INDIA'S GHG INVENTORY PROCESS

An analysis of sectoral emission profile, data sources, institutional framework and key challenges

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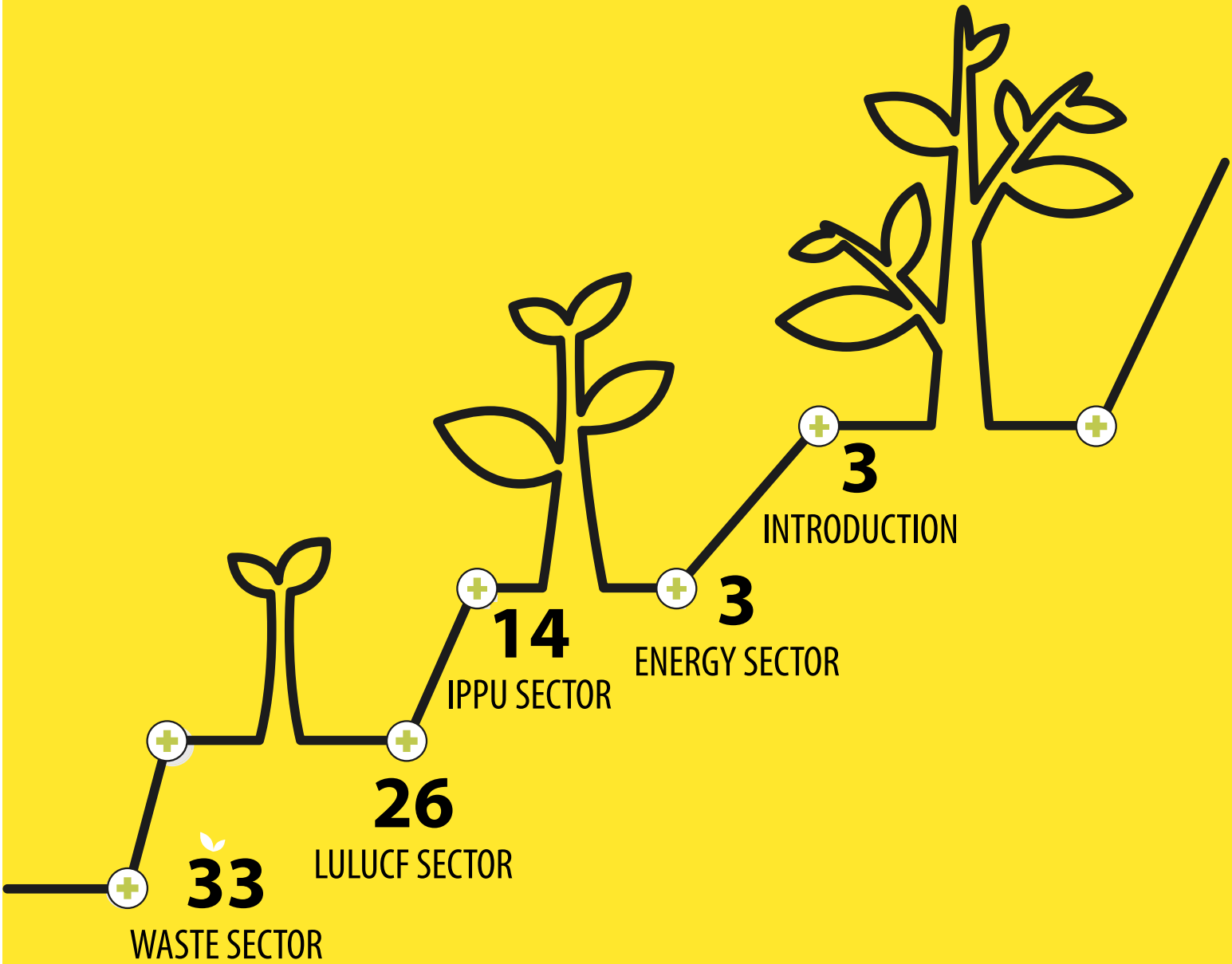
TABLE OF CONTENTS



ABBREVIATIONS

ASI	Annual Survey of Industries
BEE	Bureau of Energy Efficiency
BOD	Biochemical Oxygen Demand
BUR	Biennial Update Report
CEA	Central Electricity Authority
CH_4	Methane
CMA	Cement Manufacturers' Association
CO_2	Carbon Dioxide
CO_2 eq.	Carbon Dioxide Equivalent
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CRRI	Central Road Research Institute
CS	Country-specific Emission Factor
D	Default Emission Factor
DGMS	Directorate General of Mines Safety
DOC	Degradable Organic Carbon
DOCF	Degradable Organic Carbon Fraction
EAF	Electric Arc Furnace
EDC	1-Ethyl-3-(3-dimethylaminopropyl)carbodiimide
EF	Emission Factor
Gg	Gigagram
GPG	Good Practice Guidance
HCFC-22	Hydrochlorofluorocarbon
IFAPA	Indian Ferro Alloy Producers' Association
INC	Initial National Communication on Climate Change
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Processes and Product Use (IPPU)
ISRO	Indian Space Research Organisation
LULUCF	Land Use, Land-Use Change and Forestry
MCL	Mahanadi Coalfields Limited
MoPNG	Ministry of Petroleum and Natural Gas
Mt	Million tonnes

N_2O	Nitrous oxide
NATCOM	National Communication on Climate Change
NCV	Net Calorific Value
NEERI	National Environmental Engineering Research Institute
NSSO	National Sample Survey Office
PCC	Pollution Control Committee
SAIL	Steel Authority of India Limited
SF_6	Sulfur he xafluoride
SPCB	State Pollution Control Board
ULB	Urban Local Body
UNFCCC	United Nations Framework for Climate Change Convention
VCM	Vinyl Chloride Monomer

INTRODUCTION

India signed the United Nations Framework for Climate Change Convention (UNFCCC) on June 10, 1992, and ratified it on November 1, 1993. The Convention aims at stabilizing the greenhouse gas concentrations in the atmosphere at safer levels that would prevent dangerous anthropogenic interference with the climate system. The Ministry of Environment, Forest and Climate Change (MoEF&CC), Government of India, is the nodal agency for climate change issues and is responsible for managing climate change related-programmes and reporting information pursuant to Article 4.1 of the Convention. Adhering to the requirement of the Convention, India has submitted three national communications to the UNFCCC as follows:

Report	Submission (Month, Year)	Inventory Year
Initial National Communication (NC 1)	June, 2004	1994
Second National Communication (NC 2)	May, 2012	2000
First Biennial Update Report (BUR 1)	January, 2016	2010

During the initial National Communication on Climate Change (NC 1), a project towards preparation of India's National Communication on Climate Change (NATCOM) to the UNFCCC was initiated under the Global Environment Fund (GEF) under its enabling activities programme through the United Nations Development Programme (UNDP), India. A National Steering Committee pooling multilevel stakeholders and experts was formed and headed by Secretary, MoEF&CC, to oversee the implementation of the project. The NATCOM Cell was working in the collection of primary and secondary data relating to anthropogenic emissions of greenhouse gases (GHGs) from various sources and their removal by sinks. About 15 institutes from government, academic, association, and research organizations were involved in the process and development of the first National Communication (NC 1). The number of institutions involved in the subsequent submissions varied from 31 during second National Communication (NC 2) to 17 during first Biennial Update Report (BUR 1).

The five major sectors accounted for GHG inventory are (i) Energy, (ii) Agriculture, (iii) Industrial Process, (iv) Waste, and (v) LULUCF (land use, land-use change, and forestry). Figure 2depicts how the 'Energy' sector stands out as the largest emitter of greenhouse gas emissions during the (three) reporting period. This was followed by agriculture, industrial processes, and waste sector. The NATCOM cell in its initial report had accounted three major GHGs namely (i) carbon dioxide (CO2), (ii) methane (CH4), (iii) nitrous oxide (N20). In the subsequent reports (NATCOM 2 & First BUR), five more GHGs namely, (i) HFC-134a, (ii) HFC 23, (iii) tetrafluoromethane (CF4), (iv) hexafluoroethane (C2F6), (v) sulfer hexafluoride (SF6), were accounted for the final estimation of

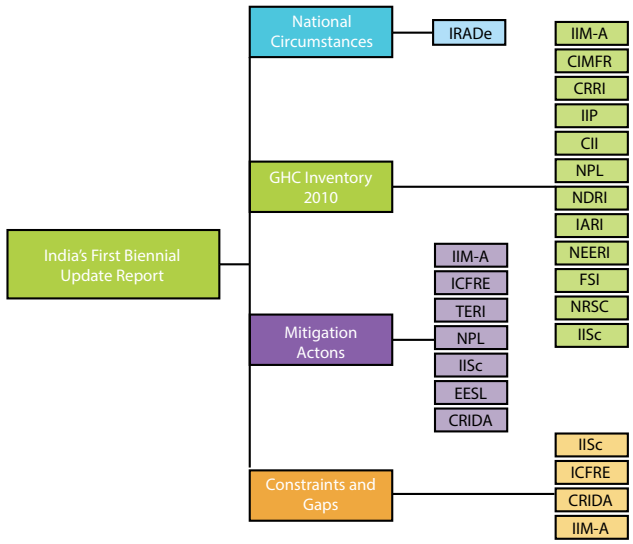


Figure 1: Institutional arrangement under the first Biennial Update Report

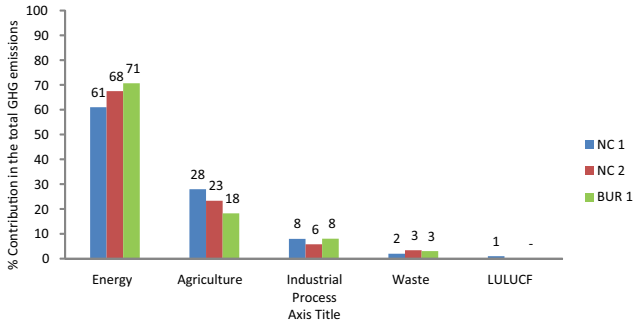


Figure 2: Comparative analysis of sectoral GHG emission contribution during NC1, NC2 and BUR1

national GHG inventories. Carbon dioxide continued to be the top contributor of national GHG inventory, during all three stages of GHG reporting.

The document elucidates on the key insights of the sectorial analysis of the five sectors responsible for the country's total GHG emissions. The publication presents a comprehensive background on the key challenges faced by different sectors and an overview of various organizations/institutions responsible for the improvement and monitoring of emission levels across these sectors. The document also enlightens the measures/ programmes planned by the government in bringing down the emissions and improving the efficiency levels. The document explicates on key information pertaining to the three key reports---Initial National Communication (NATCOM 1) 1994, Second National Communication (NATCOM 2) 2000 & 2007, and Biennial Update Report (BUR) 2010.

ENERGY SECTOR

ENERGY SECTOR

This study presents a brief summary of India's energy inventory. The first energy inventory was submitted to the United Nations Framework for Climate Change Convention (UNFCCC) in 1994. Since then, three more inventories have been prepared for the years 2000, 2007, and 2010 and submitted to the UNFCCC. The purpose of this study is to compare and remark on the progress in methodology and inventory preparation between these inventories and to outline the challenges that still need to be addressed by the inventory makers in the coming years.

Emissions from the sector

Report	Inventory year	Key sub-sectors	GHG emissions or removals (CO_2 equivalent in Gg)
Initial National Communication (NATCOM 1)	1994	All Energy - Fuel combustion - Stationary - Mobile - Fugitive fuel emissions	All energy – 743,820
Second National Communication (NATCOM 2)	2000	1A. Fossil fuel combustion and biomass 1A1: Energy industries—electricity generation, petroleum refining, and solid fuel manufacturing 1A2: Manufacturing industries—cement, iron and steel, food and beverage, textile/leather, non-specific industries, non-ferrous metals, chemicals, pulp and paper, non-metallic minerals, mining and quarrying 1A3: Transport—road, railways, aviation, and navigation 1A4: Other sectors—residential, institutional/ commercial, agriculture/fisheries 1B. Fugitive emissions 1B1: Coal mining 1B2: Oil and natural gas	1A1 – 543,749.85 1A2 – 229,079.90 1A3 – 98,104.12 1A4 – 127,686.10 1B – 12,298.74 TOTAL - 1,027,016.48
First Biennial Update Report (BUR -I)	2010	Same as above	1,510,120.76

In 2000, India emitted 1,523,777 Gg CO_2eq. (1,523.78 Mt of CO_2eq.) from the energy sector, industrial processes and product use, agriculture, and waste management sectors, of which the energy sector emissions were 1,027,016 Gg of CO_2 eq. Whereas in 1994, about 12,28,540 Gg CO_2 eq. was emitted overall, with the energy sector's share amounting to 7,43,820 Gg CO_2 eq. By 2010, the total contribution of the energy sector rose to 1,510,120 Gg of CO_2 eq.

Methodology

Report	Inventory year	Tier adopted	Emission factors
Initial National Communication (NATCOM 1)	1994	T1 for all energy	D
Second National Communication (NATCOM 2)	2000	T1 and T2 for CO_2 T1 for CH_4 T1 for N_2O	CS and D for CO_2 D for CH_4 and N_2O
First Biennial Update Report (BUR-I)	2010	Same as above	Same as above

The Intergovernmental Panel on Climate Change's (IPCC) 1996 Revised Guidelines (IPCC, 1996) were adopted for estimating the emissions from the above-mentioned categories. In 1BUR, some elements have also been adopted from the 2006 IPCC guidelines for GHG emissions estimation. Activity data in terms of consumption of various fossil fuels has been taken from the reports of the relevant ministries of the government, which keep track of the activities. The emission factors of fossil fuels, such as coal, oil, and natural gas, are the most important considerations in estimating the GHG emissions from the combustion of these fuels. In India, coal as a fuel constitutes more than 50% of the total fossil fuel mix, used for energy-related activities. Country-specific CO_2 emission factors derived on the basis of the net calorific values[1] (NCVs) of the different types of coal produced in the country, namely, coking, non-coking, and lignite have been used in this assessment.

The energy sector accounts for GHG emissions from fossil fuel combustion and fugitive emissions from the handling of fossil fuel. Fossil fuel combustion emissions form more than 90% of the total emissions from the energy sector. Amongst all the fossil fuels that are combusted, coal is the dominating fuel. Since the completion of the Initial National Communication (INC), continuous efforts have been made to update the NCVs, and thus the CO_2 emission factors of the different types of coal used in India. The integrated NCVs of the samples taken in the latest years are considered, and hence the CO_2 emission factors are within 5% of the values estimated during the INC. The CO_2 emission factors of coking coal, non-coking coal, and lignite used in the current estimates are 93.61 t/TJ, 95.81 t/TJ, and 106.51 t/ TJ, respectively. Details of the measurements carried out can be found in the INC (NATCOM, 2004, p. 37).

Key institutions

Report	Institutions
Initial National Communication (NATCOM 1)	Indian Institute of Management Ahmedabad Central Mining Research Institute Central Fuel Research Institute Central Road Research Institute Development Alternatives Group Cement Manufacturers' Association
Second National Communication (NATCOM 2)	Central Institute of Mining and Fuel Research Central Road Research Institute India Institute of Petroleum Petroleum Planning and Analysis Cell Jadavpur University The Energy and Resources Institute
First Biennial Update Report (BUR-I)	Indian Institute of Management Ahmedabad Central Institute of Mining and Fuel Research Central Road Research Institute India Institute of Petroleum

1 Source: India's Initial National Communication to UNFCCC, available at: https://unfccc.int/resource/docs/natc/indnc1.pdf; last accessed on August 29, 2018.

Data sources

The data sources used for the inventory are given in the following table along with the data collection institute, time series, frequency of collection, and accessibility.

Report	Sub-sector	Activity data parameters	Data sources	Frequency	Availability/ accessibility	Time series	Emission factors
NATCOM 1	All energy 1. Fuel combustion	Fuel combustion by type	ASI	Static	In the public domain (purchase)	1994	Default emissions factors used
	2. Fugitive fuel emissions	1. Amount of raw coal produced by surface mine (as fugitive emissions are produced during mining, whereas seam gas emissions are produced in the post-mining operation)	DGMS, Ministry of Coal, CPCB	Static	In the public domain	1994	Default emissions factors used
		2. Amount of coal burnt due to uncontrolled combustion	DGMS, Ministry of Coal, CPCB	Static	In the public domain	1994	Default emissions factors used
NATCOM 2	Energy industries		ASI				
	Electricity generation	Fuel consumption by type	CEA , ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Solid fuel manufacturing	Fuel consumption by type	ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Manufacturing industries		ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	
	Cement	Fuel consumption by type (for combustion activity)	Cement Manufacturers Association	According to the association	On purchase from the association	2000, 2007	CS
	Iron and steel	Fuel consumption by type (for combustion activity)	Joint Plant Committee (Ministry of Steel), ASI and	Annual	On purchase	2000,2007	CS
	Non Ferrous Metals	Fuel consumption by type (for combustion activity)	BEE	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Chemicals (soda ash, fertilizer, etc.)	Fuel consumption by type	Fertilizer Association of India	As per the association	On purchase	2000, 2007	Default
			Chlor-Alkali Manufacturers Association	As per the association	Reports on purchase	2000, 2007	If coal, CS If natural gas, default
	Pulp and paper	Fuel consumption by type	BEE, ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	Default

Report	Sub-sector	Activity data parameters	Data sources	Frequency	Availability/ accessibility	Time series	Emission factors
	Food and beverage	Fuel consumption by type	ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Non-metallic minerals	Fuel consumption by type	ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Mining and quarrying	Fuel consumption by type	ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Textile/leather	Fuel consumption by type	ASI	Annual	In the public domain (ASI, on purchase)	2000, 2007	CS
	Non-specific industries	Fuel consumption by type					
	Transport		CRRI	Annual	In the Public domain	2000, 2007	
	Road	Fuel consumption by type					
	Civil aviation	Fuel consumption by type					
	Railways	Fuel consumption by type	Indian Railways statistical publications				
	Navigation						
	Other sectors		NSSO	Annual	In the public domain	2000, 2007	
	Commercial/ institutional	Fuel consumption by type					CS
	Residential	Fuel consumption by type					Default
	Fugitive emissions						Default
			DGMS, Ministry of Coal, CPCB	Annual	In the public domain	2000, 2007	
	Above-ground mining	1. Amount of raw coal produced by surface mine (during mining – fugitive emissions and post-mining seam gas emissions) 2. Amount of coal burnt due to uncontrolled combustion	DGMS, Ministry of Coal, CPCB	Annual	In the public domain	2000, 2007	Default
	Underground mining	1. Amount of raw coal produced by UG Mine (during mining – fugitive emissions and post-mining seam gas emissions). 2. Number of abandoned UG mines, year of closure, % of gassy mines, methane recovered (if any)	MCL Reports, CPCB	Annual	In the public domain	2000, 2007	Default
	Oil and gas						

Report	Sub-sector	Activity data parameters	Data sources	Frequency	Availability/ accessibility	Time series	Emission factors
	Oil	Total crude oil refined in each refinery (+ IPCC default CH4 EF for fugitive emissions, includes leakages + flaring)	MoPNG, ASI	Annual	In the public domain	2000, 2007	Default
BUR -I	Same as above	Same as above	Same as above	Same as above	Same as above	2010	Same as above

Challenges

As per the previous national communications, the energy sector was responsible for 61% and 67% of the total GHG emissions during the years 1994 and 2000, respectively and was also the highest contributor to GHG emissions. This sector is primarily driven by fossil fuel combustion, namely, stationary fossil fuel combustion in electricity production, iron and steel, cement, chemicals, food and beverage, etc., and mobile combustion in the transport sector. Given this, it is imperative that the GHG inventory of the sector be developed in a robust manner keeping in mind the accuracy and frequency of activity data generation, employing country-specific emission factors wherever possible, the optimum level of data disaggregation, and quality controls and checks wherever possible. These measures will not only help in developing an automated inventory management system but will also help in moving up the tier ladder as far as the methodology is concerned.

It may be noted that the energy sector inventory is predominantly based on the Tier 1[2] and Tier 2[3] approach for CO_2 emissions and the Tier 1 approach for CH_4 and N_2O emissions. This implies employing total plant-wise fuel consumption for activity data and country-specific or IPCC default fuel emission factors. Thus, going forward, the first key challenge is to increase the sectoral coverage and data collection in all the fuel-consuming industries.

Secondly, there is uncertainty in GHG emissions even in the organized sectors, which are major GHG emitters. The uncertainty is particularly high in sectors, such as residential energy, agricultural energy, cement, iron and steel, and food and beverage. The key challenge here is to improve the accuracy of activity data generation in these industries.

Thirdly, to jump the tier ladder and eventually develop Tier 3[4] based inventories for CO_2, CH_4, and N_2O gases, it is imperative to inventorize the types of combustion technologies that are being used in each plant. Since the CH_4 and N_2O emission factors depend not only on the fuel being used but also the boiler technology as well as the operating conditions, it is worthwhile to undertake studies on the fuel-boiler-configuration combination being employed in each plant. In addition, while the Annual Survey of Industries categorizes the plant-wise fuel consumption for each fuel type, it is necessary to obtain fuel consumption in each of the combustion equipment to get a more disaggregated picture of the total GHG emissions.

The second NATCOM has seen some significant improvements in the GHG inventory process with respect to the initial submission. In the energy sector, these included, amongst other aspects, developing country-specific emission factors for some of the fuels (35% of the source categories used country-specific EFs) and developing CH_4 emission factors for fugitive emissions from coal mining.

2 Tier I approach employs the gain-loss method described in the IPCC Guidelines and the default emission factors and other parameters provided by the IPCC.

3 Tier II generally uses the same methodological approach as Tier I but applies emission factors and other parameters which are specific to the country.

4 At Tier III, higher-order methods include models and can utilize plot data provided by NFIs tailored to address national circumstances.

Industrial Processes and Product Use (IPPU) Sector

This study presents a brief summary of the IPPU inventory in India. The first IPPU inventory was submitted to the UNFCCC in 1994. Since then, three more inventories for the years 2000, 2007, and 2010 have been prepared and submitted to the UNFCCC. The purpose of this study is to compare and remark on the progress in methodology and inventory preparation between these inventories and to outline the challenges that still need to be addressed by the inventory makers in the coming years.

Emissions from the sector

In 1994, the IPPU sector emitted a total of 102,710 Gg of CO_2 eq. amounting to 8% of the total emissions. Within the IPPU sector, emissions from sub-sector, iron and steel production, contributed 43.2% (44,445 Gg of CO_2 eq.) and the cement production came second with 29.9% (30,767 Gg of CO_2 eq.) of the total IPPU emissions.

Report	Inventory year	Key sub-sectors	GHG emissions or removals (CO_2 equivalent in Gg)
Initial National Communication (NATCOM 1)	1994	**Industrial processes** Cement production Lime production Lime stone and dolomite use Soda ash use Ammonia production Carbide production Iron and steel production Ferro alloys production Aluminium production	102,710 30,767 1,901 5,751 273 14,395 302 44,445 1,295 749
Second National Communication (NATCOM 2)	2000	**IPPU** *A. Mineral products* 1. Cement production 2. Lime 3. Limestone and dolomite use 4. Soda ash production and use 5. Glass *B. Chemicals* 1. Ammonia production 2. Nitric acid production 3. Carbide production 4. Titanium dioxide 5. Methanol production 6. Ethylene production 7. EDC and VCM production 8. Ethylene oxide production 9. Acrylonitrile production 10. Carbon black production 11. Caprolactam	**88,608.07** *A. Minerals 53,558.17* 1. 44,056.00 2. 2,921.00 3. 5,961.68 4. 463.94 5. 155.54 *B. Chemicals 19,866.6* 1. 11,067.30 2. 3,643.83 3. 102.72 4. 43.75 5. 246.41 6. 3,410.15 7. 233.23 8. 53.53 9. 27.08 10. 713.98 11. 324.69

Report	Inventory year	Key sub-sectors	GHG emissions or removals (CO_2 equivalent in Gg)
		C. Metal production 1. Iron and steel production 2. Ferro alloys production 3. Aluminium production 4. Lead production 5. Zinc production 6. Magnesium production *D. Other production* 1.Production of halocarbons 2. Consumption of SF6 *E. Non-energy product use* 1. Lubricant 2. Paraffin wax	*C. 9,229.62* 1. NA 2. 1,468.65 3. 7,480.38 4. 23.22 5. 6.42 6. 250.95 *D. 5,259.10* 1. 5,199.35 2. 59.75 *E. 694.14* 1. 672.91 2. 21.23
First Biennial Update Report (BUR-I)	2010	**IPPU** *A. Mineral products* 1. Cement production 2. Lime 3. Limestone and dolomite use 4. Ceramics 5. Glass *B. Chemicals* 1. Ammonia production 2. Nitric acid production 3. Carbide production 4. Titanium dioxide 5. Methanol production 6. Ethylene production 7. EDC and VCM production 8. Ethylene oxide production 9. Acrylonitrile production 10. Carbon black production 11. Caprolactam *C. Metal production* 1. Iron and steel production 2. Ferro alloys production 3. Aluminum production 4. Lead production 5. Zinc production 6. Magnesium production *D. Other production* 1. Production of halocarbons 2. Consumption of SF6 *E. Non-energy product use* 1. Lubricant 2. Paraffin wax	**171,502** *A. 104,545* 1. 83,851 2. 20,132 3. 0 4. 7.5 5. 553.99 *B. 22,470.76* 1. 12,602.12 2. 2170.29 3. 42.93 4. 87.73 5. 261.26 6. 5,220.14 7. 286.26 8. 145.46 9. 30.37 10. 557.96 11. 343.17 *C. 26,171.33* 1. Included elsewhere- under Source Category- Energy 2. 3,716.75 3. 22,291.68 4. 28.92 5. 33.61 6. 100.38 *D. 16,712.28* 1. 16,712.28 2. NE *E. 1,603.27* 1. 1,448.35 2. 154.92

The IPPU sector emitted 88,608.07 Gg of CO_2 eq. of GHGs in 2000, out of which the minerals and chemical sub-sectors contributed the most with **53,558.17** Gg and **19,866.6** Gg CO_2 eq., respectively. The emissions in 2000 were 171,502.87 Gg CO_2 eq. with the mineral industries contributing a major portion with 104,545 Gg CO_2 eq. This increased amount was due to an increase in cement production. The emissions increased to 171,502.87 Gg CO_2 eq. by 2010 (BUR).

Methodology

For estimating the GHG emissions from the IPPU sector, the IPCC, 1996, Revised Guidelines have been used for each of the categories mentioned above.

The activity data for the various industries are sourced from national statistical organizations, listed companies, the annual reports of ministries of the Government of India, research organizations, trade magazines, and other publications of the sector associations. In the INC, Tier 2 methodology was used for iron and steel and cement, whereas Tier 1 was used for the rest of the sub-sectors. Tier 2 was used for cement in the SNC, however, Tier 2 was used for others, including iron and steel. This remained the same for the BUR. In the INC, for emission factors, country-specific emission factors were developed for emissions from cement production with clinker data from plants. Similarly, country-specific emission factors were used for iron and steel. Default IPCC emission factors were used for other sub-sectors. By the SNC, country-specific emission factors were developed for cement, nitric acid production and aluminium production, whereas default emission factors were used for other sub-sectors. These parameters remained the same for the BUR.

Key institutions

Report	Inventory year	Tier adopted	Emission factors
Initial National Communication (NATCOM 1)	1994	T II for iron and steel and cement T I for others	CS for cement CS for iron and steel D for others
Second National Communication (NATCOM 2)	2000	T II for cement production CO_2, CH_4, and N_2O T I for others	CS, D for cement, nitric acid production and aluminium production D for others
First Biennial Update Report (BUR-I)	2010	T I and II for minerals and chemicals T I and II for CO_2 emissions in metal production T I for others	CS and D for minerals and Chemicals CS and D for CO_2 emissions in metal production D for others

The IPPU inventory encompassed more subsectors from the INC to the SNC. As a result of this, the number of institutions involved in inventory preparation increased from the first inventory to the second inventory. For example, to accommodate inclusion of land use change, remote sensing institutions were involved in the inventory process. The following table summarizes the institutions involved in the INC and in the SNC. The first NATCOM included three research institutions and one government agency, whereas the second NATCOM and the first BUR included two government agencies and twelve research institutions (including universities).

Report	Institutions
Initial National Communication (NATCOM 1)	Indian Institute of Management Ahmedabad Central Mining Research Institute Central Fuel Research Institute Central Road Research Institute Development Alternatives Group Cement Manufacturers' Association
Second National Communication (NATCOM 2)	Central Institute of Mining and Fuel Research Central Road Research Institute India Institute of Petroleum Petroleum Planning and Analysis Cell Jadavpur University The Energy and Resources Institute
First Biennial Update Report (BUR-I)	Confederation of Indian Industry National Environmental Engineering Research Institute Indian Institute of Management Ahmedabad

Data sources

The data sources used for the inventory are given in the following table along with the data collection institute, time series, frequency of the collection, and accessibility.

Report	Sub-sector	Activity data parameters	Data sources	Frequency	Availability/ accessibility	Time series	Emission factors
NATCOM 1	1. Cement production	Clinker production/ cement production	ASI, CMA	The ASI provides this information on an annual basis; the CMA provides this information in its annual report.	Both on purchase	1994 No time series	CS
	2. Lime production	Amount of limestone input	Indian Mineral year Book 1995	Release based	In the public domain	1994	Default
	3. Lime stone and dolomite use	Quantity of limestone and dolomite used	Indian Mineral year Book 1982-2001	Release based	In the public domain	1994	Default
	4. Soda ash use	N/A	Uncertain	Very unreliable source	Scarce availability	1994	Default
	5. Ammonia production	N/A	Uncertain	Uncertain	Uncertain	1994	Default
	6. Carbide production	Amount of CaCO3 and petrol coke for calcium carbide and the amount of quartz for silicon carbide	N/A	N/A	N/A	1994	Default
	7. Iron and steel production	Coal consumption for reduction, steel production from pig iron, and graphite use in electric arc furnace (EAF)	SAIL; Contacting different EAF across country	SAIL - Annual; Available with EAF units/ plants	In the public domain	1994	CS
	8. Ferro alloys production	Coal consumption as the reducing agent or ferro alloy production	SAIL (2000) IFAPA (2000)	Annual	In the public domain	1994	Default
	9.Aluminium production	Quantity of aluminium produced	MoSM (1988–1999)	Annual	In the public domain	1994	Default
NATCOM 2	2 IPPU A. Mineral products						
	1. Cement production	Clinker production/ cement production	ASI, CMA	The ASI provides this information on an annual basis; the CMA provides this information in its annual report.	Both on purchase	2000, 2007	CS
	2. Lime	Amount of limestone input	Indian Mineral Yearbook 1995	Release based	In the public domain	2000, 2007	Default
	3. Limestone and dolomite use	Quantity of limestone and dolomite used	Indian Mineral Yearbook 1982–2001	Release based	In the public domain	2000, 2007	Default

	4. Soda ash production and use	N/A	N/A	N/A	N/A	2000, 2007	Default
	5. Glass	N/A	N/A	N/A	N/A	2000, 2007	Default
	B. Chemicals						
	1. Ammonia production	Urea production	ASI	Annual	In the public domain (on purchase)	2000, 2007	Default
	2. Nitric acid production	Amount of nitric acid produced	Fertilizer Association of India	Annual	In the public domain	2000, 2007	Default
	3. Carbide production	N/A	N/A	N/A	N/A	2000, 2007	Default
	4. Titanium dioxide	N/A	N/A	N/A	N/A	2000, 2007	Default
	5. Methanol production	N/A	N/A	N/A	N/A	2000, 2007	Default
	6. Ethylene production	N/A	N/A	N/A	N/A	2000, 2007	Default
	7. EDC and VCM production	N/A	N/A	N/A	N/A	2000, 2007	Default
	8. Ethylene oxide production	N/A	N/A	N/A	N/A	2000, 2007	Default
	9. Acrylonitrile production	N/A	N/A	N/A	N/A	2000, 2007	Default
	10. Carbon black production	N/A	N/A	N/A	N/A	2000, 2007	Default
	11. Caprolactam C. Metal production	N/A	N/A	N/A	N/A	2000, 2007	Default
	1. Iron and steel production	Coal consumption for reduction, steel production from pig iron, and graphite use in Electric Arc furnace (EAF)	ASI, SAIL	ASI – Annual SAIL – Annual Available with EAF units/ plants	In the public domain	2000, 2007	Default
	2. Ferro alloys production	Coal consumption as the reducing agent or ferro alloy production	ASI	Annual	In the public domain	2000, 2007	Default
	3. Aluminum production	Quantity of Aluminium produced	ASI	Annual	In the public domain	2000, 2007	Default
	4. Lead production	N/A	N/A	N/A	N/A	2000, 2007	Default
	5. Zinc production	N/A	N/A	N/A	N/A	2000, 2007	Default

	6. Magnesium production	N/A	N/A	N/A	N/A	2000, 2007	Default
	D. Other production						
	Production of halocarbons	By product of HCFC-22. HCFC-22	N/A	N/A	N/A	2000, 2007	Default
	Consumption of SF6	N/A	N/A	N/A	N/A	2000, 2007	Default
	E. Non-energy product use						
	1. Lubricant	N/A	N/A	N/A	N/A	2000, 2007	Default
	2. Paraffin wax	N/A	N/A	N/A	N/A	2000, 2007	Default
BUR -I	Same as above	Same as above	Same as above	Same as above	Same as above	2010	Same as above

Challenges

In the IPPU sector, a majority of industries were small, unorganized, and scattered and, therefore, the biggest challenge was to obtain a reliable dataset. Except for cement, iron and steel, and aluminium, inventorization of other sub-sectors required collection from individual plants and listed companies. Tier 2 methodologies and country-specific emission factors were used for cement and iron, and s Steel and Tier 1 methodology and IPCC default emission factors were used for all the other sub-sectors. However, Tier 1 methodology was used predominantly for CH_4 and N_2O emissions in all the sub-sectors. Therefore, one of the challenges is to create mechanisms for inventorization of industries within each sub-sector for fast and efficient data collection.

Upgrading to Tier 2 for cement, for instance, suggests that a detailed assessment was undertaken to arrive at a higher resolution of activity data, including activity data on clinker production. Additionally, the derivation of country-specific emissions factor was also carried out. The challenge is to develop mechanisms to collect activity data with higher detail and country-specific emission factors for the additional sub-sectors to felicitate accurate inventorization.

Specifically, iron and steel, one of the top emitters, still has no distinction between coal consumed for energy use in plant and coking coal used as a reducing agent in the blast furnace for iron (chemical process; to be covered under the IPPU). In the SNC, iron and steel emissions have been reported within the energy sector. This is an issue with a resolution. One of the ways to solve this problem can come from increasing activity data resolution wherein a detailed technological study of processes within the plant will also be beneficial in determining the amount of coal used for different processes. This could very well be extended in the case of cement and aluminium.

Land Use, Land-Use Change and Forestry (LULUCF)

This study presents a brief summary of the LULUCF inventory for India. The first LULUCF inventory was submitted to the UNFCCC in 1994. Since then, three more inventories have been prepared for the years 2000, 2007, and 2010 and have been submitted to the UNFCCC. The purpose of this study is to compare and remark on the progress in methodology and inventory preparation between these inventories and to outline the challenges that still need to be addressed by inventory makers in the coming years.

Emissions from the sector

In 2000, India emitted 1,523,777.44 Gg CO_2 eq. (1,523.78 Mt of CO_2 eq.) from the energy, industrial processes and product use, agriculture, and waste management sectors. The LULUCF sector was a net sink in 2000. With the inclusion of the LULUCF, the net emission in 2000 was 1,301,209.39 Gg of CO_2 eq. (1,301.21Mt of CO_2 eq.). The emission from the LULUCF formed 17.1% of the total GHG emissions for India.

Report	Inventory year	Key sub-sectors	GHG emissions or removals (CO_2 equivalent in Gg)
Initial National Communication (NATCOM 1)	1994	Change in the forest land; Forest and grassland conversion	-14,252 17,987
Second National Communication (NATCOM 2)	2000	Forest land remaining forest land; Land converted to forestland; Cropland remaining cropland	-66,228.80 -137,475 -15,318.44
First Biennial Update Report (BUR-I)	2010	Forest land remaining forest land; Cropland remaining cropland	-200,036.31 -110,757.17

The LULUCF is a key component of the GHG inventory. It involves estimation of carbon stock changes, CO_2 emissions and removals, and non-CO_2 GHG emissions. India used the Revised 1996 Guidelines for the LULUCF sector for the preparation of GHG inventory information for its INC. The inventory showed that the LULUCF sector was a marginal source of GHG emissions (14.2 Mt of CO_2 eq.) for the inventory year 1994. The revised 1996 IPCC Guideline has many limitations, and the inventory estimation is incomplete since all the land categories are not included and the uncertainty of GHG inventory is estimated to be high. Thus the IPCC developed GPG for the land use sectors, covering all the land use categories for the inventory. The developing countries (non-Annex I countries) are encouraged to use the IPCC-GPG 2003 approach in preparing the GHG inventory for the LULUCF sector. In this assessment, the national GHG inventory from India's LULUCF sector for the year 2000 is undertaken by using the IPCC-GPG 2003 approach.

Report	Inventory Year	Tier adopted	Emission factors
Initial National Communication (NATCOM 1)	1994	Tier 2	Country specific
Second National Communication (NATCOM 2)	2000	Tier 2	Country specific & Default
First Biennial Update Report (BUR-I)	2010	Tier 2	Country specific & Default

Methodology

For the LULUCF sector, the INC used Tier 2 to estimate the GHG emissions and removals. Tier 2 was applied to four key sectors: (a) changes in forest land; (b) forest and grassland conversion; (c) abandonment of managed land; and (d) emissions/removals from soils. According to the Tier 2 approach, country-specific activity data was used and mostly country-specific emission factors were applied. Both activity data and emission factors were taken from field surveys and literature reviews. For the SNC, land use change was included in the inventory, including conversion from grassland, cropland, settlements, and other land. From the IPCC guidelines, Approach 2 was adopted for defining the land use for estimating the carbon stock change. Approach 2 provides an assessment of both the net losses and gains in the area of specific land-use categories and what these conversions represent (i.e., changes both from and to a category) presented as land-use conversion matrix. For emission/removal estimation, Tier 2 was adopted. Therefore, mostly country-specific activity data and emission factors were applied (except for sub-sectors such as non-CO_2 emissions from biomass burning). The methods used in inventories are as follows:

Key institutions

The LULUCF inventory encompassed more sub-sectors from the INC to SNC. As a result of this, the number of institutions involved in inventory preparation increased from the first inventory to the second inventory. For example, to accommodate inclusion of land use change, remote sensing institutions were involved in the inventory process. The following below summarizes the institutions involved in the INC and in the SNC. The first NATCOM included three research institutions and one government agency, whereas the second NATCOM and first BUR included two government agencies and 12 research institutions (including universities).

Report	Institutions
Initial National Communication (NATCOM 1)	Indian Institute of Science, Bangalore Forest Survey of India Forest Research Institute Central Fuel Research Institute
Second National Communication (NATCOM 2)	Forest Survey of India Indian Council of Forestry Research and Education Indian Institute of Science National Remote Sensing Agency Arid Forest Research Institute Advanced Research Center for Bamboo and Rattans Center for Forestry Research and Human Resource Development Forest Research Center Himalayan Forest Research Institute Institute of Forest Genetics and Tree Breeding Institute of Forest Productivity Institute of Woods Science and Technology Rain Forest Research Institute Tropical Forest Research Institute
First Biennial Update Report (BUR-I)	Same as above

Data sources

The data sources used for the inventory are given in the following table along with the data collection institute, time series, frequency of collection, and accessibility.

Report	Sub-sector	Activity data parameters	Data sources	Frequency	Availability/ accessibility	Time series	Emission factors
NATCOM 1	(a) Forest land and the remaining forest land (b) Forest to grassland conversion (c) Uptake by the abandonment of the managed land (d) Emissions and removals from soils	(a) Area under forest land (b) Area of land converted (c) Area of unmanaged land (d) Soil type of forest strata	(a) Forest Survey of India (FSI) (b) (FSI) (c) Planning Commission (d) Forest Research Institute	(a) Biennial (b) Biennial (c) Static (d) Static	(a) In the public domain (b) In the public domain (c) In the public domain (d) Not in the public domain	(a) Since 1987 (b) Since 1987 (c) From 1984–1994 (d) 1994	(a) Country-specific emission factors from field measurements and literature (b) Country-specific emission factors from field measurements and literature (c) Country-specific emission factors from the literature review (d) Country-specific emission factors from the literature review

NATCOM 2	(1) Forestland	(1a) Area under Forest Land (1b) Area of forestland burnt	(1a) FSI and the National Remote Sensing Centre (1b) FAO	(1a) Biennial (1b) Annual	(1a) In the public domain (1b) In the public domain	(1a) From 1987 to 2013 (1b) 2000–2014	(1a) Country-specific emission factors developed by the National Forest Inventory and FSI (1b) Default emission factors from the Food and Agriculture Organization (FAO) reports
	(2) Cropland	(2a) Area under crop land	(2a) National Remote Sensing Centre	(2a) Annual	(2a) Paid for	(2a) From 1987 to 2013	(2a) Country-specific emission factors from the FSI reports
	(3) Grassland	(3a) Area under grassland	(3a) National Remote Sensing Centre	(3a) Annual	(3a) Paid for	(3a) From 1987 to 2013	(3a) Country-specific emission factors from the FSI reports
	(4) Settlements	(4a) Area under settlements	(4a) National Remote Sensing Centre	(4a) Annual	(4a) Paid for	(4a) From 1987 to 2013	(4a) Country-specific emission factors from the FSI reports
BUR -I	Same as above	Same as above	Same as above	Same as above	Same as above	Same as above	Same as above

Challenges

Forestry and land use inventory have made significant progress between the two submitted reports. There is still, however, a large uncertainty that plagues the LULUCF sector. The uncertainty estimates of the LULUCF are considerably higher than in other parts of the inventory, such as energy transformation, transportation, industrial processes, and agriculture.

The LULUCF sector still faces challenges in Tier 2 inventory preparation. One of the biggest challenges is the lack of data. While there have been improvements in meeting data needs between NATCOM 1 and NATCOM 2, there is still a limited availability of data according to forest, crop and plantation types, land use data, dominant tree species, soil carbon data, fuelwood consumption, etc. One of the main discrepancies lies in the form of data presented. Forest and plantation type are frequently recorded by the FSI; however, the FSI presents this data through reports (not in a spatially explicit form though). Spatial maps classified on the basis of forest and plantation and crop type are essential to carrying out a robust inventory. While land use maps exist, this data needs to be overlapped with a more detailed land use in terms of forest and crop and plantation types. The ISRO-Bhuvan creates land use maps explicit in the forest type but not in plantation and crop type. Further, the frequency of the data is sparse (i.e., the frequency of the data is sparse). Carbon stock change method, a relatively coarse methodology for the estimation of GHG emissions from the LULUCF was used for estimating GHG emissions and removal for forest land. The carbon stock change method involves analysing the difference in land use change between two time periods. Further, the data on the area of biomass burnt, area of biomass harvested, area of biomass affected by pest and diseases, area of biomass flooded, and so on are not available for all the districts in the government reports. Without accurate data on the area of biomass lost annually, the removals in the GHG inventory for the LULUCF will be overestimated by some amount. The area of the land flooded is particularly important (especially if this land is significant) as flooding leads to methane emissions from soils due to anaerobic decomposition of the dead organic matter. Without data on the area of forest land burnt, the estimation for forest emissions will be underestimated as it will not take into account the carbon dioxide emissions from the burning of biomass. Although FSI publish forest related data every two years, there is a need to establish a real time monitoring system.

Secondly, for those sectors for which there exist country-specific emission factors, there is a large scope for improvement in the measurement process. Both these aspects contribute to uncertainty in EFs as a result of which the GHG inventory may have a wide variability. For the LULUCF, emission factors on a stratified resolution need to be developed based on the climatic zone and forest type. Development of country-specific emission factors, particularly for biomass expansion factor is an area that needs improvement as it is essential in extrapolating stock data. Further, soil carbon density data is available on a limited capacity as a result of which estimates for carbon dioxide and methane emissions from soils have not been included in the inventory. However, there have been rigorous efforts in the improvization of the sector and the generation of country-specific factors in the second communication, which has resulted in the jump from Tier I to Tier II from the first to the second NATCOM.

WASTE SECTOR

Emissions from the Sector

Communication/report	Inventory year	Sector/ Key emitters	GHG emissions (CO_2 eq. in Gg yr-1)
Initial National Communication (NATCOM 1)	1994	Waste • MSW disposal • D&C WW • Industrial WW • Human sewage	23,233 12,222 7,539 1,302 2,170
Second National Communication (NATCOM 2)	2000	Waste (for 2000) • MSW disposal • D&C WW • Industrial WW Waste (for 2007) • MSW disposal • D&C WW • Industrial WW	52,552 10,252 23,163 19,137 57,725 12,695 22,980 22,050
First Biennial Update Report (BUR-I)	2010	Waste • MSW Disposal • D&C WW • Industrial WW	65,052 13,964 29,377 21,711

D&C : Domestic and commercial | WW: Wastewater | MSW: Municipal solid waste

Methodology

Communication/report	Inventory year	Sector	Tier approach	Emission factors
NATCOM 1	1994	Waste • MSW disposal • D&C WW • Industrial WW	 100% T1 100% T1 100% T1	 100 % D 100 % D 100 % D
NATCOM 2	2000	Waste • MSW disposal • D&C WW • Industrial WW	 100% T2 100% T1 50% T1, 50% T2	 50% CS, 50% D 100% D 50% CS, 50% D
BUR-I	2010	Waste • MSW disposal • D&C WW • Industrial WW	 100% T2 73% T1, 27% T2 50% T1, 50% T2	 50% CS, 50% D 27% CS, 73% D 50% CS, 50% D

D: Default | CS: Country specific

Key Institutions

Communication/report	Institutions	Organization responsible
NATCOM 1	Government = a Associations = b NGOs = c Research institutions = d	National Environmental Engineering Research institute
NATCOM 2	Same as above	National Environmental Engineering Research Institute and National Physical Laboratory
BUR-I	Same as above	National Environmental Engineering Research Institute and National Physical Laboratory

Data Sources

National Communication /Report	Sector	Sub-sectors/ Key sources within the sector	Activity data parameters corresponding to each sub-sector or the key source within the sector	Activity data sources	Frequency of reporting .	Availability/ accessibility	Time series of AD or report or periodicity	Emission factors
NATCOM 1	Waste	a) MSW disposal b) D&C WW c) Industrial WW d) Human sewage	Type of solid waste produced a) Per capita solid waste produced b) BOD of waste water c) Industrial and domestic waste water generation d) Other activity data not indicated in report	For a, b, and c : secondary source (no data source mentioned) -for d: CPCB 1997 as a source with an average figure of 135lpcd and 8% industrial waste water generation, statistical abstract for industrial production	a) No specific timeframe b) for a yearly statistical abstract	a) CPCB documents are Publically available for free c) Statistical abstracts are available for payment, but sometimes not in the desired units of production.		D: these are as per IPCC, 1996 etc. But in the case of CS: COINDS, published by the CPCB, statistical data for industrial production, and the Census of India were the source for emission of industry-specific emissions.
NATCOM 2/BUR -I	Waste	MSW disposal	Population	Census of India	Decadal	Accessible publically for free		D: these are as per the IPCC, 2006 CS: data published by the CPCB,
			Degradable organic carbon	Secondary source(not clearly mentioned)	Not known			
			Methane correction factor	IPCC, 2006	Yearly	Accessible publically for free		

National Communication /Report	Sector	Sub-sectors/ Key sources within the sector	Activity data parameters corresponding to each sub-sector or the key source within the sector	Activity data sources	Frequency of reporting .	Availability/ accessibility	Time series of AD or report or periodicity	Emission factors
			Solid waste generation	CPCB	Yearly	Accessible publically for free		
			Solid waste characteristics	CPCB	Not defined	Publically available		
			Fraction of waste Landfilled	CPCB				
			Degradable organic carbon fraction	IPCC, 2006				
			Methane correction factor	IPCC, 2006				
			CH4 fraction in landfill gas	IPCC, 2006				
			Half-life of waste	IPCC, 2006				
			CH4 oxidized	No data				
			CH4 recovered	No data				
		Domestic & Commercial WW	Population bifurcation on income groups	NSSO report	Two yearly	Accessible publically for free		D: these are as per the IPCC, 2006 CS: data published by the CPCB, NSSO, etc.
			Population	Census of India, 2011	Decadal	Accessible publically for free		
			Degradable organic component	IPCC, 2006				
			Correction factor of industrial BOD discharge into sewers	IPCC, 2006				
			Methane production potential	IPCC, 2006				
			Degree of utilization of treatment pathways for each income group	Source: unknown				

National Communication /Report	Sector	Sub-sectors/ Key sources within the sector	Activity data parameters corresponding to each sub-sector or the key source within the sector	Activity data sources	Frequency of reporting .	Availability/ accessibility	Time series of AD or report or periodicity	Emission factors
			Methane correction factor for various treatment pathways	IPCC, 2006				
			Fraction of Nitrogen in protein	IPCC, 2006				
			Fraction of non-consumption protein	IPCC, 2006				
			Emission factor for nitrous oxide	IPCC, 2006				
			Nitrogen removed in sludge	No data				
			Sludge removed from treatment	No data				
			Methane recovered and flared	No data				
		Industrial WW	Industrial production	Statistical survey, the CPCB, industry association	Yearly/as and when available.	Publically available for free/priced		
			Emission factors for industrial wastewater	Literature survey, Industrial visit and, the IPCC, 2006				
			Methane recovered from industries	No source				
			Waste water generated per tonne of the production and COD load	COINDS and MINAS by CPCB, literature survey, industry visit, IPCC 2006				
			Methane production capacity from the treatment units	IPCC, 2006				
			Methane correction factor for the treatment systems	The IPCC, 2006, industrial visit, literature review, and industrial associations				
			Sludge removed in each industrial sector	No data				

Challenges

Municipal solid waste disposal

- Getting 50 years of data on solid waste generation, collection, and disposal as well as characteristic of waste is a challenge. IPCC 2006 requires about 5 half-life period data to calculate efficiently.
- Half-life of waste is calculated based on the India average's temperature and precipitation value, whereas this varies from region to region based on precipitation and average temperatures. Also, information related to landfills characteristics including deep/ shallow and managed/unmanaged is not available and documented.
- The methane correction factors used are the default IPCC values and the India-specific values are a challenge.
- We need to move from India-average GHG inventory to city-specific GHG emissions inventory for better estimates with Tier-III approach.
- Validation of the IPCC, 2006, model with respect to actual methane emissions from landfills is still missing. This can help to get an accurate emissions inventory.
- There is a lack of physical and chemical characterization for city-specific solid waste. Also, actual waste generated is not recorded in any Indian city, city only records waste collected.
- Data availability on methane oxidized and captured is a challenge.
- Waste characteristics need to be recorded for every season and every city to assess the quantity and quality variation. However, the waste characterization data is not generated by cities frequently and it was only in 2004 when NEERI conducted a study for 59 cities across India. However, similar studies at this large a scale need to be conducted.

Domestic and commercial waste water

- Regional data on the per capita BOD discharge is a challenge.
- The accurate correction factor for additional industrial BOD discharged into sewers according to the Indian conditions is a challenge.
- The methane production potential, according to the IPCC, 2006, is available but not according to the Indian conditions.
- Per cent utilization of the different treatment pathways in each city is still a big gap and pose a challenge.
- Getting data on fraction of nitrogen in protein, fraction of non-consumed protein, and emission factor for nitrous oxide as per the Indian conditions is a challenge
- Regional data on sludge removed, methane flared from treatment pathways, and the emission factor from each treatment trajectory is still a challenge as sometimes data is present with the local body, but is not documented properly in the public domain for utilization.
- Cities, generally, do not quantify and characterize the domestic waste water generated. There is a need to establish these values on a city level due to the impact of environmental, social, and economic factors. Data on actual waste water quantity treated in the existing treatment plants and treatment efficiency over the years are not available in the public domain. Further, data on methane generation, recovery and flaring from the existing treatment plants is not documented.

Industrial waste water

- Data on the industrial production in tonnes and the treated wastewater quantity and quality from each industry is available with the SPCB's but is not available to other agencies.
- Data on the emission factor of methane generation as per unit of the COD is as per the IPCC, 2006, which in turn needs to be validated for Indian conditions.
- The methane correction factor for each industrial sector based on the treatment technology is a challenge.
- Regional data on treatment technology employed for waste water treatment in each industry, treatment efficiency, sludge removed, and the methane captured and utilized poses a challenge. This data is submitted by each industry in an environmental statement to SPCBs but not available for public use.

Project title
A transparency framework for Implementing INDCs in India: setting commonly accepted monitoring and verification system

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