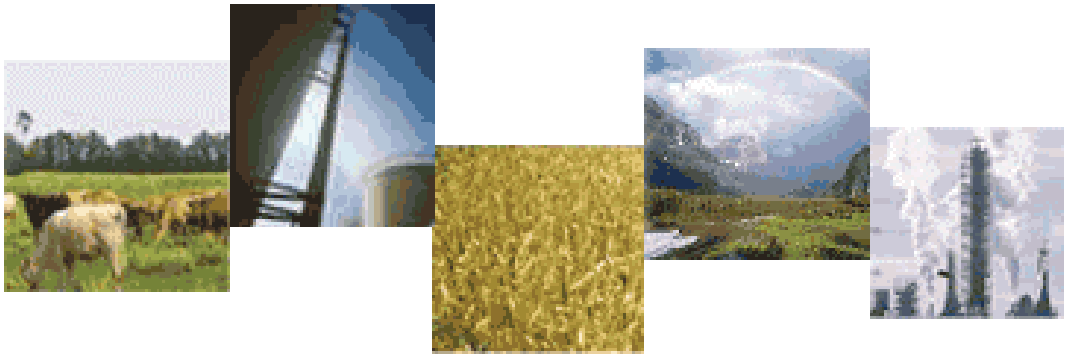
Natcom india
Ministry of Environment & Forests
Govt.of India



Inventory Estimation for Greenhouse Gas Emissions

Background

- India is a Party to the UNFCCC
- UNFCCC enjoins upon Parties to furnish information on implementation of commitments
- Developing countries to furnish information in accordance with Article 4.1 and Article 12.1
- Information is to be furnished as per 10/CP.2 in the form of an Initial National Communication, inter alia
- Inventories of Greenhouse Gases
  - Promote sustainable development, resource conservation and sink enhancement
  - Take climate change considerations into national planning process
  - Promote and cooperate
    - Training
    - Public awareness
    - Scientific research

Inventory Estimation (IE)

In accordance with Article 4, paragraph 1,each Party shall communicate to the Conference of Parties, through the Secretariat, a national inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, to the extent its capacities permit, using comparable methodologies to be promoted and agreed upon by the Conference of Parties.

Inventory Estimates (IE): Sectors Covered

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

Basket of Gases

Non-Annex I Countries to include:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)

At their discretion, the Parties may also include:

- Sulphur Dioxide ($SO_{2)}$
- Nitrogen Oxides (NO_X)
- Carbon Monoxide (CO)
- Non Methane Volatile Organic Carbon (NMVOC)
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur Hexafluoride (SF_6)

Inventory Methodologies

GHG inventories for 1994 are being prepared as per the Revised IPCC Inventory Guidelines that provide for the following levels:

Tier 1	**National level fuel consumption and common emission factors (tC/unit fuel used), Combustion technologies not accounted for**
Tier 2	**Fuel combustion attributed to sufficiently homogenous technology types (like Sub-critical pulverized coal for power generation) using representative emission factors**
Tier 3	**Emissions from activity figures (and not fuel consumption) like km traveled, emission factors expressed directly in terms of unit of activity like tC/kWh of power generated**

Tier I Methodology

Total Emissions =

Σ **(Net national fuel consumption * Emission factor)**

Sources

Sources (coal, oil, gas etc)

Consumption in Million Tonnes (MT) or Tera Joules (TJ)

Emission factor in Carbon/unit of fuel consumed

Tier II Methodology

Total Emissions =

$$\sum_{\text{Sources}} \sum_{\text{Sectors}} \sum_{\text{Technologies}} (\text{Activity level} * \text{Emission factor})$$

Sources (coal, oil etc), Sectors (power, transport etc), Technologies (Sub-Cr. PC etc)

Consumption in Million Tonnes (MT) or Tera Joules (TJ)

Emission factor in Carbon/unit of fuel consumed

Tier III Methodology

Total Emissions =

$$\sum_{\text{Sectors}} \sum_{\text{Activity}} \sum_{\text{Technologies}} (\text{Activity level} * \text{Emission factor})$$

Sectors (power, transport etc)
Activity (power generated, km traveled etc)
Technologies (Sub-Cr. PC, 2 stroke scooters etc)
Emission factor in Carbon/unit of source activity for respective technology

Sectors covered

Energy & Transformation Sector

Emissions due to fuel combustion in the following sectors:

- **Energy and transformation industries (Electric power generation, Petroleum refining, Manufacture of solid fuels)**
- **Manufacturing industries and construction (Iron and steel, cement, non-ferrous metals, chemicals and fertilizer, pulp and paper, brick, sugar, food and beverages, other industries)**
- **Transport (Aviation, Road, Railways, Navigation/Shipping)**
- **Other sectors (commercial, residential, agriculture/forestry/ fishing)**

Fuel Sources

- Liquid fossil
  - Primary fuels(Crude oil, Natural gas liquids)
  - Secondary fuels (Gasoline, Jet kerosene,Other kerosene,
  - Gas/Diesel, Fuel oil, LPG, Ethane, Naphtha, Bitumen, Lubricants, Petroleum Coke, Refinery Feed stocks)
- Solid fossil
  - Primary Fuels (Coal, Lignite, Peat)
  - Secondary Fuels (Coke)
- Gaseous fossil [Natural Gas (dry)]
- Biomass (Solid, Liquid, and Gas biomass)

Industrial Process (IP) Inventory

Industrial Processes that release emissions during chemical or physical transform of materials. e.g. Clinker formation from lime releases CO_2

Basic methodology remains the same

(Emissions = Activity level * Emission factor)

Industrial Process Sources

Emissions due to the following manufacturing processes;

- Cement production
- High calcium lime and dolomitic lime production
- Lime stone consumption in iron and steel plants
- Calcium Carbide and Silicon Carbide production
- Adipic acid production
- Nitric acid production
- Soda ash manufacturing (Trona consumption)
- Asphalt roofing manufacturing and Road paving with asphalt
- Glass manufacturing

Industrial Process Sources (contd.)

- Ammonia production
- Production of other chemicals (like Carbon black, Sulfuric acid, Styrene etc.)
- Production of Ferroalloys (of Silicon, Manganese, Chromium etc)
- Aluminium production and Manganese foundries
- Pulp and paper industry
- Production of beverages and food products
- Emissions of Halocarbons (HFCs and PFCs) and SF_6 from bulk production, refrigeration, foam production, extinguishers, aerosols, solvents and other applications

Agriculture Sector

Emissions from the agriculture sector cover the following activities;

- **Enteric Fermentation (CH_4)**
- **Manure management (CH_4 and N_2O)**
- **Rice Cultivation (CH_4)**
- **Field burning of Agricultural crop residue (non-CO_2 gases)**
- **Agricultural soils (N_2O)**

Enteric Fermentation

CH_4 produced as a byproduct of the digestive process by which carbohydrates are broken down into micro organisms and then into simple molecules for absorption.

Enteric Fermentation - Tier I

- Live stock population by type for different climate regimes (no. of heads)
- Default emission factors by region (kg CH_4/ head/ year)
- Milk Production by region (kg/ head/ year)

Enteric Fermentation - Tier II

Indian Method (Blaxter-Clapperton Equation)

- Average annual population by age group
- Body weight by age
- Feed intake
- Methane conversion rate

IPCC method (Modified Version of Blaxter-Clapperton equation)

- Average annual population
- Daily feed intake
  - Weight
  - Average weight gain per day
  - Feeding situation
  - Milk production per day
  - Average amount of work performed per day
  - Percentage of lactating cows
  - Feeding digestibility
- Methane conversion rate

Manure Management

CH_4 emitted due to decomposition of manure under anaerobic conditions

N_2O is produced from Nitrogen excretion of animals

Manure Management

CH_4 emission

- Animal population
- Emission factor by climate and by region (kg CH_4/ head/ year)

N_2O emissions

- Live stock population by climate
- Nitrogen excretion per animal per day
- Fraction of manure managed in different manure management systems (eg. Anaerobic lagoons, liquid systems, others)

In India, 50% buffalo manure is used for fuel, remainder is managed in dry systems, and 1/3rd swine manure is managed as liquids. Thus GHG emissions from this source is expected to be very low.

Rice Cultivation

Anaerobic decomposition of organic material in the soil under submerged conditions in rice fields produces methane and is transported to the atmosphere by diffusive transport through rice plants during the growing season.

CH_4 emission is dependent upon:

- **agricultural practices - water regimes**
- **cultivar types**
- **soil characteristics - organic content of the soil**
- **climate etc.**

Field Burning of Agricultural Residue

Non-CO_2 gases estimated from this source are estimated; as it is assumed here that CO_2 released in the atmosphere during burning is re-absorbed in the next growing season.

Gases: CH_4, N_2O, NO_X and CO

Data required: Different types of crop residue quantities like that for rice, wheat, maize, barley, etc.

Estimate: total dry matter biomass by weight

Carbon content of that biomass

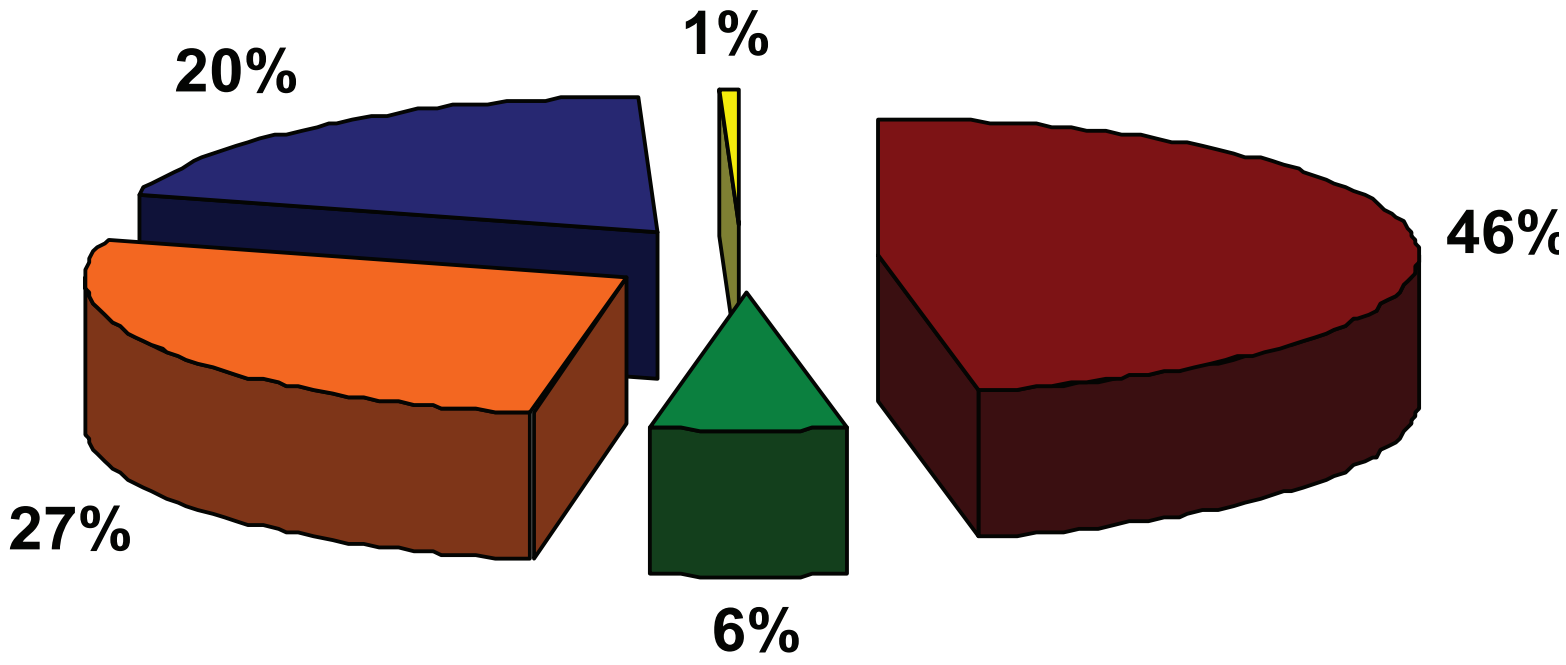
Use conversion ratios to estimate non-CO_2 gas

Agricultural Soils - N_2O

Direct emission from agricultural fields

- Amount of Nitrogen input
  - Nitrogen fertilizer
  - Nitrogen-fixing by crops
  - Live stock nitrogen excretion
  - Nitrogen input from crop residue
- Direct emissions excluding and including cultivation of histosols
- Emissions due to grazing of animals
- Indirect emissions due to atmospheric decomposition of NH_3 and NO_X
- Indirect emissions from leaching

Contribution of GHG emissions in Agriculture sector



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

Emissions from the LULUCF sector cover the following :

- Changes in forest and other woody biomass
- Annual forest and grass land conversion
- Abandonment of managed lands
- CO_2 emission or uptake from soils

Changes in forest and other woody biomass

It can produce significant carbon fluxes

- Management of Commercial forests
- Other afforestation and reforestation programs

Data can be obtained through:

- Commercial harvest statistics
- Fuel wood consumption accounting

Calculate

Net change in biomass and then convert it to Carbon flux

- **Positive value implies net CO_2 removal from the atmosphere**
- **Negative value implies net CO_2 emissions into the atmosphere**

Annual Forest and Grass Land Conversion

Relatively difficult to estimate since response of biological systems varies over different time scales:

- **Biomass burning occurs within a year**
- **Decomposition of wood takes place over a decade**
- **Loss of soil carbon occurs over several decades**

Therefore all categories to be estimated and added up for annual flux from this category

Abandonment of Managed Lands

Net CO_2 removals by biomass accumulation from abandonment of managed lands which re-grow and do not degrade

- **Cultivated lands**
- **pasture lands**

Since re-growth rates are slower after a time, the period considered are:

- **Land abandoned up to 20 years prior to inventory year**
- **Land abandoned during 20 - 100 years prior to reference year**

CO_2 Emission or Uptake from Soils

- Changes in carbon stored in soil and litter of mineral soils due to changes in landuse practices
- CO_2 emissions from organic soils converted to agriculture or plantation forestry
- CO_2 emissions due to liming of agriculture soils

Waste Sector

Emissions from the waste sector cover the following activities;

- CH_4 emission from municipal solid waste (MSW) disposal (as per IPCC guidelines, only urban areas considered)
- CH_4 emission from waste water handling
- Domestic/Commercial waste water and sludge
- Industrial waste water

CH_4 emission from Municipal Solid Waste Disposal

Anaerobic decomposition of organic matter by methanogenic bacteria in MSW sites lead to CH_4 emissions

Data required

- Urban and rural population statistics
- Waste statistics (kg waste generated per person per day)
- household waste
- garden waste
- commercial/market waste
- organic industrial solid waste
- Fraction of MSW disposed to SW disposal sites
- MSW disposal rates (kg/ person/day)
- Fraction of Degradable organic carbon content of MSW
- Categories of waste disposal sites - managed, unmanaged

CH_4 emission from waste water

High organic content of the waste water leads to substantial emission of CH4 from this source

Data required

- **Population**
- **Bio chemical Oxygen Demand (domestic/commercial & sludge)**
- **Chemical Oxygen Demand (Industrial)**
- **Specific industry outputs of waste water and sludge prod.**
- **Information on handling systems**

Illustrative Example:
IPCC Tier 1 Methodology for Energy &Transformation sector

IPCC Tier 1 Methodology (for CO_2)

- Fuel Combustion mainly releases CO_2

- Some CO, CH_4 and non-methane hydrocarbons are also released, which oxidize to CO_2 within a few days to 10-11 years.

IPCC Tier 1 Methodology (CO_2) Contd.

1. Estimate national fuel consumption by fuel type (e.g. coal, oil, natural gas)

Consumption = Production + Imports – Exports -International Bunkers - Stock Change

Non-coking coal = (215.8 + 0.682 - 0.419 - 0 - 1.234) million tons

= 214.829 MT for the year 1994

(similarly for other types of coal and other fuels)

2. Convert the fuel data to a common energy unit (Terra Joule, TJ), if necessary.

Non-coking coal = 214.829 MT * 19980 TJ/MT

= 4292283 TJ

We are measuring some of these factors under UR component of the NATCOM project

IPCC Tier 1 Methodology (CO_2)

3. Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels.

   Carbon emission factor = 25.8 tons of carbon/TJ of non-coking coal combusted (tC/TJ)

   Carbon content of the fuel = 4292283 TJ * 25.8 tC/TJ

   = 110740.9 Gg C (thousand tons)

4. Estimate the amount of carbon stored in products for long periods of time.

   Nil for coal combustion (appreciable for wooden products, natural gas for ammonia production etc.)

IPCC Tier 1 Methodology (CO_2)

5. Account for carbon not oxidized during combustion.

   About 2% remains un-oxidized as per IPCC default values

We are measuring this factor under UR component of the NATCOM project

Actual carbon emissions = 0.98 * 110740.9 Gg C

=108526.094 Gg C

6. **Convert emissions of carbon to full molecular weight of CO_2.**

   CO_2 emissions = carbon emissions * 44/12

   = 108526.094 * 44/12 Gg CO_2

   = 397929.01 Gg CO_2

Illustrative Example:
IPCC Tier 2 Methodology for Energy &Transformation sector

IPCC Tier 2 Methodology (CO_2)

1. Estimate national fuel consumption by fuel type (e.g. coal, oil, natural gas) at sector/ representative technology level

   Non-coking coal consumption in power sector

   = 160.85 MT for the year 1994

   (similarly for all types of coal and other fuels for various sectors/ representative technology levels)

2. Convert the fuel data to a common energy unit (Terra Joule,TJ), if necessary.

   Non-coking coal = 160.85 MT * 19980 TJ/MT

   = 3213783 TJ

IPCC Tier 2 Methodology (CO_2)

3. **Select carbon emission factors for each fuel/product type and estimate the total carbon content of the fuels.**

Carbon emission factor = 25.8 tons of carbon/TJ of non-coking coal combusted (tC/TJ) in power plants

We are measuring some of these factors for a few power, steel and cement plants under UR component of NATCOM

The remaining steps are the same for Tier I and 2 methodologies.

Quality Assurance/Quality Control

Quality Control

QC is a system of routine technical activities to measure and control the quality of the inventory as it is being developed.

The QC system is designed to:

- **Provide routine and consistent checks to ensure data integrity, correctness and completeness**
- **Identify and address errors and omissions**
- **Document and archive inventory material and record all QC activities**

Quality Assurance

A planned system of review procedures conducted by third party upon a finalized inventory to verify that:

- **Data quality objectives were met**
- **Ensure that the inventory represents the best possible estimate of emissions and sinks given the current state of scientific knowledge and data availability**
- **Support the effectiveness of the QC program**

Quality Control Considerations

- Technical (sector specific)
- Practical
  - Assessing national circumstances
  - QA/QC level compatible with Inventory estimation methodology (Tier 1/2/3)
  - Focus resources onto Key Source Categories

QA/QC Plan

- Outline QA/QC activities that will be implemented
- Scheduled time frame
- Outline of the processes and schedule to review all source categories
- Internal document, available for external review
- Useful to refer to ISO series (e.g. UK and the Netherlands)
- General QC procedures and peer review
- Use combination of manual and automated data checks

Activity Data QC

- Ascertain the QA/QC practices adopted by the original data source. If minimum activities listed in the QA/QC plan were satisfied, use it giving proper references.

- Otherwise attempt to establish QA/QC checks on the secondary data. Verify/compare data from diverse sources.

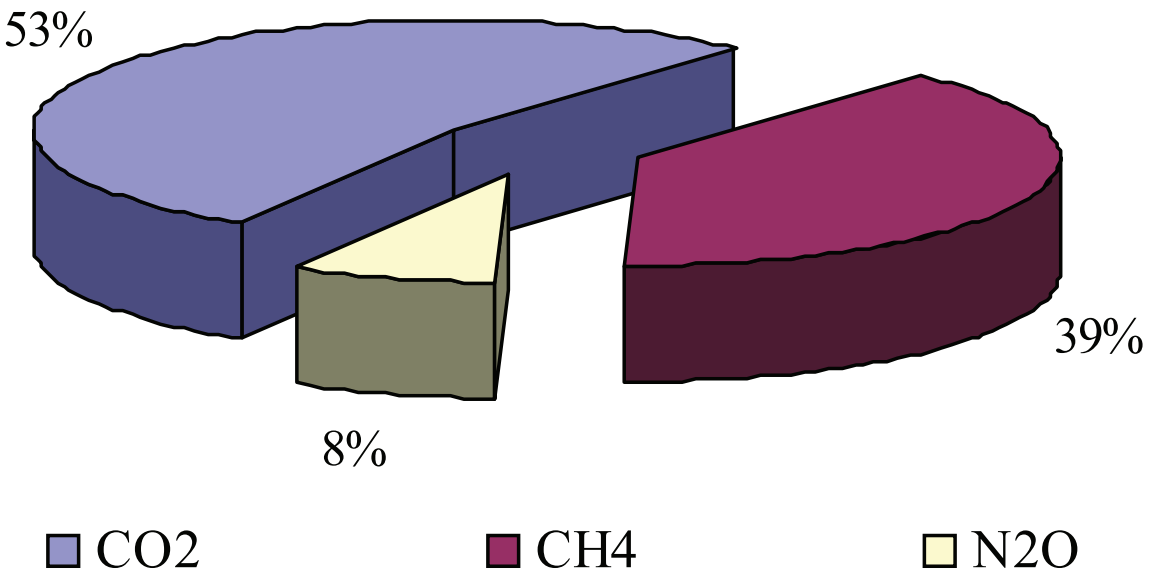
- If that is also not possible, then document the inadequacies associated with the secondary data QC as part of the Summary Report on QA/QC.

QA Procedures

- QA by third party, not involved with inventory preparation
- Inventory may be reviewed as a whole or in parts
- Conduct a basic expert peer review (Tier 1 QA) before the inventory is submitted. It is a data review and not a data audit. Identify potential problems and make corrections where possible.
- Give priority for QA for key source categories
- Sector specific QA (Tier 2) indicated in chapter 2-5 of Good practice report

Status of Indian GHG Inventory Estimates

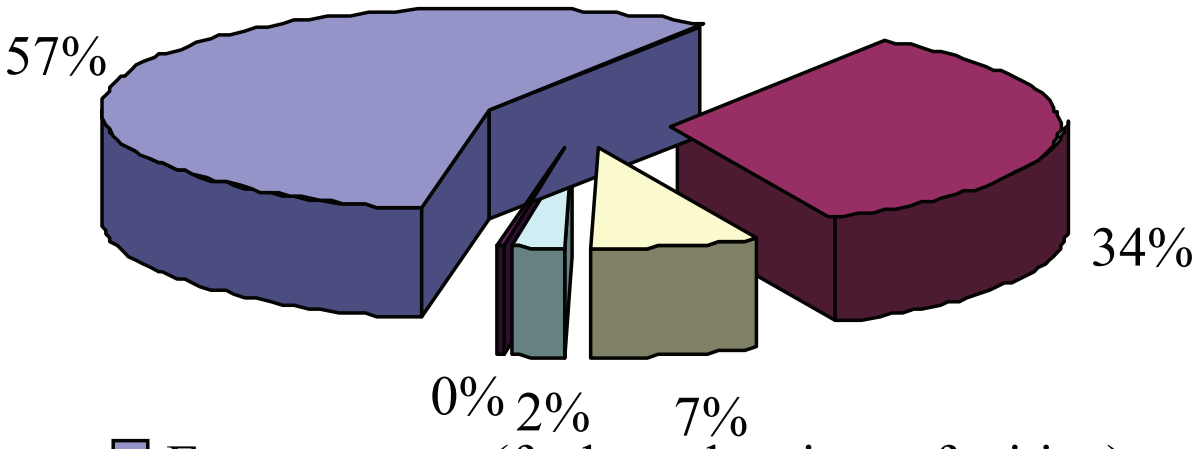
Contribution to GWP (1990)



CO_2 equivalent GWP	1001 MT

CO_2 Equivalent: Major Contributors

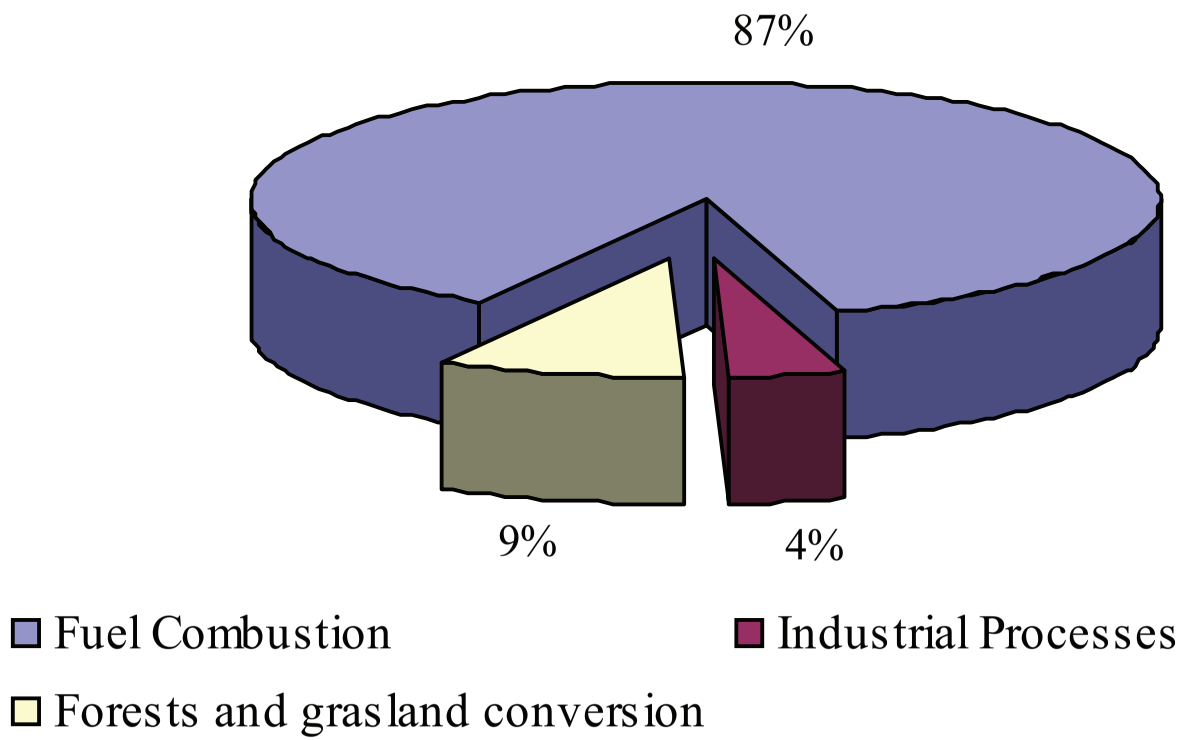
All India Emissions = 1001 MT



CO_2 Emissions: Major Contributors

53% contribution to Indian CO_2 equivalent GHG emissions

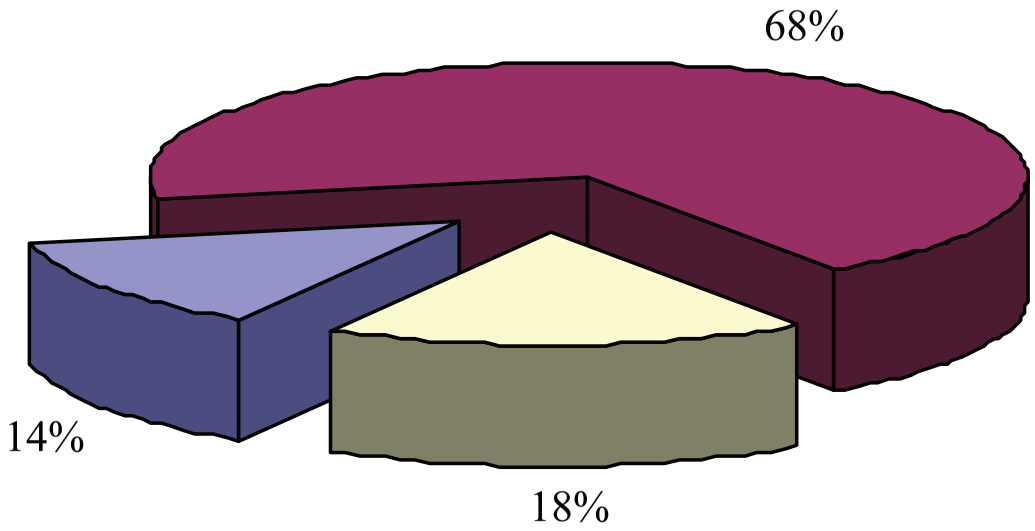
All India Emissions =534 MT



CO_2 emissions from biomass burning are not included in national totals

Methane:Major Contributors

All India Emissions = 18.5 MT

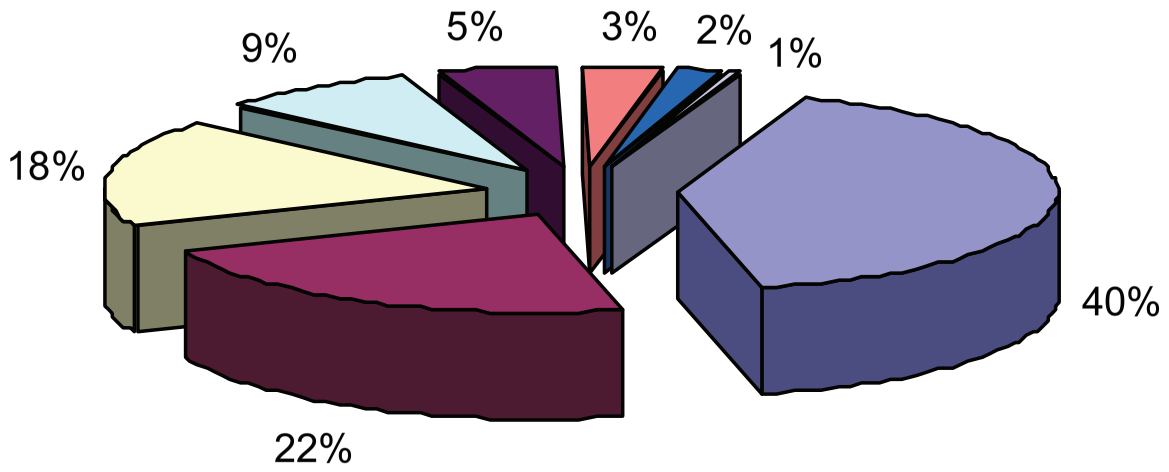


- Total Emissions from energy sector (fuel combustion + fugitive)
- Total Emissions from agricultural sources
- Total emissions from waste

Methane : Sectoral Contributors

39% contribution to Indian CO_2 equivalent GHG emissions

All India Emissions = 18.5 MT



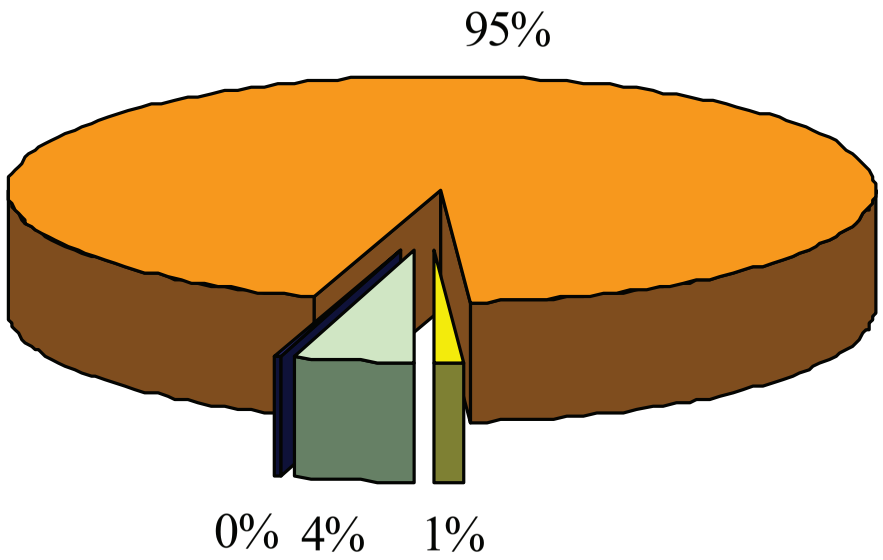
- Enteric fermentation
- Rice cultivation
- Waste
- Biomass Burning
- Manure management
- Oil and natural gas
- Solid fuels
- Field burning of agricultural residues

CH_4 Emissions according to 1996 methodology

N_2O : Major Contributors

8% contribution to Indian CO_2 equivalent GHG emissions

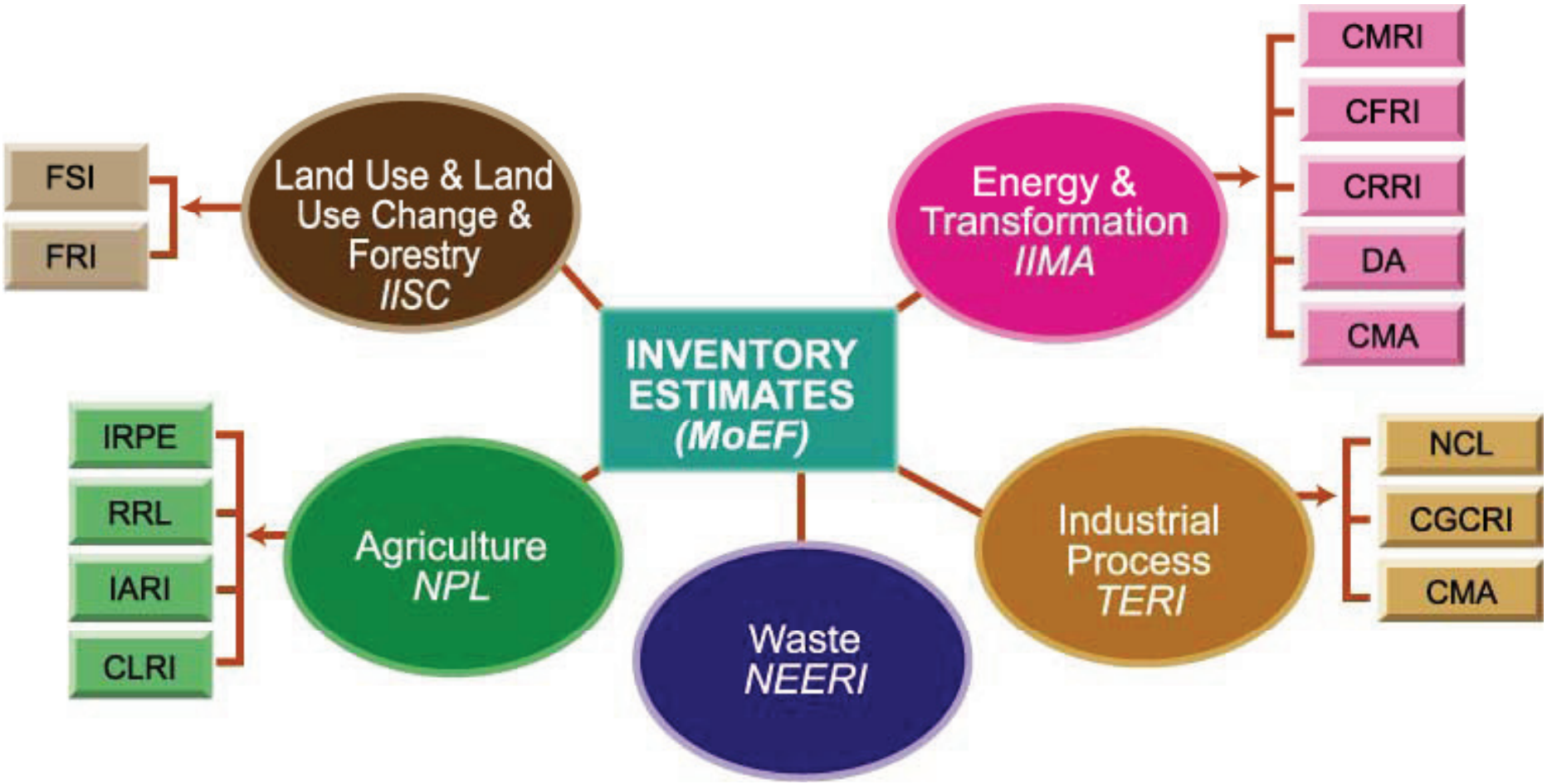
All India Emissions = 0.255 MT



NATCOM Institutional Framework:

Inventory Estimation

IE: Institutional Arrangement



IE: Geographical Institutional Distribution