calculated as using national-level annual growth rates as shown in Table 88.

Table 88: Calculation of growth rates for per capita waste generation based on reported data

YEAR	APPLICABLE ANNUAL GROWTH RATE[149]	ESTIMATED DAILY PER CAPITA WASTE GENERATION (KG/DAY)[150]
1951	1.15%	0.280
1961	1.03%	0.317
1971	1.47%	0.353
1981	0.70%	0.414
1991	1.22%	0.445
2007	1.22%	0.533[151]

Calculation of mass of Waste deposited W

Year 1954

- Total urban population for Andhra Pradesh = 5,676,580 persons[152]
- Applicable annual growth rate for per capita waste generation from Table 88= 1.15%

Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

[147] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

[148] As per IPCC 2006 Guidelines, Vol. 5. Chapter 3: Solid Waste disposal, Table 3.4. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

[149] Annual growth rates have been estimated based on per capita generation rates reported at national-level for certain years as given in the Table 25 of this note and have been used in the emission estimation to calculate per capita generation rates for the rest of the years for Andhra Pradesh, using reported capita generation for the state in 2005 as the basis.

[150] Reported capita generation for the state in 2005 is used as the basis to calculate per capita generation for the rest of the years using applicable annual growth rate in per capita generation across time periods as indicated in Table 58

[151] Reported data from CPCB: Waste Generation and Composition, Table 1. State-wise per capita waste generation is based on reported per capita waste generation for cities in the state. Available at http://www.cpcb.nic.in/wast/municipalwast/Waste_generation_Composition.pdf

[152] Estimated based on urban population for year 1951 and annual growth rate of 1.58% calculated based on decadel growth rate from 1951-1961 as per Census of India data.

- Per capita waste generation, 1951 from Table 88= 0.280 kg/day/person
- Estimated per capita waste generation, 1954= 0.280 x [1+ (1.15% x 3)] = 0.291 kg/day/person
- Percent of generated waste that is sent to disposal sites = 70%[153]

Mass of waste deposited, year 1954 (W_{1954})
= Total urban population x per capita waste generation x 365 days x percent of generated waste sent to disposal site
= 5,676,580 persons x 0.291 kg/day/person x 365 days x 70%[153]
= 422.69 gigagram (Gg)[154]

Year 1955

- Total urban population for Andhra Pradesh = 5,761,998 persons
- Applicable annual growth rate for per capita waste generation from Table 88= 1.15%
- Reported per capita waste generation, 1951 from Table 88= 0.280 kg/day/person
- Estimated per capita waste generation, 1955= 0.280 x [1+ (1.15% x 4)] = 5,761,998 kg/day/person
- Percent of generated waste that is sent to disposal sites = 70%[153]

Mass of waste deposited, year 1955 (W_{1955})
= Total urban population x per capita waste generation x 365 days x percent of generated waste sent to disposal site
= 5,761,998 persons x 0.280 kg/day/person x 365 days x 70%
= 434.41 Gg

Similarly calculated for the intermediate years up to 2005

Year 2005

- Total urban population for Andhra Pradesh = 23,772,994 persons[155]
- Applicable growth rate for per capita waste generation from Table 88= 1.22%
- Reported per capita waste generation, 2005 from Table 88 = 0.533 kg/day/person
- Percent of generated waste that is sent to disposal sites = 70%[153]

Mass of waste deposited, year 2005 (W_{2005})
= Total urban population x per capita waste generation x 365 days x percent of generated waste sent to disposal site
= 23,772,994 persons x 0.533 kg/day/person x 365 days x 70%[153]
= 3,239.47 Gg

Step 2: Calculation of DOC based on Waste Composition data as per Equation 4

Waste composition available across the three years of 1971, 1995 and 2005 is assumed to be applicable for adjacent time periods i.e. 1954-1994, 1995-2004 and 2005-2014 (see Table 89). Using the default values for DOC content for degradable wet waste fractions **(DOC_i)** in waste, the DOC values for the organic portion of the waste are calculated for the time periods 1954-1994, 1995-2004 and 2005-2014 as shown in Table 89.

Table 89: Calculation of DOC content value using Waste Composition data

YEAR	FRACTION OF WASTE TYPE I BY WASTE CATEGORY (WI)			CALCULATION FOR DOC FOR OVERALL WASTE (IN FRACTION) $DOC = \sum_i (DOCi * Wi)$	APPLICABLE TIME PERIOD CONSIDERED FOR ESTIMATED DOC VALUE
	PAPER	TEXTILES	COMPOSTABLE MATTER		
1971[54]	4.14%	3.83%	41.24%	(40% x 4.14%) + (24% x 3.83%) + (15% x 41.24%)	**1954-1994**

[153] Ministry of Environment and Forests, Government of India (2012): India - Second National Communication Report, 2012 to the UNFCCC, Page 76. Available at: http://unfccc.int/resource/docs/natc/indnc2.pdf
[154] 1 gigagram= 1,000,000 kg
[155] Estimated based on urban population for year 2001 and 2011 and decadel growth rate from 2001-2011 as per Census of India data. Available at http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf

YEAR	FRACTION OF WASTE TYPE I BY WASTE CATEGORY (WI)			CALCULATION FOR DOC FOR OVERALL WASTE (IN FRACTION) $DOC = \sum_i (\mathrm{DOCi} * \mathrm{Wi})$	APPLICABLE TIME PERIOD CONSIDERED FOR ESTIMATED DOC VALUE
	PAPER	TEXTILES	COMPOSTABLE MATTER		
				=0.088	
1995[54]	5.78%	3.50%	41.80%	(40% x 5.78%) + (24% x 3.5%) + (15% x 41.8%) =0.094	**1995-2004**
2005[55]	7.37%	3.99%	53.19%	(40% x 7.37%)+ (24% x 3.99%) + (15% x 53.19%) =0.119	**2005-2014**
Default DOC Content values (Wet waste) in fraction (DOC_i)[156]	40%	24%	15%	-	-

Step 3: Calculation of decomposable DOC deposited ($DDOC_m$) as per Equation 3

$DDOC_m$=W x DOC x DOCf x MCF

<u>Year 1954</u>

- Mass of waste deposited (W_{1954}) **=**422.69 Gg
- $DOC_{1954\text{-}1994}$= 0.088 Gg C/Gg waste
- DOCf = 0.5
- MCF = 0.4

$DDOC_{m(1954)}$ = W x DOC x DOCf x MCF
= 422.69 Gg x 0.088 Gg C/Gg waste x 0.5 x 0.4
= 7.41Gg C

<u>Year 1955</u>

- Mass of waste deposited (W_{1955}) **=** 434.41 Gg
- $DOC_{1954\text{-}1994}$= 0.088 Gg C/Gg waste
- DOCf = 0.5
- MCF = 0.4

$DDOC_{m(1955)}$ = W x DOC x DOCf x MCF
= 434.41 Gg x 0.088 Gg C/Gg waste x 0.5 x 0.4
= 7.61Gg C

Similarly calculated for the intermediate years up to 2005

<u>Year 2005</u>

- Mass of waste deposited (W_{2005}) **=**3,239.47 Gg
- $DOC_{2005\text{-}2014}$= 0.119 Gg C/Gg waste
- DOCf = 0.5
- MCF = 0.4

$DDOC_{m(2005)}$ = W x DOC x DOCf x MCF
= 3,239.47 Gg x 0.119 Gg C/Gg waste x 0.5 x 0.4
= 76.98 Gg C

Step 4: Calculation of $DDOC_m$ Accumulated in the Disposal Site at the End of Year T ($DDOC_{maT}$) as per Equation 5

[156] As per 2006 IPCC Guidelines, Vol. 5, Chapter 2: Waste Generation, Composition and Management Data, Table 2.6. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf

$DDOC_{maT} = DDOC_{mdT} + (DDOC_{maT-1} \times e^{\wedge(-k)})$

Year 1954

- $DDOC_{m\ (1954)} =$ 7.41 Gg C
- $DDOC_{maT-1\ (1953)} =$ 0 Gg C[157]
- Euler's constant e = 2.718
- k = 0.17

$$DDOC_{maT\ (1954)} = DDOC_{m\ (1954)} + (DDOC_{maT-1\ (1953)} \times e^{\wedge(-k)})$$
$$= 7.41 + (0 \times 2.718^{\wedge(-0.17)})$$
$$= 7.41 \text{ Gg C}$$

Year 1955

- $DDOC_{m\ (1955)} =$ 7.61 Gg C
- $DDOC_{maT-1\ (1954)} =$ 7.61 Gg C
- Euler's constant e = 2.718
- k = 0.17

$$DDOC_{maT\ (1955)} = DDOC_{m\ (1955)} + (DDOC_{maT-1\ (1954)} \times e^{\wedge(-k)})$$
$$= 7.61 + (7.41 \times 2.718^{\wedge(-0.17)})$$
$$= 13.86 \text{ Gg C}$$

Similarly calculated for the intermediate years up to 2005

Year 2005

- $DDOC_{m\ (2005)} =$ 76.98 Gg C
- $DDOC_{maT-1\ (2004)} =$ 58.42 Gg C
- Euler's constant e = 2.718
- k = 0.17

$$DDOC_{maT\ (2005)} = DDOC_{m\ (2005)} + (DDOC_{maT-1\ (2004)} \times e^{\wedge(-k)})$$
$$= 76.98 + (58.42 \times 2.718^{\wedge(-0.17)})$$
$$= 338.03 \text{ Gg C}$$

Step 5: Calculation of $DDOC_m$ Decomposed at the end of year T ($DDOC_{m\ decompT}$) as per Equation 6

$DDOC_{mdecompT} = DDOC_{maT-1} \times (1 - e^{\wedge(-k)})$

Year 1954

- $DDOC_{maT-1\ (1953)} =$ 0 Gg C
- Euler's constant e = 2.718
- k = 0.17

$$DDOC_{mdecompT\ (1954)} = DDOC_{maT-1\ (1953)} \times (1 - e^{\wedge(-k)})$$
$$= 0 \times (1 - 2.718^{\wedge(-0.17)})$$
$$= 0 \text{ Gg C}$$

Year 1955

- $DDOC_{maT-1\ (1954)} =$ 7.41 Gg C
- Euler's constant e = 2.718
- k = 0.17

$$DDOC_{mdecompT\ (1955)} = DDOC_{maT-1\ (1954)} \times (1 - e^{\wedge(-k)})$$
$$= 7.41 \times (1 - 2.718^{\wedge(-0.17)})$$
$$= 1.16 \text{ Gg C}$$

[157] Waste disposal is considered from 1954 onwards and therefore DDOCm accumulated in 1953 is assumed to be zero

Similarly calculated for the intermediate years up to 2005

Year 2005

- $DDOC_{maT-1\ (2004)}$ = 309.42 Gg C
- Euler's constant e = 2.718
- k = 0.17

$DDOC_{mdecompT\ (2005)} = DDOC_{maT-1\ (2004)} \times (1 - e^{\wedge(-k)})$
$= 309.42 \times (1\text{-}2.718^{\wedge(-0.17)})$
$= 48.37$ Gg C

Step 6: Calculation of CH_4 generated ($CH_{4generatedT}$) from decomposed $DDOC_m$ as per Equation 2

$CH_{4generatedT} = DDOC_{mdecompT} \times F \times 16/12$

Year 1954

- $DDOC_{mdecompT\ (1954)}$ = 0 Gg C
- F = default value of 0.5

$CH_{4generatedT\ (1954)} = DDOC_{mdecompT\ (1954)} \times F \times 16/12$
$= 0 \times 0.5 \times 16/12$
$= 0$ Gg CH_4

Year 1955

- $DDOC_{mdecompT\ (1955)}$ = 1.16 Gg C
- F = default value of 0.5

$CH_{4generatedT\ (1955)} = DDOC_{mdecompT\ (1955)} \times F \times 16/12$
$= 1.16 \times 0.5 \times 16/12$
$= 0.77$ Gg CH_4

Similarly calculated for the intermediate years up to 2005

Year 2005

- $DDOC_{mdecompT\ (2005)}$ = 48.37 Gg C
- F = default value of 0.5

$CH_{4generatedT\ (2005)} = DDOC_{mdecompT\ (2005)} \times F \times 16/12$
$= 48.37 \times 0.5 \times 16/12$
$= 32.25$ Gg CH_4

Step 7: Calculation of Total CH_4 emission from solid waste disposal sites as per Equation 1
CH_4 Emissions = $[\sum CH_{4\ generatedT} - R_T] \times (1\text{-}OX_T)$

Year 1954

- $CH_{4generatedT\ (1954)}$ = 0 Gg CH_4
- R_T = default value of 0
- OX_T = default value of 0

CH_4 Emissions $_{(1954)} = [CH_{4generatedT\ (1954)} - R_T] \times ((1\text{-}OX_T)$
$= [0 – 0] \times (1\text{-}\ 0)$
$= 0$ Gg $CH_4 = 0 \times 10^3$ tonnes of CH_4
$= 0$ tonnes of CH_4

Year 1955

- $CH_{4generatedT\ (1955)}$ = 0.77 Gg CH_4
- R_T = default value of 0
- OX_T = default value of 0

CH_4 Emissions $_{(1955)}$ = [$CH_{4generatedT\ (1955)}$ - R_T] x ((1-OX_T)
= [0.77 – 0] x (1- 0)
= 0.77 Gg CH_4= 0.77 x 10^3 tonnes of CH_4
= 771.86 tonnes of CH_4

Similarly calculated for the intermediate years up to 2005

Year 2005

- $CH_{4generatedT\ (2005)}$ = 32.25 Gg CH_4
- R_T = default value of 0
- OX_T = default value of 0

CH_4 Emissions $_{(2005)}$ = [$CH_{4generatedT\ (2005)}$ - R_T] x ((1-OX_T)
= [32.25 – 0] x (1- 0)
= 32.25 Gg CH_4 = 32.25 x 10^3 tonnes of CH_4
= 32,245.67 tonnes of CH_4

Step 8: Calculation of Total CH_4 emissions from Solid Waste Disposal in tonnes of CO_2e

Total CH_4 emissions from Solid Waste Disposal for Andhra Pradesh in tonnes of CO_2e (2005)
= (Emission in tonnes of CH_4 x GWP of CH_4)
= 32,245.67 x 21[158]
= 16,208.99 tonnes of CO_2e

1.22.2 Sample Emission Estimate Calculation for 4D1 Domestic Wastewater Treatment and Discharge for Andhra Pradesh for Year 2005

1) Sample Calculation for CH_4 Emission from Domestic Wastewater Emission for Andhra Pradesh for Year 2005

$$CH4\ Emissions = \sum_{i,j}[(U_i * Ti\ _j * EFj)](TOW\ - S) - R$$ -------*Equation 7*

Where,

CH_4 Emissions	= Methane emissions in inventory year, kg CH_4/yr
TOW	= total organics in wastewater in inventory year, kg BOD/yr
S	= organic component removed as sludge in inventory year, kg BOD/yr (default value of 0[159])
U_i	= fraction of population in income group i in inventory year
$T_{i,j}$	= degree of utilization of treatment/discharge pathway or system j, for each income group fraction i in inventory year
i	= income group: rural, urban high income and urban low income
j	= each treatment/discharge pathway or system
EF_j	= emission factor, kg CH_4/kg BOD
R	= amount of CH_4 recovered in inventory year, kg CH_4/yr (default value of 0[160])

The emission factor EF_j for the various type treatment system or discharge pathways is a function of the maximum CH_4 producing potential (B_o) and the corresponding methane correction factor (MCF) for the waste water treatment and discharge system.

$$CH4\ Emission\ Factor\ EF_j = B_O * MCFj$$ --------*Equation 8*

Where,

[158] 100-year GWP values specified for CH_4 is 21 as per the IPCC Second Assessment Report, 1996, Technical Summary, Table 4. Available at https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf
[159] As per 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 6: Wastewater Treatment and Discharge. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[160] As per 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 6: Wastewater Treatment and Discharge and NEERI document on Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

EF_j = emission factor, kg CH_4/kg BOD
j = each treatment/discharge pathway or system
B_o = maximum CH_4 producing capacity, kg CH_4/kg BOD (Default value 0.6[161])
MCF_j = methane correction factor (fraction)
The equation for TOW in domestic wastewater is:

$$TOW = P * BOD * 0.001 * I * 365 \quad \text{-------- Equation 9}$$

Where,
TOW = total organics in wastewater in inventory year, kg BOD/yr
P = population in inventory year, (person)
BOD = country-specific per capita BOD in inventory year, g/person/day,
0.001 = conversion from grams BOD to kg BOD
I = correction factor for additional industrial BOD discharged into sewers

Step 1: Calculation of TOW as per Equation 9

- State Population P (2005) = 79,558,315 persons[162]
- BOD = 40.5 gm/person/day[163]
- I= default value[164] (1.00 for uncollected wastewater; 1.25 for collected wastewater)

TOW (total country)
= $P * BOD * 0.001 * I * 365$
= 79,558,315 persons x 40.5 gm/person/day x 0.001 x 1 x 365 days
= 1,176,070,791.49 kg BOD/Year

TOW, collected portion of wastewater - urban
= Total State TOW x 19.95%[165] (share of piped sewer system for urban areas) x 1.25
= 1,176,070,791.49 kg BOD/Year x 50.8% x 1.25
=293,258,584.17 kg BOD/Year

TOW, uncollected portion of wastewater - urban
= Total State TOW x (1-19.95%) (uncollected share of wastewater for urban areas) x 1.00
= 1,176,070,791.49 kg BOD/Year x 80.05% x 1.00
= 941,463,924.15 kg BOD/Year

TOW, uncollected portion of wastewater - rural[166]
= Total Country TOW x (1-0.77%) (uncollected share of wastewater for rural areas) x 1.00
= 1,176,070,791.49 kg BOD/Year x 99.23%[167] x 1.00
= 1,167,019,164.93 kg BOD/Year

Step 2: Calculation of CH_4 Emission Factor for each Treatment Discharge Pathway as per Equation 8

[161] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Table 6.2. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[162] Estimated based on country population for year 2001 and 2011 and decadel growth rate from 2001-2011 as per Census of India data. Available at http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf
[163] NEERI document on Inventorization of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf
[164] Based on 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[165] Refer to Table 42 in this note for details of sources and calculation of this value
[166] As reported in India's Second National Communication, the waste water generated in rural areas is not handled or treated in any way and decomposes under aerobic conditions. Using this basis, the proportion of rural wastewater that is collected and conveyed through sewer systems is also assumed to not undergo any treatment downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions. Therefore emissions are estimated only for uncollected portion for rural domestic wastewater
[167] Refer to Table 47 in this note for details of sources and calculation of this value

Table 90: CH_4 Emission factor calculation for Treatment Pathway in Urban and Rural income groups

INCOME GROUP (I)	TREATMENT/ DISCHARGE PATHWAY OR SYSTEM (J)	DEGREE OF UTILIZATION OF TREATMENT/ DISCHARGE PATHWAY OR SYSTEM J, FOR EACH INCOME GROUP FRACTION I ($T_{I,J}$)[168]	MCFJ[169]	BO (KG CH_4/KG BOD)	EFJ = BO X MCFJ (KG CH4/KG BOD)
Urban	Septic Tank (uncollected)	0.26	0.5	0.6	0.30
	Latrine (uncollected)	0.15	0.1	0.6	0.06
	Public Latrine (uncollected)	0.03	0.5	0.6	0.30
	Others/None (Uncollected)	0.36	0.1	0.6	0.06
	Sewer (collected and not treated)	0.199 (Sewer) x 55.5% of waste water collected and not treated in Andhra Pradesh = 0.11071	0.5	0.6	0.30
	Sewer (collected and anaerobic treatment)	(0.199 (Sewer) – 0.11071) (Sewer collected and not treated) x 0% (share of wastewater collected through sewer and treated anaerobically in Andhra Pradesh) = 0	0.8	0.6	0.48
	Sewer (collected and aerobic treatment, not well managed)	(0.199 (Sewer) – 0.11071) x 100% (share of wastewater collected through sewer and treated anaerobically in Andhra Pradesh) = 0.089	0.3	0.6	0.18
Rural	Septic Tank uncollected)	0.076	0.50	0.6	0.30
	Latrine (uncollected)	0.064	0.10	0.6	0.06
	Public Latrine (Uncollected)	0.033	0.50	0.6	0.30
	Sewer (Open and closed drainage)	0.008	0	0.6	0
	Other & None (Uncollected)	0.820	0.10	0.6	0.06

Step 3: CH_4 Emission Calculation for each income Group by Treatment type as per Equation 7

$$CH4\ Emissions = \sum_{i,j} [(U_i * Ti_{,j} * EFj)](TOW - S) - R$$

A) Urban

- Ui =0.273[170]
- Ti,j for different treatment/discharge pathways from Table 90 above
- EFj for different treatment/discharge pathways from Table 90 above

CH_4 emissions from Treatment/Discharge Pathways classified as 'Uncollected'

a) CH_4 emissions from Septic tank (uncollected)
= (0.273 x 0.26 x 0.30 kg CH_4/kg BOD) x 941,463,924.15 kg BOD/Year
= 20,268,575.16 kg CH_4/year

b) CH_4 emissions from Latrine (uncollected)
= (0.273 x 0.15 x 0.06 kg CH_4/kg BOD) x 941,463,924.15 kg BOD/Year
= 2,329,001.87 kg CH_4/year

c) CH_4 emissions from Public Latrine (uncollected)

168 Refer to Table 42 and Table 47 in this note for details of sources and calculation of these values
169 Refer to Table 50 in this note for further details
170Based on share of urban population reported for Andhra Pradesh for year 2001 as per Census of India statistics. http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf

= (0.273 x 0.03 x 0.30 kg CH_4/kg BOD) x 941,463,924.15 kg BOD/Year
= 2,430,089.14 kg CH_4/year

CH_4 emissions from Other/None (uncollected and not treated)
= (0.273 x 0.36 x 0.06 kg CH4/kg BOD) x 941,463,924.15 kg BOD/Year
= 5,478,312.48 kg CH4/year

CH_4 emissions from Treatment/Discharge Pathways classified as 'Collected'

e) CH_4 emissions from Sewer (collected and not treated)
= (0.273 x 0.11071 x 0.30 kg CH_4/kg BOD) x 293,258,584.17
= 2,659,501.12 kg CH_4/year

f) CH_4 emissions from Sewer (collected and anaerobic treatment)
= (0.273 x 0 x 0.48 kg CH_4/kg BOD) x 293,258,584.17 kg BOD/Year
= 0 kg CH_4/year

g) CH_4 emissions from Sewer (collected and Aerobic treatment, not well managed)
= (0.273 x 0.089 x 0.18 kg CH_4/kg BOD) x 293,258,584.17 kg BOD/Year
= 1,279,501.92 kg CH_4/year

Total Urban Domestic Wastewater CH_4 emissions (tonnes of CH_4)

= (20,268,575.16 + 2,329,001.87 + 2,430,089.14 + 5,478,312.48 + 2,659,501.12 + 0 + 1,279,501.92) kg CH_4/year /1000

= 34,446.9867 tonnes of CH_4

Total CH_4 emissions from Urban Domestic Wastewater in tonnes of CO_2e (2005)
= Emission in tonnes of CH_4 x GWP of CH_4
= 34,446.9867 x 21[158]
= 723,386.72 tonnes of CO_2e

B) Rural

- Ui =0.727[171]
- Ti,j for different treatment/discharge pathways from Table 90 above
- EFj for different treatment/discharge pathways from Table 90 above

CH_4 emissions from Treatment/Discharge Pathways classified as 'Uncollected'

a) CH_4 emissions from Septic tank (uncollected)
= (0.727 x 0.076 x 0.30 kg CH_4/kg BOD) x 1,167,019,164.93 kg BOD/Year
= 19,247,713.14 kg CH_4/year

b) CH_4 emissions from Latrine (uncollected)
= (0.727 x 0.064 x 0.06 kg CH_4/kg BOD) x 1,167,019,164.93 kg BOD/Year
= 3,257,731.90 kg CH_4/year

c) CH_4 emissions from Other (uncollected and not treated)
= (0.727 x 0.033 x 0.30 kg CH_4/kg BOD) x 1,167,019,164.93 kg BOD/Year
= 8,300,864.84 kg CH_4/year

d) CH_4 emissions from None
= (0.727 x 0.820 x 0.06 kg CH_4/kg BOD) x 1,167,019,164.93 kg BOD/Year
= 41,742,845.78 kg CH_4/year

171 Based on share of rural population reported for Andhra Pradesh for year 2001 as per Census of India statistics. http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf

CH_4 emissions from Treatment/Discharge Pathways classified as 'Collected'

a) CH_4 emissions from Sewer (collected and not treated)
= 0 kg CH_4/year[172]

Total Rural Domestic Wastewater CH_4 emissions (tonnes of CH_4)

= (19,247,713.14 + 3,257,731.90 + 8,300,864.84 + 0 + 41,742,845.78) CH_4/year /1000
= 72,549.16 tonnes of CH_4

Total CH_4 emissions from Rural Domestic Wastewater in tonnes of CO_2e (2005)
= Emission in tonnes of CH_4 x GWP of CH_4
= 72,549.16 x 21[158]
= 1,523,532.27 tonnes of CO_2e

Grand Total CH_4 emissions from Domestic Wastewater for Andhra Pradesh, year 2005
= Urban wastewater CH_4 emission + Rural wastewater CH_4 emission
= 723,386.72 + 1,523,532.27
= 2,246,918.99 tonnes of CO_2e

2) Sample Calculation for N2O Emission from Domestic Wastewater for Andhra Pradesh for Year 2005

$$N_2O\ Emissions = N_{EFFLUENT} * EF_{EFFLUENT} * 44/28$$ ------ *Equation 10*

Where,

N_2O emissions	= N_2O emissions in inventory year, kg N_2O/yr
$N_{EFFLUENT}$	= nitrogen in the effluent discharged to aquatic environments, kg N/yr
$EF_{EFFLUENT}$	= emission factor for N_2O emissions from discharged to wastewater, kg N_2O-N/kg N
44/28	is used for conversion of kg N_2O-N into kg N_2O.

$$N_{EFFLUENT} = (P * Protein * F_{NPR} * F_{NON\_CON} * F_{IND\_COM}) - N_{SLUDGE}$$ -------*Equation 11*

$N_{EFFLUENT}$	= total annual amount of nitrogen in the wastewater effluent, kg N/yr
P	= human population
Protein	= annual per capita protein consumption, kg/person/yr
F_{NPR}	= fraction of nitrogen in protein, kg N/kg protein (default value of 0.16 used as per 2006 IPCC guidelines for wastewater[173])
$F_{NON-CON}$	= factor for non-consumed protein added to the wastewater (default value of 1.4 used as per 2006 IPCC guidelines for wastewater[174])
$F_{IND-COM}$	= factor for industrial and commercial co-discharged protein into the sewer system, (default value of 1.25 used as per 2006 IPCC guidelines for wastewater[174])
N_{SLUDGE}	= nitrogen removed with sludge, kg N/yr (default value of 0 used as per 2006 IPCC guidelines for wastewater[174])

A) N_2O Emissions from Urban Population for Andhra Pradesh

Step 1: Calculation of Total Nitrogen in the wastewater effluent as per Equation 11

$N_{EFFLUENT}$ = (P x Protein x F_{NPR} x $F_{NON-CON}$ x $F_{IND-COM}$) - N_{SLUDGE}

[172] As reported in India's Second National Communication, rural wastewater that is collected and conveyed through sewer systems is also assumed to not undergo any treatment downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions.
[173] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Equation 6.8. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[174] As per 2006 IPCC Guidelines, Vol. 5, Chapter 6: Wastewater Treatment and Discharge, Section 6.3.1.3. Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

- Urban population, 2005 = 23,772,994 persons[175]
- Annual per capita protein consumption = 50.9 gm/person/day[176] x 365 day=18.58 kg/capita/day
- Fraction of Nitrogen in Protein (F_{NPR}) = 0.16
- Factor for Non-consumed protein added to the wastewater ($F_{NON-CON}$) = 1.40
- Factor for industrial and commercial co-discharged protein into the sewer system ($_{FIND-COM}$)= 1.25
- Nitrogen removed with sludge (N_{SLUDGE}) = 0

Total annual nitrogen in the wastewater effluent
= (23,772,994 persons x 18.58 kg/person/year x 0.16 x 1.4 x 1.25) – 0
=123,666,639.33 kg N/Year

Step 2: Calculation of N_2O emissions as per Equation 10

N_2O Emissions = $N_{EFFLUENT}$ x $EF_{EFFLUENT}$ x 44/28

- Total annual amount of nitrogen in the wastewater effluent ($N_{EFFLUENT}$) = 123,666,639.33 kg N/Year
- Emission Factor for N_2O emissions from discharged to wastewater ($EF_{EFFLUENT}$) = 0.005 kg N_2O-N/kg N
- 44/28 - The factor is the conversion of kg N_2O-N into kg N_2O = 1.57

Total N_2O Emission from Domestic Wastewater (Urban) (tonnes of N_2O)
= (123,666,639.33 kg N/Year x 0.005 kg N_2O-N/kg N x 1.57)/1000
= 971.67 tonnes of N_2O

Total N_2O Emission from Domestic Wastewater (Urban) (tonnes of CO_2e)
= Emission in tonnes of N_2O x GWP of N_2O
= 971.67 x 310[177]
= 301,216.60 tonnes CO_2e

B) N_2O emissions from Rural Population

Step 1: Calculation of Total Nitrogen in the wastewater effluent as per Equation 11

$N_{EFFLUENT}$ = (P x Protein x F_{NPR} x $_{FNON-CON}$ x $F_{IND-COM}$) - N_{SLUDGE}

- Rural population = 55,785,321 persons[178]
- Annual per capita protein consumption = 49.8 gm/person/year[176] x 365 days= 18.18 kg/person/year
- Fraction of Nitrogen in Protein (F_{NPR}) = 0.16
- Factor for Non-consumed protein added to the wastewater ($F_{NON-CON}$) = 1.40
- Factor for industrial and commercial co-discharged protein into the sewer system ($_{FIND-COM}$)= 1.25
- Nitrogen removed with sludge (N_{SLUDGE}) = 0

Total annual nitrogen in the wastewater effluent
= (55,785,321 persons x 18.18 kg/person/year x 0.16 x 1.4 x 1.25) – 0
= 283,922,738.35 kg N/Year

Step 2: Calculation of N_2O emissions as per Equation 10

N_2O Emissions = $N_{EFFLUENT}$ x $EF_{EFFLUENT}$ x 44/28

[175] Estimated based on urban population for year 2001 and 2011 and decadel growth rate from 2001-2011 as per Census of India data. Available at http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf
[176] Refer Table 52 in this note for further details
[177] 100-year GWP values specified for N2O is 310 as per the IPCC Second Assessment Report, 1996, Technical Summary, Table 4. Available at https://www.ipcc.ch/ipccreports/sar/wg_I/ipcc_sar_wg_I_full_report.pdf
[178] Estimated based on urban population for year 2001 and decadel growth rate from 2001-2011 as per Census of India data. Available at http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%20307.pdf

- Total annual amount of nitrogen in the wastewater effluent ($N_{EFFLUENT}$) = 283,922,738.35 kg N/Year kg N/Year
- Emission Factor for N_2O emissions from discharged to wastewater ($EF_{EFFLUENT}$) = 0.005 kg N_2O-N/kg N
- 44/28 - The factor is the conversion of kg N_2O-N into kg N_2O = 1.57

Total N_2O Emission from Domestic Wastewater (Rural) (tonnes of N_2O)
= (283,922,738.35 kg nitrogen x 0.005 N_2O-N/kg N x 1.57)/1000
= 2,230.82 tonnes of N_2O

Total Emission from Domestic Wastewater (Rural) (tonnes of CO_2e)
= Emission in tonnes of N_2O x GWP of N_2O
= 2,230.82x 310[177]
= 691,554.67 tonnes CO_2e

Grand Total N_2O emissions from Domestic Wastewater at the National-level, year 2005
= Urban wastewater N_2O emission + Rural wastewater N_2O emission
= 301,216.60 + 691,554.67
= 992,771.27 tonnes of CO_2e

1.22.3 Sample Emission Estimate Calculation for 4D1 Industrial Wastewater Treatment and Discharge for Karnataka for Year 2007

Total CH_4 Emissions from Industrial Waste Water

$$CH4\ Emissions = \sum_i (TOW_i - Si)EF_i - Ri$$ -------*Equation 12*

Where,
CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr
TOWi = total organically degradable material in wastewater from industry i in inventory year, kg COD/yr
i = industrial sector
Si = organic component removed as sludge in inventory year, kg COD/yr
EFi = emission factor for industry i, kg CH_4/kg COD for treatment/discharge pathway or system(s) used in inventory year
Ri = amount of CH_4 recovered in inventory year, kg CH_4/yr (default value of 0[179])

The equation for TOW in industrial wastewater is

$$TOWi = P_i * Wi * CODi$$ -------- *Equation 13*

Where,
TOWi = total organically degradable material in wastewater for industry i, kg COD/yr
i = industrial sector
Pi = total industrial product for industrial sector i, t/yr
Wi = wastewater generated, m^3 /t product
CODi= chemical oxygen demand, kg COD/m^3

Equation for CH_4 emission factor calculation for industry sector

$$EF_i = B_o * MCFj$$ -------- *Equation 14*

Where,
EFj = emission factor for each treatment/discharge pathway or system, kg CH_4/kg COD
j = each treatment/discharge pathway or system
Bo = maximum CH_4 producing capacity, kg CH_4/kg COD
MCFj = methane correction factor (fraction)

Step 1: Calculation of TOW as per Equation 13

[179] As per 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 6: Wastewater Treatment and Discharge and NEERI document on Inventorisation of Methane Emissions from Domestic & Key Industries Wastewater – Indian Network for Climate Change Assessment, 2010. Available at: http://www.moef.nic.in/sites/default/files/M%20Karthik.pdf

TOWi = Pi ∗ Wi ∗ CODi

- Pi: Production for industry sector i (2007), tonnes[180]
- Wi: Wastewater generated for industry sector i, m^3/tonne product[181]
- CODi: Chemical oxygen demand for industry sector i[182], kg COD/m^3

(a) Pulp & Paper
= $Pi_{\text{Pulp \& Paper}}$ x $Wi_{\text{Pulp \& Paper}}$ x $CODi_{\text{Pulp \& Paper}}$
= 505,880 tonnes x 79.83 m^3/tonne x 5.90 kg COD/m^3
= 238,269,418 kg COD/yr

(b) Fertilizer

Nitrogenous
= $Pi_{\text{Fertilizer}}$ x $Wi_{\text{Fertilizer}}$ x $CODi_{\text{Fertilizer}}$
= 218,925 tonnes x 8 m^3/tonne x 3 kg COD/m^3
= 5,254,200 kg COD/yr

Phosphatic
= $Pi_{\text{Fertilizer}}$ x $Wi_{\text{Fertilizer}}$ x $CODi_{\text{Fertilizer}}$
= 104,400 tonnes x 8 m^3/tonne x 3 kg COD/m^3
= 2,505,600 kg COD/yr

(c) Sugar
= Pi_{Sugar} x Wi_{Sugar} x $CODi_{\text{Sugar}}$
= 2,840,500 tonnes x 1 m^3/tonne x 2.50 kg COD/m^3
= 7,101,250 kg COD/yr

(d) Coffee
= Pi_{Coffee} x Wi_{Coffee} x $CODi_{\text{Coffee}}$
= 195,188 tonnes x 5 m^3/tonne x 9 kg COD/m^3
= 8,783,438 kg COD/yr

(e) Dairy
= Pi_{Dairy} x Wi_{Dairy} x $CODi_{\text{Dairy}}$
= 4,250,693 tonnes x 3 m^3/tonne x 2.24 kg COD/m^3
= 28,564,660 kg COD/yr

(f) Meat
= Pi_{Meat} x Wi_{Meat} x $CODi_{\text{Meat}}$
= 300 tonnes x 11.70 m^3/tonne x 4.10 kg COD/m^3
= 14,391 kg COD/yr

(g) Tannery
= Pi_{Tannery} x Wi_{Tannery} x $CODi_{\text{Tannery}}$
= 9,840 tonnes x 32 m^3/tonne x 3.10 Kg COD/m^3
= 976,172 kg COD/yr

(h) Iron & Steel
Pig Iron
= $Pi_{\text{Iron \& Steel}}$ x $Wi_{\text{Iron \& Steel}}$ x $CODi_{\text{Iron \& Steel}}$
= 985,170 tonnes x 60 m^3/tonne x 0.55 kg COD/m^3
= 32,510,625 kg COD/yr

Sponge Iron
= $Pi_{\text{Iron \& Steel}}$ x $Wi_{\text{Iron \& Steel}}$ x $CODi_{\text{Iron \& Steel}}$

[180] Refer Table 64 of this note for details of data sources for production data for all industry sectors
[181] Refer Table 65 of this note for details of sources of this parameter for all industry sectors
[182] Refer Table 66 of this note for details of sources of this parameter for all industry sectors

= 268,104 tonnes x 60 m^3/tonne x 0.55 kg COD/m^3
= 8,847,442 kg COD/yr

Finished Steel
= $Pi_{Iron\ \&\ Steel}$ x $Wi_{Iron\ \&\ Steel}$ x $CODi_{Iron\ \&\ Steel}$
= 12,268,682 tonnes x 60 m^3/tonne x 0.55 kg COD/m^3
= 404,866,510 kg COD/yr

(i) Petroleum
= $Pi_{Petroleum}$ x $Wi_{Petroleum}$ x $CODi_{Petroleum}$
= 12,219,140 tonnes x 0.7 m^3/tonne x 1.0 kg COD/m^3
= 8,553,398 kg COD/yr

(j) Rubber
= Pi_{Rubber} x Wi_{Rubber} x $CODi_{Rubber}$
= 42,987 tonnes x 26.3 m^3/tonne x 6.12 Kg COD/m^3
= 6,919,070 kg COD/yr

Step 2: Calculation of CH_4 Emission Factors for Industry Sectors based on Treatment/Discharge Pathway as per Equation 14

Table 91: Calculation of the Industry-wise Methane Correction Factor

INDUSTRY[183]	Bo (KG CH_4/KG COD)[184]	MCF[185]	$EF_I = B_O$ x MCF (KG CH_4/KG COD)
Iron & Steel	0.25	0	0
Fertilizer	0.25	0.2	0.05
Sugar	0.25	0.8	0.2
Coffee	0.25	0.8	0.2
Petroleum Refineries	0.25	0	0
Dairy	0.25	0.8	0.2
Meat	0.25	0.8	0.2
Pulp & Paper	0.25	0.8	0.2
Rubber	0.25	0	0
Tannery	0.25	0.2	0.05

Step 3: Calculation of CH_4 Emission as per the Equation 12

CH_4 Emissions (tonnes) = $\sum_i$ ((TOWi -Si) x EFi/1000) – Ri

(a) Pulp & Paper
- TOWi = 238,269,418 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 kg CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((238,269,418 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD)/1000 - 0
= 47,654 tonnes CH_4

(b) Fertilizer
Nitrogenous
- TOWi = 5,254,200 kg COD/yr
- Si = 0.35 kg COD/yr

[183] Refer Table 67 in this note for further details on the prevalent treatment technology and corresponding MCF values
[184] Bo value is taken as default value as per 2006 IPCC Guidelines, Vol. 5, Chapter 6.
Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf
[185] MCF value is taken based on treatment systems listed in 2006 IPCC Guidelines, Vol. 5, Chapter 6, Table 6.8 (see Table 63 in this note). Available at http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_6_Ch6_Wastewater.pdf

- EFi = 0.20 kg CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((5,254,200 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD)/1000 - 0
= 263 tonnes CH_4

Phosphatic

- TOWi = 2,505,600 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 kg CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((2,505,600 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD)/1000 - 0
= 125 tonnes CH_4

(c) Sugar

- TOWi = 7,101,250 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 kg CH_4/kg BOD
- Ri = 70%

CH_4 Emissions (tonnes) (without methane recovery)
= (TOWi – Si) x EFi / 1000
= ((7,101,250 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD)/1000
= 1420.25 tonnes CH_4

CH_4 Emission (tonnes) (post Methane recovery)
= CH_4 emission (without methane recovery) x (1 – Methane recovery fraction)
= 1420.25 x (1-0.70)
= 426.07 tonnes CH_4

(d) Coffee

- TOWi = 8,783,438 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 kg CH_4/kg BOD
- Ri = 0%

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((8,783,438 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg kg CH_4/kg BOD)/1000 - 0
= 1,757 tonnes CH_4

(e) Dairy

- TOWi = 28,564,660 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 kg CH_4/kg BOD
- Ri = 75%

CH_4 Emissions (tonnes) (without methane recovery)
= (TOWi – Si) x EFi / 1000
= ((28,564,660 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD)/1000
= 5,712.93 tonnes CH_4

CH_4 Emission (tonnes) (post Methane recovery)

= CH_4 emission (without methane recovery) x (1 – Methane recovery fraction)
= 5,712.93 x (1 – 0.75)
= 1,428 tonnes CH_4

(f) Meat

- TOWi = 14,391 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 kg CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((14,391 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD))/ 1000 - 0
= 2.88 tonnes CH_4

(g) Tannery

- TOWi = 976,172 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0.20 CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((976,172 kg COD/yr – 0.35 kg COD/yr) x 0.20 kg CH_4/kg BOD))/ 1000 - 0
= 48.81 tonnes CH_4

(h) Iron & Steel

Pig Iron

- TOWi = 32,510,625 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi =0 CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((32,510,625 kg COD/yr – 0.35 kg COD/yr) x 0 kg CH_4/kg BOD))/ 1000 - 0
= 0 tonnes CH_4

Sponge Iron

- TOWi = 8,847,442 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi =0 CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((8,847,442 kg COD/yr – 0.35 kg COD/yr) x 0 kg CH_4/kg BOD))/ 1000 - 0
= 0 tonnes CH_4

Finished Steel

- TOWi = 404,866,510 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi =0 CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((404,866,510 kg COD/yr – 0.35 kg COD/yr) x 0 kg CH_4/kg BOD))/ 1000 - 0

= 0 tonnes CH_4

(i) Petroleum

- TOWi = 8,553,398 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi= 0 CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((8,553,398 kg COD/yr – 0.35 kg COD/yr) x 0 kg CH_4/kg BOD))/ 1000 - 0
= 0 tonnes CH_4

(j) Rubber

- TOWi = 6,919,070 kg COD/yr
- Si = 0.35 kg COD/yr
- EFi = 0 CH_4/kg BOD
- Ri = 0

CH_4 Emissions (tonnes)
= ((TOWi – Si) x EFi / 1000) - Ri
= ((6,919,070 kg COD/yr – 0.35 kg COD/yr) x 0 kg CH_4/kg BOD))/ 1000 - 0
= 0 tonnes CH_4

Step 4: Total CH_4 emissions from industrial wastewater in tonnes of CO_2e

CH_4 Emission (tonnes CO_2e) = Emission in tonnes of CH_4 x GWP of CH_4[158]

(a) Pulp & Paper
= 47,654 x 21
= 1,000,732 tonnes CO_2e

(b) Fertilizer
Nitrogenous Fertilizer
= 263 x 21
= 5,517 tonnes CO_2e

Phosphatic Fertilizer
125.3 x 21
= 2,631 tonnes CO_2e

Fertilizer (Total)
= 8,147.8 tonnes CO_2e

(c) Sugar
= 426.07 x 21
= 8,947.57 tonnes CO_2e

(d) Coffee
= 1,757 x 21
= 36,890 tonnes CO_2e

(e) Dairy
= 1,428 x 21
= 29,993 tonnes CO_2e

(f) Meat
= 2.88 x 21
= 60.4 tonnes CO_2e

(g) Tannery

= 48.81 x 21

= 1,024.98 tonnes CO_2e

(h) Iron & Steel

= 0 x 21

= 0 tonnes CO_2e

(i) Petroleum

= 0 x 21

= 0 tonnes CO_2e

(j) Rubber

= 0 x 21

= 0 tonnes CO_2e

Total CH_4 emissions from industrial wastewater in tonnes of CO_2e (2007)

= Sum of CH_4 emissions from all industrial sectors (i.e. Pulp & Paper + Fertilizer + Sugar + Coffee + Dairy + Beer + Meat + Soft Drink + Tannery + Iron & Steel + Petroleum + Rubber)

= 1,000,732+ 8,147.8 + 8,947.57+36,890 +29,993 + 60.4 + 1,024.98 + 0 + 0 + 0

= 1,085,795.55 tonnes of CO_2e