



GHG inventory preparation - India's Experience

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The Framework of presentation

National Circumstances and Diversity of activities

Inventory Development

- Chronology of inventory development
- Inventory of 1994
- Uncertainty reduction
- Development of indigenous emission factors
- Utilisation of national emission factors

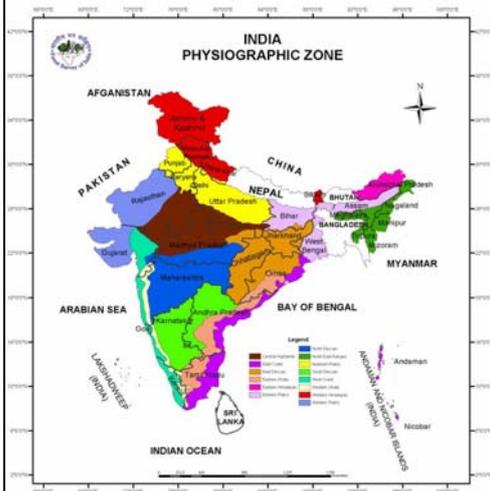
Constraints and gaps in inventory development

Need for improvement

- Sectors requiring improvement
- Steps of refinement of GHG inventory

Further Capacity building requirements

The Setting



India is a vast country (3.28 million sq km)

Diverse physiographical features

Himalayas, Coastal areas, northern plains, peninsular plateau and islands

Occupies 2.4% of the world's land area but support 16.2% of the world's human population

Dominating feature of climate is the Monsoon

Endowed with varied soils, climate, biodiversity and ecological regions

Under such diverse natural conditions, a billion people speaking different languages, following different religions, inhabiting in rural and urban areas live in harmony under a democratic system

Diversity in emissions

Regional and sectoral variability exists in emissions across a large country like India

Wide technology diversity complicates India specific estimates as new and vintage technologies co-exist

For example:

Energy and transformation industries

Different fuel combustion technologies operational

Industrial Process

Diverse production technologies

Agriculture

Dispersed sources therefore difficult to assess activity data

Land use Land use Change and Forestry

Assessment of all forest types still not covered

Waste

Rising urban population

Chronology of Inventory Development						
Gases	CO ₂ CH ₄	CO ₂ CH ₄	CH ₄	CO ₂ , CH ₄ , N ₂ O, NO _x , CO, NMVOC	CH ₄	CO ₂ , CH ₄ , N ₂ O
Sectors	Fossil Fuel Rice Animals	Transport Coal mines 1992 CH ₄ campaign Animals-Tier-II	Seasonally integrated approach and new classification of rice fields based on water regimes developed	Additional sources: Biomass burning, cement prod. oil & nat. gas Manure crop residue soils and MSW	1998 methane Campaign & CH ₄ coefficients organically amended soils	Mostly all sources
EF	Used Published EF	Used Published & also developed for rice	developed EF for various water regimes	IPCC default + own published	EF developed for organically amended soil	EF developed for key sectors
Base year	1990	1990	1990-1995	1990-1995	1998	1994
Ref.	Mitra, 1991	Mitra, 1992	Parashar et al., 1997	ALGAS, India, 1998	Gupta et al. 1999	NATCOM 2004

Inventory Estimation- Scope



Sectors Covered:

- Energy and Transformation
- Industrial Processes
- Agriculture
- Land Use, Land Use Change & Forestry
- Waste

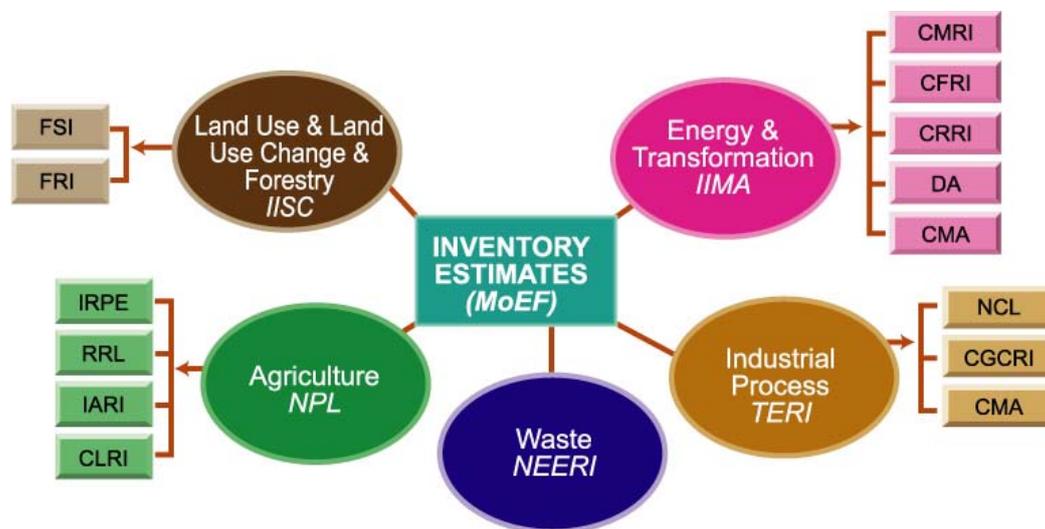
Gases Covered:

- Carbon dioxide (CO₂)
- Methane (CH₄)
- Nitrous Oxide (N₂O)

Base year: 1994

Guidelines: IPCC 1996

Inventory Estimation - Institutional Arrangement



19 Research Teams

GHG Emissions from Sources and Removals by Sinks - India 1994

GHG source and sink categories (Gg per year)	CO ₂ emissions	CO ₂ removals	CH ₄	N ₂ O	CO ₂ eq. emissions*
Total (Net) National Emission	817023	23533	18083	178	1228540
1. All Energy	679470		2896	11.4	743820
2. Industrial Processes	99878		2	9	102710
3. Agriculture			14175	151	344485
4. Land use, Land-use change and Forestry*	37675	23533	6.5	0.04	14292
5. Other sources as appropriate and to the extent possible					0
5a. Waste			1003	7	23233
5b. Emissions from Bunker fuels #	3373				3373

*Converted by using GWP indexed multipliers of 21 and 310 for converting CH₄ and N₂O respectively.

Sectoral emissions - Energy and Industrial Processes

GHG source and sink categories (Gg per year)	CO ₂ emissions	CO ₂ removals	CH ₄	N ₂ O	CO ₂ eq. emissions*
Total (Net) National Emission	817023	23533	18083	178	1228540
1. All Energy	679470		2896	11.4	743820
<i>Fuel combustion</i>					
Energy and transformation industries	353518			4.9	355037
Industry	149806			2.8	150674
Transport	79880		9	0.7	80286
Commercial/institutional	20509			0.2	20571
Residential	43794			0.4	43918
All other sectors	31963			0.4	32087
Biomass burnt for energy			1636	2.0	34976
<i>Fugitive Fuel Emission</i>					
Oil and natural gas system			601		12621
Coal mining			650		13650
2. Industrial Processes	99878		2	9	102710

Sectoral emissions- Agriculture

GHG source and sink categories (Gg per year)	CO ₂ emissions	CO ₂ removals	CH ₄	N ₂ O	CO ₂ eq. emissions*
Total (Net) National Emission	817023	23533	18083	178	1228540
3. Agriculture			14175	151	344485
<i>Enteric Fermentation</i>			8972		188412
<i>Manure Management</i>			946	1	20176
<i>Rice Cultivation</i>			4090		85890
<i>Agricultural crop residue</i>			167	4	4747
<i>Emission from Soils</i>				146	45260

Sectoral Emissions – Land Use, Land Use Changes and Forestry

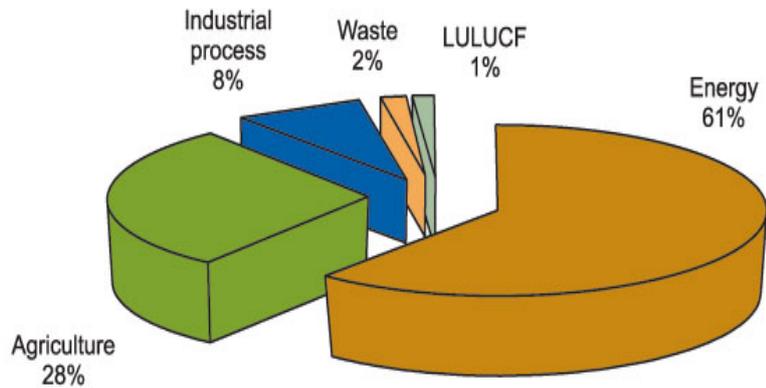
GHG source and sink categories (Gg per year)	CO ₂ emissions	CO ₂ removals	CH ₄	N ₂ O	CO ₂ eq. emissions*
Total (Net) National Emission	817023	23533	18083	178	1228540
4. Land use, Land-use change and Forestry*	37675	23533	6.5	0.04	14292
Changes in forest and other woody biomass stock		14252			(14252)
Forest and grassland conversion	17987				17987
Trace gases from biomass burning			6.5	0.04	150
Uptake from abandonment of managed lands		9281			(9281)
Emissions and removals from soils	19688				19688

Sectoral Emissions – Waste Management

GHG source and sink categories (Gg per year)	CO ₂ emissions	CO ₂ removals	CH ₄	N ₂ O	CO ₂ eq. emissions*
Total (Net) National Emission	817023	23533	18083	178	1228540
5. Other sources as appropriate and to the extent possible					0
5a. Waste			1003	7	23233
Municipal solid waste disposal			582		12222
Domestic waste water			359		7539
Industrial waste water			62		1302
Human sewage				7	2170
5b. Emissions from Bunker fuels #	3373				3373
Aviation	2880				2880
Navigation	493				493

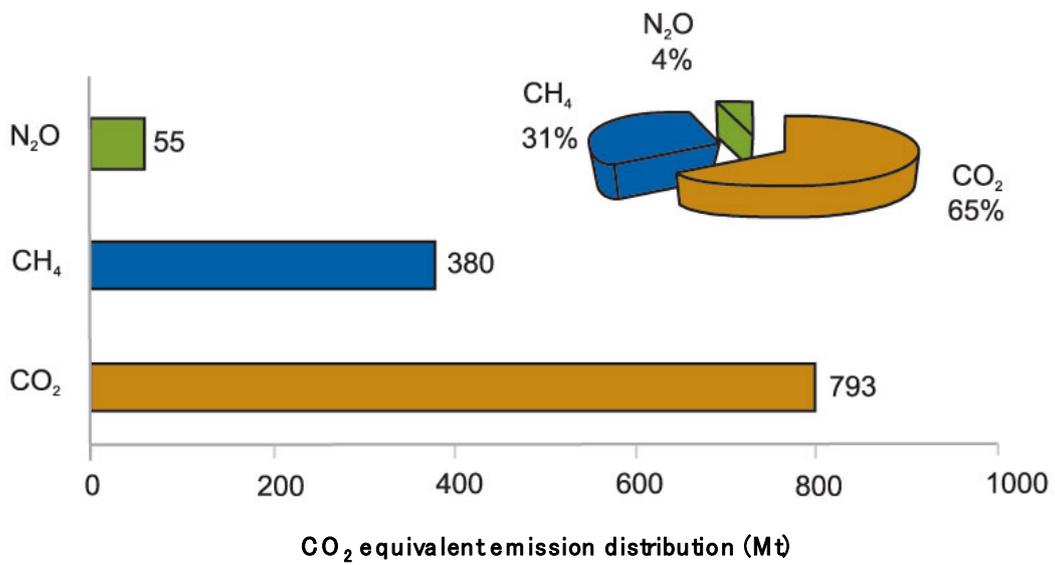
Not counted in the national totals.

Sectoral Distribution of GHG emissions – India 1994

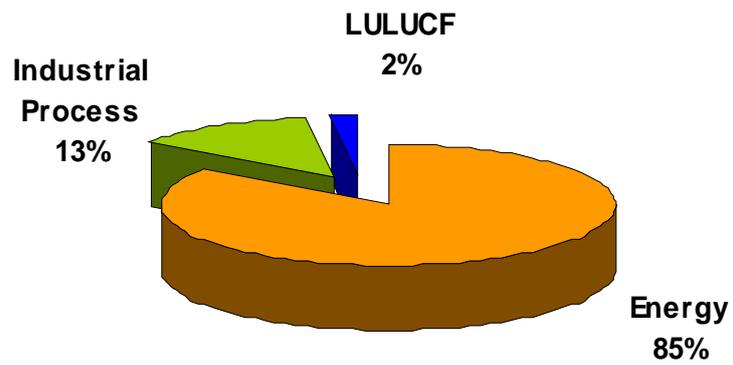


Emissions in terms of CO₂ equivalent

Relative GHG Emissions - India 1994

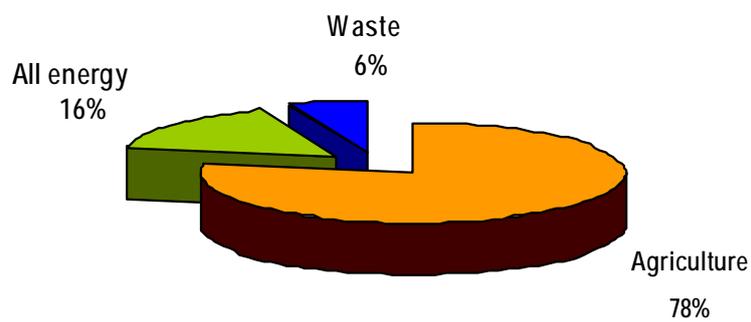


CO₂ Emission Distribution in 1994



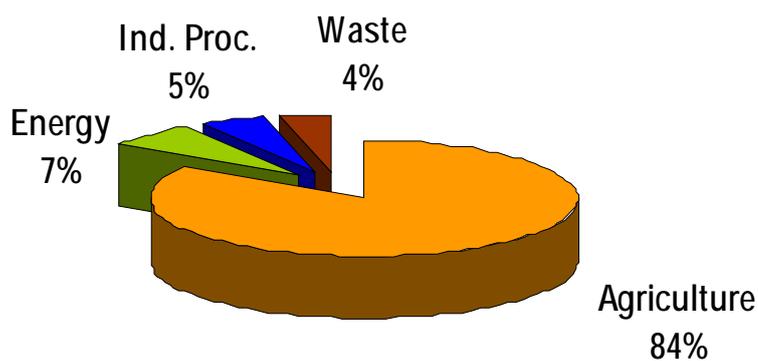
Key sources: Energy and transformation industries
Steel & Cement Production

CH₄ Emission Distribution in 1994



Key sources : Enteric fermentation
Rice cultivation

N₂O Emission Distribution in 1994



Key sources: N₂O emissions from Soils

Levels of inventory estimations

- Tier 1** Takes into account the gross consumption and average emissions factors.
e.g. National level fuel consumption and common emission factors (tC/unit fuel used),
- Tier 2** Refers to estimations based on sub-sectoral consumption and emissions coefficients developed representing specific conditions.
e.g. Fuel combustion attributed to technology types (like Sub-critical pulverized coal for power generation)
- Tier 3** Refers to emission estimates made using detailed activity and specific emission coefficients
e.g. emission factors expressed directly in terms of unit of activity like tC/kWh of power generated

Share of different Tiers used for NATCOM GHG estimates

Tier-I approach	23%
Tier-II approach	70%
Tier III approach	7%

Uncertainties in Inventory Estimation

- Top down and bottom up estimates of national activity data have variations due to aggregation errors
- Existing activity data reporting formats are not meant for inventory reporting purposes
- Most of the IPCC default emission coefficients not representative of India specific coefficients
- Methodological issues

Uncertainty Reduction

To capture the diversity of Indian emission characteristics

To enhance the quality of the inventory

Fresh emissions measurements / estimations were undertaken in some sectors



Energy and Transformation Sector

Calorific values of Indian coals
CH₄ from Coal mining
GHGs from Road Transport
CO₂ from some power, steel & cement plants

Industrial Process

N₂O from Nitric Acid Production
CO₂ from Cement, Lime and Dolomite

Agriculture Sector

CH₄ from Enteric Fermentation
CH₄ from Rice Cultivation
N₂O from Soils
GHG from biomass combustion

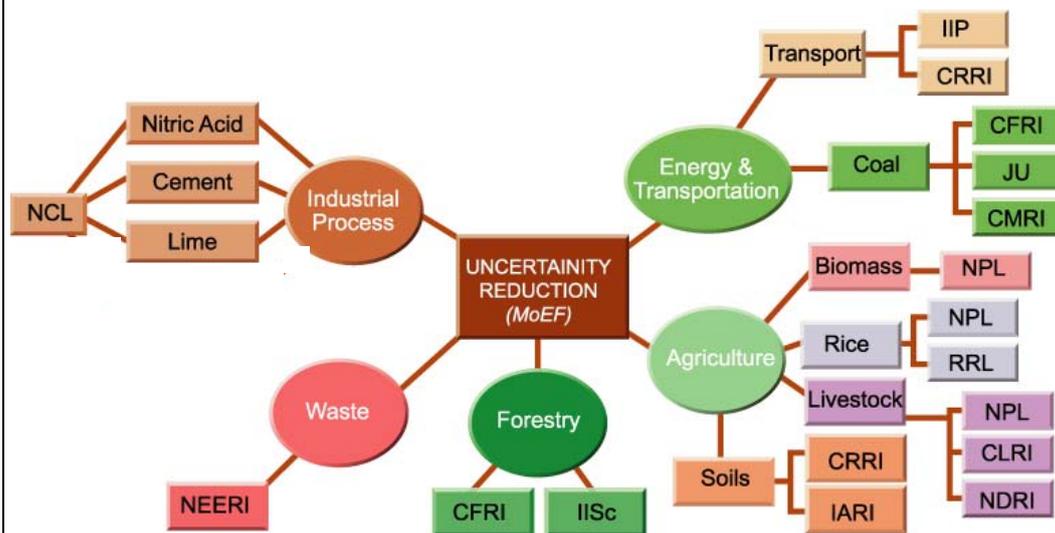
Forestry

Estimation of annual growth rates

Waste

CH₄ Municipal Solid Waste

Uncertainty Reduction – Institutional Arrangement



17 Research Teams

Indigenous Emission Factors Developed for India

		Emission Factor (EF)	Reference
Indian Coal	NCV TJ/Kt	t CO₂/TJ	
Coking coal	24.18±0.3	25.53	Choudhury et al., 2004
Non-coking coal	19.63±0.4	26.13	
Lignite	9.69±0.4	28.95	
Road Transport sector		TCO/Tj	
Gasoline	2W/3W	43.9 ± 7.3	Singh et al., 2004a, Singhal et al, 2004
	Car/Taxi	61.5 ± 4.0	
Diesel Oil	MCV/HCV	71.4 ± 0.55	
	LCV	71.4 ± 0.5	

India specific emission factorscontd.

		Emission Factor (EF)	Reference
Coal Mining		m³CH₄/ton	Singh, 2004
<i>Underground mining</i>			
During Mining	Degree I	2.91	
	Degree II	13.08	
	Degree III	23.64	
Post mining	Degree I	0.98	
	Degree II	2.15	
	Degree III	3.12	
<i>Surface mining</i>		1.83	
During Mining		0.23	
Post mining			

India specific emission factorscontd.

	Emission Factor (EF)	Reference
Cement manufacturing	tons/ton of clinker	Rao et al., 2004
	0.534 - 0.539	
Nitric acid production	kg per ton of N₂O	Rao et. al., 2004
Medium pressure plant	6.48 - 13.79	
High pressure plants	1.54 - 4.13	
Dual pressure plant	0.24 - 0.57	

India specific emission factorscontd.

	Emission Factor (EF)	Reference
Rice Ecosystem	g CH₄/m²	Gupta et al., 2004
Upland	0	
Rain fed Flood Prone	19.0±6.0	
Rain fed, Drought Prone	7.0±2	
Irrigated, Continuously Flooded	17.5±4.0	
Irrigated Single Aeration	6.6±1.9	
Irrigated Multiple Aeration	2.0±1.5	
Deep Water	19.0±6.0	

India specific emission factorscontd.

		Emission Factor	Reference
Enteric fermentation		g CH₄ / animal	Singhal et al., 2004 Swamy et al., 2004
Dairy cattle	Indigenous	28±5	
	Cross bred	43±5	
Non dairy cattle (Indigenous)	0-1 yrs	9±3	
	1-3 year	23±8	
	Adult	32±6	
Non-dairy cattle (Cross Bred)	0-1 year	11±3	
	1-2 ½ year	26±5	
	Adult	33±4	
Dairy buffalo		50±17	
Non- Dairy buffalo	0-1 year	8±3	
	1-3 year	22±6	
	Adult	44±11	
Sheep		4±1	
Goat		4±1	

Possible Reasons for Variation in Some Coefficients

Coefficient type	Possible reasons for variation of Indian coefficients from IPCC default values
CO ₂ from coal combustion	Coal composition, boiler/ combustion efficiency, regional variations across the country, coal definition issues
Industrial process emissions	Technological variability in level and extent of control processes
CH ₄ from enteric fermentation	Thinner cattle, not so rich feed type
CH ₄ from rice paddy cultivation	Irrigation practices, fertilizer and soil types in India are not conducive to high CH ₄ production
CH ₄ from Municipal Solid Waste	Waste composition, waste collection levels and mechanisms, dump management, reduction technologies

Status of Preparation GHG inventory – Energy Sector

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Type of emission factor used
Energy sector			
Energy and transformation industries	28.9	Tier II	I
Industry	12.3	Tier I	D
Transport	6.5	Tier II	I
Residential	3.6	Tier I	D
Biomass burnt for energy	2.8	Tier I	D
All other energy sectors	2.6	Tier I	D
Commercial-institutional	1.7	Tier I	D
Coal mining	1.1	Tier II	I
Oil and natural gas system	1.0	Tier I	D

I: Indigenously developed, D: IPCC Default Emission factors

Status of Preparation GHG inventory – Industrial Processes

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Type of emission factor used
Industrial Processes			
Iron and Steel production	3.6	Tier I	D
Cement production	2.5	Tier II	I
Nitric acid production	0.2	Tier II	I
Ammonia production	1.2	Tier I	D
All Others	0.9	Tier I	D

I: Indigenously developed, D: IPCC Default Emission factors

Status of Preparation GHG inventory – Agriculture

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Type of emission factor used
Agriculture sector			
Enteric Fermentation	15.3	Tier III	I
Rice Cultivation	7.0	Tier III	I
Emission from Soils	3.7	Tier I	D
Manure Management	1.6	Tier I	D
Agricultural crop residue	0.4	Tier I	D

I: Indigenously developed, D: IPCC Default Emission factors

Status of Preparation GHG inventory – LULUCF and Waste			
	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Type of emission factor used
LULUCF			
Emissions and removals from soils	1.6	Tier I	D
Forest and Grassland Conversion	1.5	Tier I	D
Trace gases from biomass burning	0.0	Tier I	D
Uptake from abandonment of Managed lands	-0.8	Tier I	D
Changes in Forest and other woody biomass stock	-1.2	Tier I	D
Waste sector			
Municipal Solid Waste Disposal	1.0	Tier I	D
Domestic/Industrial Waste water	0.7	Tier I	D
Human Sewage	0.2	Tier I	D

I: Indigenously developed, D: IPCC Default Emission factors

Constraints and Gaps in Inventory Estimation		
Gaps and constraints	Description	Potential measures (examples)
Data organization	Published data not available in IPCC-friendly formats for inventory reporting	Design consistent reporting formats
	Inconsistency in top-down and bottom-up data sets for same activities	Data collection consistency required
	Mismatch in sectoral details across different published documents	Design consistent reporting formats
Non-availability of relevant data	Time series data for some specific inventory sub-categories, e.g., municipal solid waste sites	Generate relevant data sets
	Data for informal sectors of economy	Conduct data surveys
	Data for refining inventory to higher tier levels	Data depths to be improved
Non-accessibility of data	Proprietary data for inventory reporting at Tier III level	Involve industry and monitoring institutions
	Data not in electronic formats	Identify critical datasets and digitize
	Lack of institutional arrangements for data sharing	Establish protocols
	Time delays in data access	Awareness generation

Constraints and Gaps in Inventory Estimation

Gaps and constraints	Description	Potential measures (examples)
Technical and institutional capacity needs	Training the activity data generating institutions in GHG inventory methodologies and data formats	Arrange extensive training programmes
	Institutionalize linkages of inventory estimation with broader perspectives of climate change research	Wider dissemination activities
Non-representative emission coefficients	Inadequate sample size for representative emission coefficient measurements in many sub-sectors	Conduct more measurements
Limited resources to sustain national communication efforts	Sustain and enhance research networks established under Initial National Communication	Global Environment Facility (GEF)/ international funding
	India-specific emission coefficients	Conduct adequate sample measurements for key source categories
	Vulnerability assessment and adaptation	Sectoral and sub-regional impact scenario generation, layered data generation and organization, modelling efforts, case studies for most vulnerable regions
	Data centre and website	National centre to be established

Sectors requiring improvement - Energy

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Desirability of switching over to a higher tier in the future	Whether improvement in activity data Required	Desirability of use of IPCC Good Practice guidance
ENERGY					
Energy and transformation industries	28.9	Tier II	Tier III	Y	Y
Industry	12.3	Tier I	Tier II	Y	Y
Transport	6.5	Tier II	Tier III	Y	
Residential	3.6	Tier I	Tier II	Y	
Biomass burnt for energy	2.8	Tier I	Tier II		
All other energy sectors	2.6	Tier I	Tier II		
Commercial-institutional	1.7	Tier I	Tier II		
Coal mining	1.1	Tier II	Tier III	Y	
Oil and natural gas system	1.0	Tier I	Tier II	Y	

Sectors requiring improvement - Industrial Processes

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Desirability of switching over to a higher tier in the future	Whether improvement in activity data Required	Desirability of use of IPCC Good Practice guidance
<i>INDUSTRIAL PROCESSES</i>					
Iron and Steel production	3.6	Tier I	Tier III	Y	Y
Cement production	2.5	Tier II	Tier III	Y	Y
Ammonia production	1.2	Tier I	Tier I		
All Others	1.1	Tier I	Tier I		

Sectors requiring improvement - Agriculture

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Desirability of switching over to a higher tier in the future	Whether improvement in activity data Required	Desirability of use of IPCC Good Practice guidance
<i>AGRICULTURE</i>					
Enteric Fermentation	15.3	Tier III	Tier III	Y	Y
Rice Cultivation	7.0	Tier III	Tier III	Y	Y
Emission from Soils	3.7	Tier I	Tier II	Y	
Manure Management	1.6	Tier I	Tier I		
Agricultural crop residue	0.4	Tier I	Tier I		

Sectors requiring improvement - LULUCF

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Desirability of switching over to a higher tier in the future	Whether improvement in activity data Required	Desirability of use of IPCC Good Practice guidance
<i>LULUCF</i>					
Emissions and removals from soils	1.6	Tier I	Tier III	Y	Y
Forest and Grassland Conversion	1.5	Tier I	Tier III	Y	Y
Trace gases from biomass burning	0.0	Tier I	Tier II	Y	Y
Uptake from abandonment of Managed lands	-0.8	Tier I	Tier III	Y	Y
Changes in Forest and other woody biomass stock	-1.2	Tier I	Tier III	Y	Y

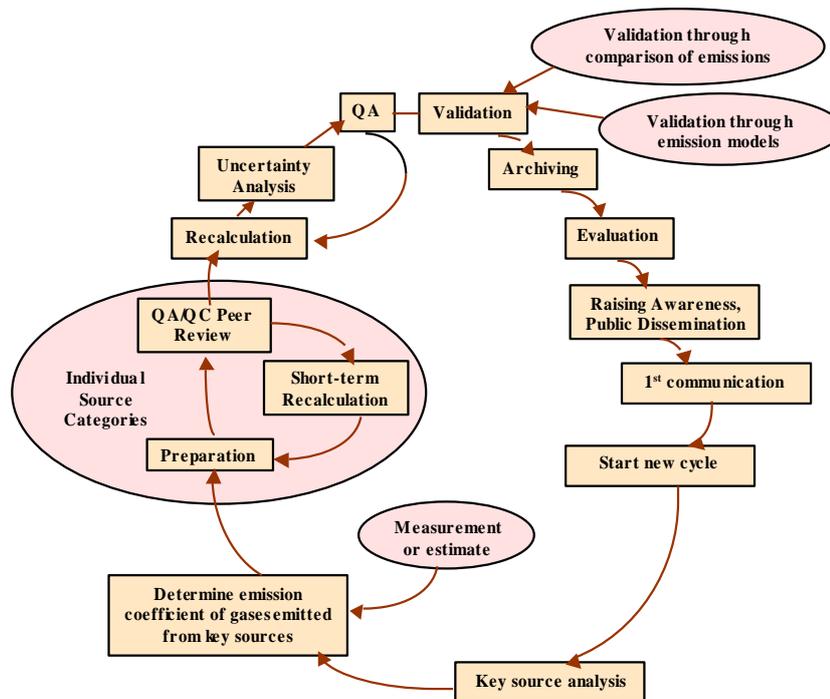
Sectors requiring improvement – Waste Management

	Percentage of the total National CO ₂ eq. emissions	Tier used in the Initial NATCOM	Desirability of switching over to a higher tier in the future	Whether improvement in activity data Required	Desirability of use of IPCC Good Practice guidance
<i>WASTE MANAGEMENT</i>					
Municipal Solid Waste Disposal	1.0	Tier I	Tier III	Y	Y
Domestic/Industrial Waste water	0.7	Tier I	Tier II	Y	
Human Sewage	0.2	Tier I	Tier I		

Steps of refinement of GHG estimations

- Through higher sectoral disaggregation and hence riding the Tier ladder
- Following Good Practices of Uncertainty Management and Quality Assurance and Quality Control
- Comparing emission estimates with model runs
- Comparisons with national, regional and global inventories

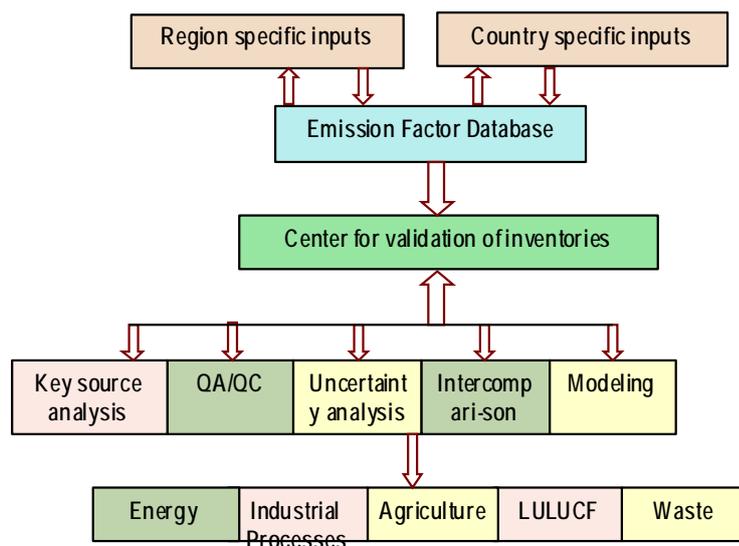
Steps for refinement of GHG estimations



Capacity Building efforts required for further refinement

- Continuous and improved networking
- Bridging data Gaps
- Strengthening existing emission coefficients
- Training on inventory development for estimating inventories of new gases, revised guidelines for preparation of inventories
- Developing emission factors representing Indian conditions for new gases to be reported
- Establishing an Emission Factor Data Base and a Nodal Centre for validation of inventories

Framework for a centre for validation of emission inventories and an emission factor database



Thank You