GHG Platform INDIA

Building Sustainable National and Sub National Greenhouse Gas Estimates

ENERGY Sector

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Abbreviations

Acronym	*Abbreviation*
ATF	Aviation Turbine Fuel
BESCOM	Bangalore Electricity Supply Company Limited
BMTC	Bangalore Metropolitan Transport Corporation
BUR	Biennial Update Report
CAGR	Compound Annual Growth Rate
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CEEW	Council on Energy, Environment and Water
CH_4	Methane
CMFRI	Central Marine Fisheries Research Institute
CNG	Compressed Natural Gas
CO_2	Carbon dioxide
CSTEP	Center for Study of Science, Technology and Policy
EF	Emission Factor
FO	Furnace Oil
FOWIND	Facilitating Offshore Wind in India
GAIL	Gas (India) Limited
GDP	Gross Domestic Product
GGGI	Global Green Growth Initiative
GHG	Greenhouse Gas
GoK	Government of Karnataka
kT	Kilo Tonnes
HSDO	High Speed Diesel Oil
ICLEI	International Council for Local Environmental Initiatives
IISD	International Institute for Sustainable Development
INCCA	Indian Network on Climate Change Assessment
IPCC	Intergovernmental Panel on Climate Change
LDO	Light Diesel Oil
LPG	Liquefied Petroleum Gas
LSHS	Low Sulphur Heavy Stock
MoC	Ministry of Coal
MoPNG	Ministry of Petroleum and Natural Gas
N_2O	Nitrous Oxide
NDC	Nationally Determined Contribution
NSSO	National Sample Survey Office
OC	Open Cast
PCMC	Per Capita Monthly Consumption
PNG	Piped Natural Gas
QoL	Quality of Life
SAPCC	State Action Plan on Climate Change
T	Tonnes
TJ	Tera Joules
tCO_2e	Tonnes of Carbon Dioxide equivalent
UG	Under Ground

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Version Control

Version	Date	Description
01.0	September 28,2017	This methodology note includes an estimation and analysis of India's annual state-level GHG emissions for the period 2005-2014 for the Energy Sector, prepared by CSTEP under the GHG Platform India initiative (www.ghgplatform-india.org). This sector has estimated GHG emissions for 2014 in addition to the estimates calculated for other sectors. Industry Sector includes emissions from IPPU and emissions from fuel combustion within industries. However, emissions from electricity generation from autoproducers (non-utilities) that are attached to industrial units, are accounted in Energy sector. To maintain consistency with national estimates published by Government of India, vide Biennial Update Report (BUR-2010) and Indian Network for Climate Change Assessment (INCCA-2007), 'autoproducers which produce electricity for their own use are reported in electricity generation (1A1ai) sector under fuel combustion emissions (1A) in energy. This document is undergoing a peer review process, however, any changes that may be made further will not have an impact on the figures and estimates. Once the review process is completed, the final document will be uploaded and the same shall be updated in this section.

Executive Summary

Brief Information of GHG estimates:
India's total GHG emissions for the Energy sector (excluding energy use in Industries) was estimated to be 1617.62 Million tCO_2e in 2014, in comparison with 1028.71 Million tCO_2e in 2005; a 57.24% increase compared to base year level. In 2014, GHG Emissions from transport, others and fugitive sector witnessed an increase of 101.37%, 31.94% and 6.87% respectively, in comparison to 2005.

Table 1: Summary of GHG Emissions

Sector	Sub-sector	Base Year (2005) (Million tCO_2e)	Current Year (2014) (Million tCO_2e)	% change	Base Year (2005), (Million tCO_2e)	Current Year (2014), (Million tCO_2e)
		GWP-AR2[a]			GWP-AR5[b]	
Energy	Electricity Generation (1A1ai)	765.67	1209.16	57.92	806.13	1185.22
	Transport (1A3)	113.27	228.09	101.37	113.05	227.72
	Others (1A4)	116.79	154.09	31.94	123.69	160.36
	Fugitive (1B)	35.46	37.90	6.88	47.29	50.54
Total		1031.19	1629.24	58.00	1090.16	1623.84

a) CH_4-21; N_2O-310 b) CH_4-28; N_2O-265

Major Inventory developments and Calculations:
2006 IPCC guidelines for national GHG inventories methodology has been followed for calculating emissions from the sub-sectors under the Energy sector. Emissions are obtained by multiplying activity data for a specific fuel or fuel type with its associated Emission Factor (EF). A combination of Tier I and Tier II EFs are employed from national EF (INCCA) and IPCC good practice guidance documents (IPCC, 2006). All emission factors employed in this exercise remain unchanged in comparison to the national emissions estimation. Few assumptions used to estimate activity data, in select sectors, have been revised based on reliable sources.

Summary of GHG Trends:
Around 75% of emissions from the energy sector can be attributed to electricity generation in 2005; however, this attribution increased from 763 Million tCO_2e in 2005 to 1197 Million tCO_2e in 2014. State level emission, of select states, from energy sector that includes four sub-sectors are depicted in Figure 1. Between 2005 and 2014, energy sector based emissions grew at 5.1% (CAGR), according to GHGPI estimates.

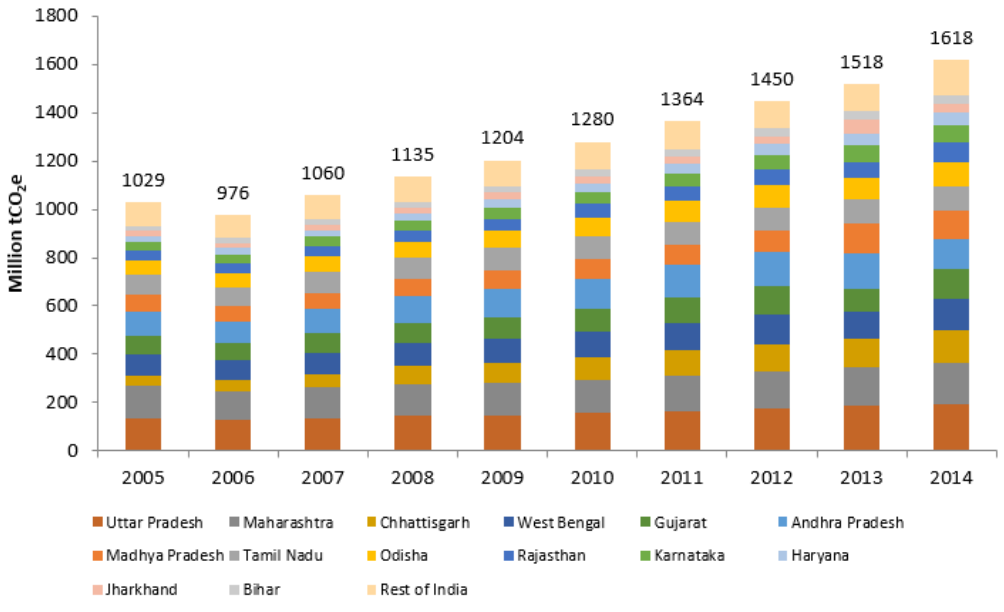

Figure 1: State wise Emissions from Energy Sector

Highlights on major emitting source categories:

In 2014, electricity generation was estimated to be the largest contributor of GHG emissions in the energy sector, contributing to 74% of emissions, followed by transport (14%), fugitive emissions from fuel production (2%) and others (10%). The energy sector emissions majorly include emissions generated from electricity generation from grid connected and auto producers, burning of fuels in transportation vehicles, emissions from cooking, heating and lighting. A detailed performance of these sub-sectors, in the context of emissions, is tabulated below:

Table 2: Time-series GHG Emissions (2005-2014)

Level 1	Level 2	Level 3	Level 4	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Energy (Million tCO_2e (GWP) – AR2	Fuel Combustion Emissions (1A)	Public Electricity Generation(1A1ai)		729.13	626.91	673.04	717.21	755.73	794.20	852.11	916.33	964.28	1041.33
		Industries(1A1ai)		36.54	71.22	90.86	104.96	113.88	128.53	139.83	149.06	156.33	167.83
		Transport(1A3)	Road (1A3b)	96.04	106.10	116.75	128.32	142.03	156.33	170.01	183.27	194.57	199.95
			Railways(1A3c)	6.49	6.66	7.12	7.64	8.01	8.38	8.64	8.98	9.32	9.57
			Aviation(1A3a)	9.89	11.86	13.71	13.87	14.25	15.46	16.88	16.62	17.58	17.54
			Navigation(1A3d)	0.86	1.00	0.95	1.28	1.67	2.28	1.48	0.94	0.94	1.04
		Others(1A4)	Residential(1A4b)	95.85	97.87	100.33	103.56	103.20	103.61	103.89	103.48	106.37	114.52
			Commercial(1A4a)	3.51	4.25	5.28	6.02	6.87	7.47	7.97	8.55	8.74	8.45
			Agriculture (1A4ci,1A4cii)	14.30	15.28	18.96	19.59	21.10	22.13	23.73	25.45	26.45	25.96
			Fisheries(1A4ciii)	3.12	3.33	3.54	3.75	3.97	4.35	4.49	4.66	4.88	5.15
	Fugitive Emissions from Fuel Production (1B)		Coal(1B1)	19.77	19.55	19.95	20.71	21.39	21.02	20.51	20.75	20.62	21.03
			Oil(1B2a)	0.25	0.25	0.26	0.26	0.26	0.29	0.30	0.30	0.30	0.30
			Natural Gas(1B2b)	15.45	15.33	15.54	15.69	21.36	25.18	23.93	21.42	19.03	16.57
	Total			1031.19	979.62	1066.29	1142.84	1213.73	1289.25	1373.77	1459.81	1529.42	1629.24

Introduction

Background Information on GHG estimates

GHG estimates reporting: The main objective of GHG India Platform is to provide estimates of continuous time-series GHG emissions for India, based on the 2006 IPCC guidelines for national GHG inventories methodology. This report encompasses energy sector's emission estimations between 2005 and 2014.

Gases: The GHGs accounted for are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O), and CO_2 equivalent using Global Warming Potential based on IPCC second Assessment Report (SAR).

Key Source Categories/ Sub-categories: 1A1ai- Electricity Generation (Public Electricity Generation and auto producers, as indicated in version control); 1A3- Transport (1A3aii Domestic Civil Aviation, 1A3b Road Transportation (Fuel based), 1A3c Railways and 1A3dii Domestic Water borne navigation); 1A4- Other Sectors (1A4a Commercial/Institutional, 1A4b Residential, 1A4ci Agriculture- Stationary, 1A4ciii Fishing-mobile combustion) and 1B- Fugitive Emissions from Fuels (1B1a Coal mining and handling 1B1ai *Underground Mines* - 1B1ai1 Mining, 1B1ai2 Post-mining gas emissions, 1B1aii *Surface Mines* - 1B1aii1 Mining, 1B1aii2 Post-mining gas emissions, 1B2 Oil and Natural Gas 1B2a Oil 1B2b Natural Gas)

GHG Estimation period: The GHG Estimation period is 2005 to 2014. The baseline year for achieving nationally determined contribution (NDC) targets is reported to be 2005 as per the commitments proposed by the Ministry of Environment, Forest and Climate Change to UNFCCC (MoEFCC, 2015). In this backdrop, all the targets proposed including emission intensity reduction that needs to be realised, are compared to 2005 levels. Therefore, we identified 2005 as the base year in this exercise.

Institutional Arrangement and Capacity

Institutional, legal and procedural arrangements: A schematic representation of institutional arrangement is presented below:

Registered Office Address:
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Note: The registered office address is responsible for carrying out the current assignment.

Few relevant projects of CSTEP, in the context of emissions calculations and estimations, are explained below:

a. CSTEP evolved the Green Economy Strategy for Karnataka, which was released by the Chief Minister and endorsed by the Government of Karnataka (GoK). It quantitatively examined the various options provided in the State Action Plan on Climate Change (SAPCC) and provided baseline inventories, mitigation

potential by 2030 and the co-benefits (jobs, land and water use, inclusivity, local pollution) of the most promising options. The study prepared a roadmap for pursuit of the most promising technology and policy options in Karnataka. Subsequently, CSTEP also worked closely with GoK to provide technical support to the Electric Bus pilot project in Bengaluru, held capacity-building workshops for mid and senior-level bureaucrats on green growth planning, and knowledge dissemination for Waste Heat Recovery options in the state's cement and steel industries. CSTEP's Quality of Life (QoL) Report, released in August 2015 approached India's Climate Policy from a sustainable development perspective. Our research found that India can reduce emission intensity in energy and energy related sectors by 30% of 2005 levels, with a 44% contribution of fossil-free capacity in the electricity generation mix. At the same time, it could also meet its developmental targets of providing affordable housing, increasing manufacturing's contribution to Gross Domestic Product (GDP), ensuring access to electricity and clean cooking fuels, and achieving significant improvements in resource-use efficiency (land, water, raw materials).

b. CSTEP has undertaken a project to conduct a benefit cost assessment of emission standards for thermal power plants in India. This project aims to examine the overall impact of emissions standards, implemented in 2015, and analyse the role of pollution control technologies to abate emissions (SO_x, NO_x, Particulate Matter). Furthermore, the study attempts to propose a framework to quantify the health benefits, in comparison with accrued costs, using plant-level data.

c. CSTEP is undertaking research studies to understand the sector-wise implications of Nationally Determined Contributions (NDCs) and the commitments related to the creation of additional sink and non-fossil capacity. Our initial findings (refer to this link) indicate that:
   i. Energy and Industry sectors will need to contribute 85–88% mitigation envisaged by the NDCs
   ii. Despite ambitious RE targets, the emissions intensity of energy supply (CO_2/Energy) will increase owing to growth in Liquefied Petroleum Gas (LPG) access and transportation demands
   iii. Energy Intensity of GDP (Energy/GDP) will need to reduce to half by 2030 to compensate for the increase in CO_2/Energy.

Technical competence of staff:

Name: Murali Ramakrishnan Ananthakumar
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Competence: Low carbon energy policy, climate policy, economic assessment of energy efficiency in industries and energy systems modelling. His expertise is concentrated in the field of energy efficiency in Industries, especially cement, iron and steel manufacturing, mobile telecom industry, and operational performance standards and technologies for thermal power plants.
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Name: Yeshika Malik
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GHG Estimation Preparation, Data Collection, Process and Storage

GHG Estimates preparation: In this exercise, a time series (2005 to 2014) emissions estimation for all the sectors at the sub-national level is conducted. Based on the literature survey and discussions with partner institutions, the 2006 IPCC guidelines for national GHG inventories Methodology was employed to estimate emissions based on fuel sources, sub-sectoral activities and emission factors. As described in section '1.A.1 Energy Industries', this exercise employs a combination of tier I and tier II emission factors from national reports (INCCA) (MoEF, 2010) and IPCC good practice guidance documents (IPCC, 2006). Finally, to convert all the non-CO_2 gases into CO_2e unit, global warming potential of 21 (CH_4) and 310 (N_2O) are employed, as per the IPCC. Based on the need, we have engaged with experts to resolve technical difficulties in data identification and processing.

Planning and methodology improvement: Activity data were collected for all the four sub-sectors in the Energy sector.

a. To estimate emissions from electricity generation (1A1ai), fuel wise electricity generated from 2004 to 2014 was collected from CEA reports. Electricity generated from public electricity generation and auto producers, in industries, were collected. Data reported in other sources published by the Ministry of Power were used to validate the quality of data from CEA reports. As per 2006 IPCC guidelines for national GHG inventories, emissions from Combined Heat and Power Generation (CHP) (141aii) must be reported under 1A1a Main activity electricity and heat production. However, electricity from biomass (bagasse based cogeneration) based CHP is reported in CEA under Renewable Energy System. As a carbon neutral source, since biomass acts as both source and sink, emissions from biomass based CHP electricity is not applicable in this exercise. According to 2006 IPCC guidelines, emissions from auto producers (undertakings which generate electricity wholly or partly for their own use, as an activity that supports their primary activity) should be assigned to the sector where they were generated and not under 1 A 1 a. But, in this exercise, emissions from electricity generation from auto producers are considered in 1A1a to maintain consistency with national estimates published by Government of India.
b. 2006 IPCC guidelines for national GHG inventories employs vehicle wise activity data to estimate emissions from transport sector (1A3). However, in this exercise, we have adopted an alternative strategy due to paucity of data pertaining to type of fuel used in every vehicle. Fuels used in each mode (road, rail, air and water) are collectively reported as four entities by the Ministry of Petroleum and Natural Gas (MoPNG). These values are collected for identified periods and validated with reports published by Ministry of Road Transport and Highway (MoRTH).

c. Emissions from 'Other' sector require activity data i.e., energy consumed at households and commercial/institutional establishments. To ascertain fuels consumed in households, we have resorted to using the National Sample Survey Office (NSSO) datasets that provides quantity of fuel consumed at households across urban and rural levels. MoPNG statistics indicate the amount of fuel (LPG, NG, Kerosene and Diesel) consumed in the commercial sector; this is used as the activity data. Energy consumption in agricultural sector can be categorised into two types: stationary combustion (1A4ci) of diesel for pumping and mobile combustion (1A4cii) of diesel in farm mechanisation. The activity data prepared also takes into account diesel consumed in both pump sets and tractors obtained from MoPNG. Emissions from fisheries (1A4ciii) include diesel and kerosene consumed by fishing fleets.
d. Activity data required to estimate fugitive emissions from fuel production (1B) include production data of coal, oil and natural gas. These data are obtained from provisional coal statistics report published by the Ministry of Coal (MoC) and MoPNG statistics report. However, underground coal production data with degree of gassiness is unavailable; thus, a 33.33% distribution across three levels of degree of gassiness was assumed to apply activity (mining and post mining) based emission factors (MoEF, 2010).

Data collection, processing and storage: Hard copies and soft copies of reports and datasets are obtained to estimate emissions from electricity generation and the 'other' sector. The fee paid included the transaction fee required to procure the data from government agencies. CEA All India Electricity statistics report for year 2004-05, 2005-06, 2011-12, 2013-14, 2014-15 were purchased to account for fuel-wise electricity generated in the corresponding years. In addition, consumer expenditure reports and raw data-sets published by the National Sample Survey Office (NSSO) for rounds[1]' 61, 62, 63, 64, 66 and 68 were requested to be obtained, by paying transaction fee, in order to estimate specific fuel consumed in residential sector for select years. Various reports (refer to data sources) available in public domain from MoPNG and MoC were downloaded to obtain activity level data for transport and fuel production. In a few instances, the Right to Information (RTI) was filed with respective agencies to avail disaggregated fuel consumption numbers. This data was also helpful in validating data obtained from public domain.

General description of methodology and data sources
Estimation methods: The methodology used for estimating the GHG emissions employs a combination of country-specific data, emission factors and the methodologies that are in-line with 2006 IPCC guidelines for national GHG inventories.

Data Sources: All major sources of activity data are listed in the table below. Emission factors are either obtained from INCCA report (government sources), fuel emission factors (MoEF, 2010) and good practice documents (IPCC, 2006).

Table 3: Principal Data Sources

NAME OF SECTOR	SUB-SECTOR	PRINCIPAL DATA SOURCE	PRINCIPAL COLLECTION MECHANISM
Energy Industries	Electricity Generation (1A1ai)	Central Electricity Authority (CEA) All India Electricity statistics (CEA, 2007; CEA, 2008; CEA, 2009; CEA, 2010; CEA, 2011; CEA, 2012; CEA, 2014)	Published data from CEA website (Hard Copies)
	Others – Residential (1A4b)	NSSO Consumer Expenditure (Type 2) Reports and Raw Data for rounds (61, 62, 63, 64, 66 and 68)	Report (Hard Copies) for 62, 63, 64 Soft copies of raw data in CD for 61, 66 and 68th round
	Fugitive – Solid Fuels (1B1)	Provisional Coal Statistics report published by Ministry of Coal (2012-13, 2013-14, 2014-15)	Online reports from MoC
	Transport (1A3); Others (1A4a, 1A4c); Fugitive – Oil and Natural Gas (1B2)	Petroleum Planning and Analysis Cell (PPAC) published by MoPNG	Online reports

[1] The National Sample Survey Office (NSSO) conducts nationwide socio-economic surveys as part of its 'rounds'. Here each round indicate the duration in years. The surveys are usually a household survey, the respondent households being selected at random through a scientific statistical design covering practically the entire geographical area of the country. These data are further refined into reports that cover several aspects of household capital expenditure by type of expenditure, source of finance etc. The raw data sets created during the survey is also available for users to conduct analyses.

Brief description of key source categories

Between 2005 and 2014, the share of emissions from solid fuels increased from 73% to 75% in the energy sector (save industries). In 2014, the total emissions from solid fuels in energy sector were estimated to be 1217.53 Million tCO_2e. Combustion of coal and lignite in electricity generation (1A1ai), contributed to around 94.71% of emissions from solid fuels. Emissions from combustion of liquid fuels (Motor Spirit, High Speed Diesel Oil (HSDO), Light Diesel Oil and Furnace Oil) in transport (1A3) accounted for 210.03 Million tCO_2e in 2014. Liquid fuels (Kerosene, Diesel, HSDO and Furnace Oil) accounted to 41.56% of emissions in the other sector, in addition to 26.7% from solid fuels (fuelwood, coke, coal and charcoal) and 31.74% from gaseous fuels (LPG and Natural Gas) application, in the year 2014.

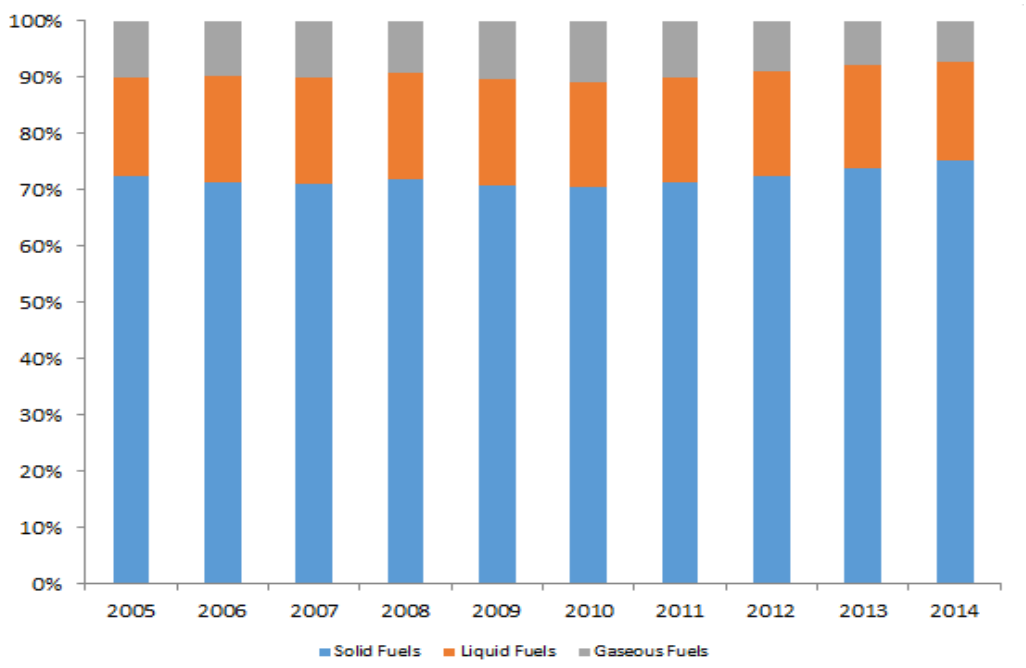

Figure 2: Emissions Contribution from Combustion of Fuels

Uncertainty Evaluation

Uncertainty arises when multiple data sources are used, across several sub-sectors, to estimate total emissions from energy sector. Activity data and emission factors are derived from measurement data from various sub-sectors. Emission estimates, therefore, present high uncertainties due to inaccuracies and variations with processes established to measure data points. Other factors include aggregation errors, incomplete data and mismatches that arise while compiling the activity data from measured data. Table 4 shows uncertainty calculated from activity data and emissions factors using propagation of errors approach, published by GoI in NATCOM II (MoEF, 2012). The uncertainty in activity data were derived based on expert solicitation, and the emission factor uncertainty are computed from a combination of both statistical (standard deviation) and secondary literature.

Table 4: Uncertainty in emissions from fuel combustion

IPCC Source Category	Sector	Gas	Activity data uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
Electricity production	Energy	CO_2	10	5	11.18
Road Transport	Energy	CO_2	5	0	5
Residential	Energy	CO_2	25	5	25.49
Agriculture/Fisheries	Energy	CO_2	25	5	25.49
Residential	Energy	CH_4	10	150	150.33

General Assessment of Completeness

Electricity Generation (1A1ai)
Although CEA All India Electricity statistics publishes yearly activity data pertaining to different fuels used for electricity generation sector, data for the Financial Year (FY) 2011-12 was not available. In cases where activity data were unavailable for intermediate years, linear interpolation of data was used to calculate the activity data. Linear interpolation implies taking an average of previous year's data and next year to calculate the intermediate year.

Transport Sector (1A3)
Sector and mode specific activity data for the FY 2004 – 05, 2005 – 06 and 2006 - 07 were not available from the Ministry of Petroleum and Natural Gas (MoPNG) reports, due to change in reporting structure. Owing to the structural changes in the report, share of fuels recorded in 2007-08 is attributed to above mentioned years.

Other Sector (1A4)
The GHG estimates were calculated based on activity data available from reports published by government agencies. Due to lack of certain data in public domain, linear interpolation and extrapolation method has been applied. Since NSSO survey on household expenditure is not conducted every year, consumption data on fuelwood, coke, coal and charcoal in residential sector for the years 2008-09, 2010-11, 2012-13, 2013-14 and 2014-15 are not available in the public domain. The diesel consumption in generator sets (commercial and residential sectors) and in agricultural pump sets and farm mechanization are not accounted for by any government agencies. About 80% of the diesel sold is accounted under 'Miscellaneous' sector, which includes the diesel consumption in DG sets and agriculture sector. Based on Nielson's survey for PPAC in 2012-13, the sharing of diesel sales among various sectors were accounted for. This is the only report that mentions the sector wise sharing of diesel and petrol in Indian sector. The same sharing pattern is assumed from 2004-05 to 2014-15 due to lack of data in other years. Similarly, the sales of Piped Natural Gas (PNG) in commercial sector is not available in the public domain and this is considered to be the left over, after considering the total sales in residential and transport sector from the total sales on City Gas Distribution companies. In case of fisheries sector, there is no information pertaining to the total sales of diesel and kerosene for fishing fleets. The GHG estimates for this sector were calculated based on data available from academic journal papers.

Fugitive Emissions (1B)
Most of the data were available from reliable government sources, except few activity data (such as leakage rate in natural gas production and breakup of coal production from UG mines based on the depth of mining). Few data points, particular activity data (refinery throughput, number of wells and natural gas internal use) in continuous time-series are not available. Thus, linear interpolation method was adopted. In addition, there were few instances where sectoral proxy variable (oil production) was used to determine the dependent variable (refinery throughput) – especially in the Oil sub-category. Apart from these assumptions, the leakage rate was assumed to be 1.65% (Muller) of natural gas production across states and coal production from UG mines from all three levels of gassiness.

Trends in Emissions

Electricity Generation: The increasing trend of emissions from coal, gas, lignite, and naphtha based power plants indicate increased usage of solid and gaseous fuels. Further, a decreasing trend of emissions was witnessed in the consumption of liquid fuels such as fuel oil, diesel, and low sulphur heavy stock (LSHS). More than 90% of the emissions from public electricity generation sector are contributed by 12 states.

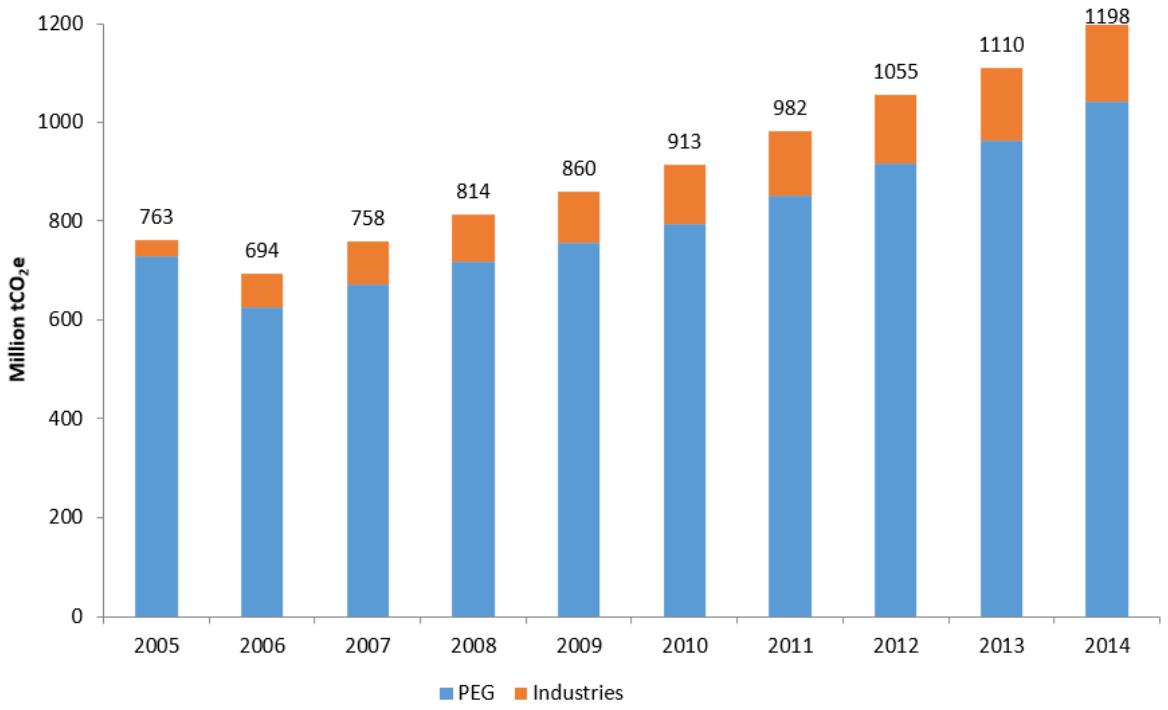

Figure 3: Emissions from Electricity Generation (2005-2014)

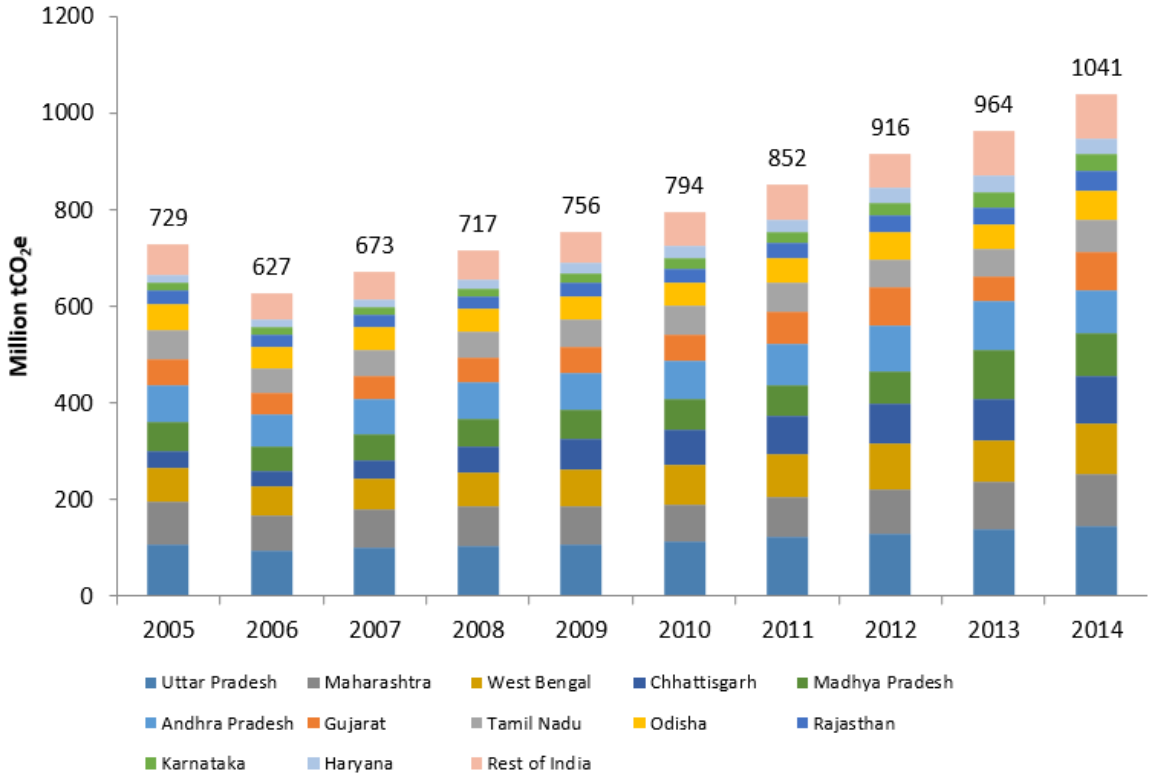

Figure 4: State wise Emissions from Public Electricity Generation

Other sector: Emissions from the residential sector is primarily attributed to combustion of LPG, natural gas, diesel, fuelwood and kerosene. Diesel and gas (natural gas and LPG) showcased an increasing trend, while consumption of fuelwood and kerosene decreased between 2005 and 2014. In 2014, diesel usage in agricultural sector accounted for 92% of the emissions in this sector, and the other fuels (LPG, Furnace oil and LSHS) usage accounted for the remaining eight percent. Residential sector contributed to 74% of the other sector

emissions in the reporting year (2014). More than 90% of the emissions from residential sector are contributed by 16 states.

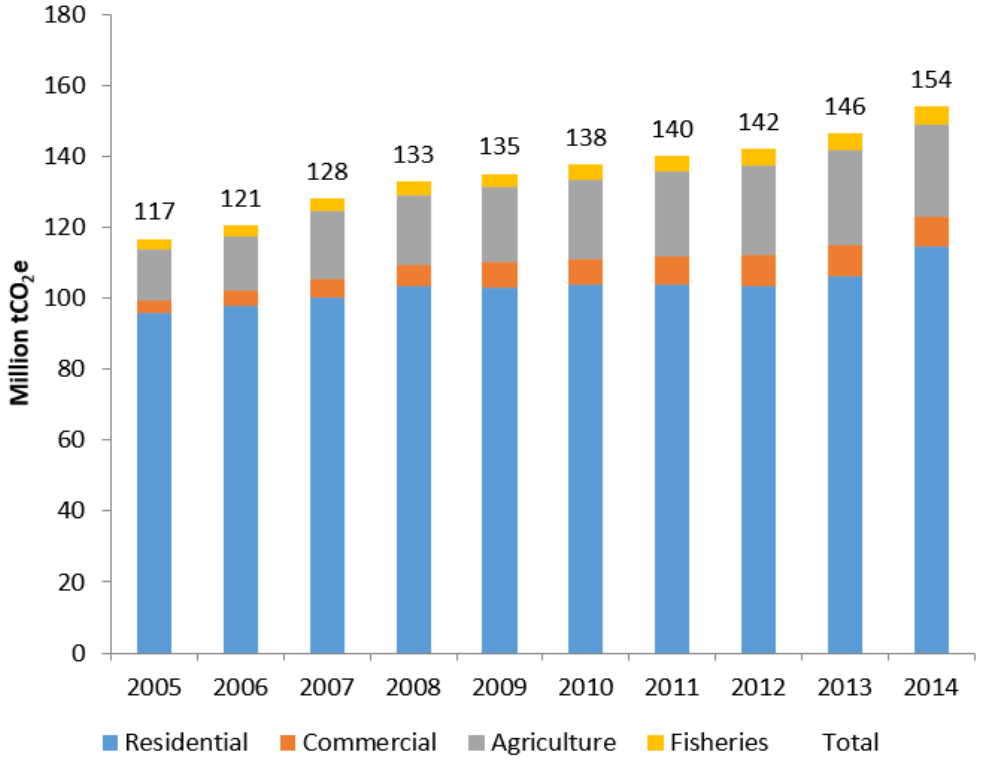

Figure 5: Emissions from the Other Sector (2005-2014)

Figure 6: State wise Emissions from Residential Sector (2005-2014)

Fugitive: Coal production increased from 406.0 Mt in 2005 to 600.7 Mt in 2014. The share of coal produced from underground mines and surface mines changed from 15% and 85% in 2005 to 8% and 92% in 2014. The

increase in the share of emissions from oil and gas extraction between 2009 and 2011 can be attributed to increased production of crude oil and natural gas.

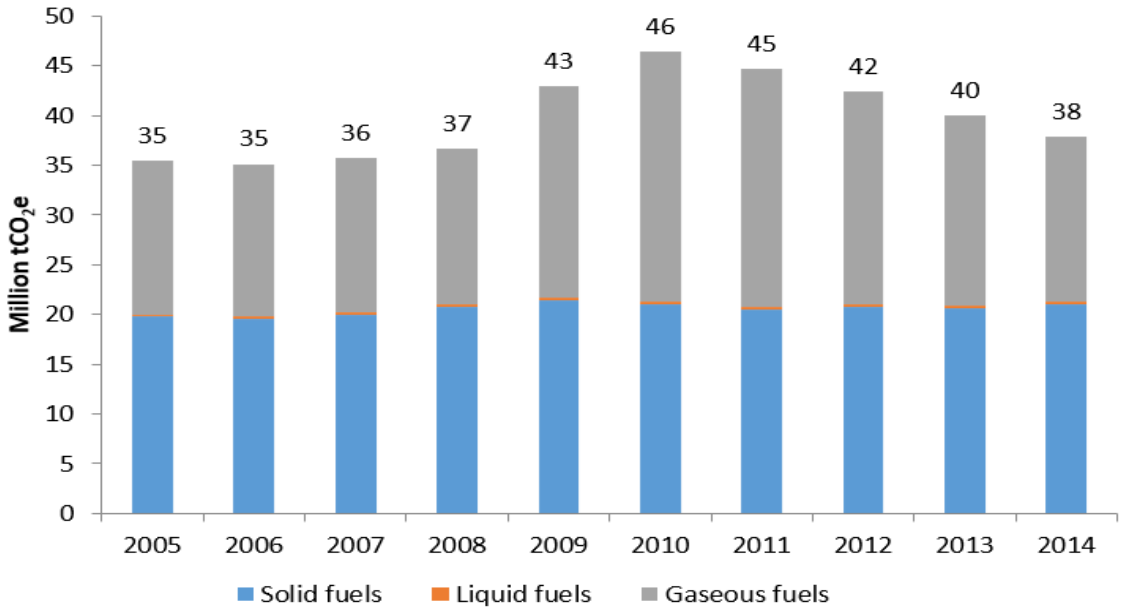

Figure 7: Emissions from Fuel Production - Fugitive (2005-2014)

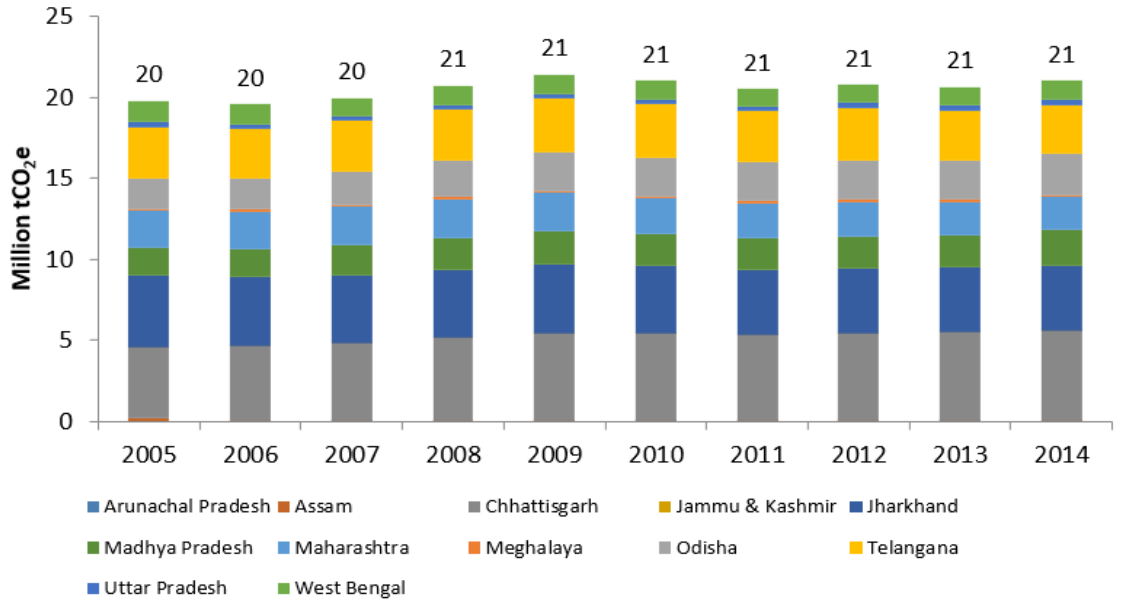

Figure 8: Emissions from Coal Production-Fugitive (2005-2014)

Transport: Periodical increase in the consumption of motor spirit and HSDO is ascribed to the increasing demand of two wheelers and four wheelers in households. The motor spirit consumption doubled between 2005 and 2014, from 8.2 Million tons to 18.6 million tons. Road transport sector contributed to 88% of emissions from transport sector, in 2014.

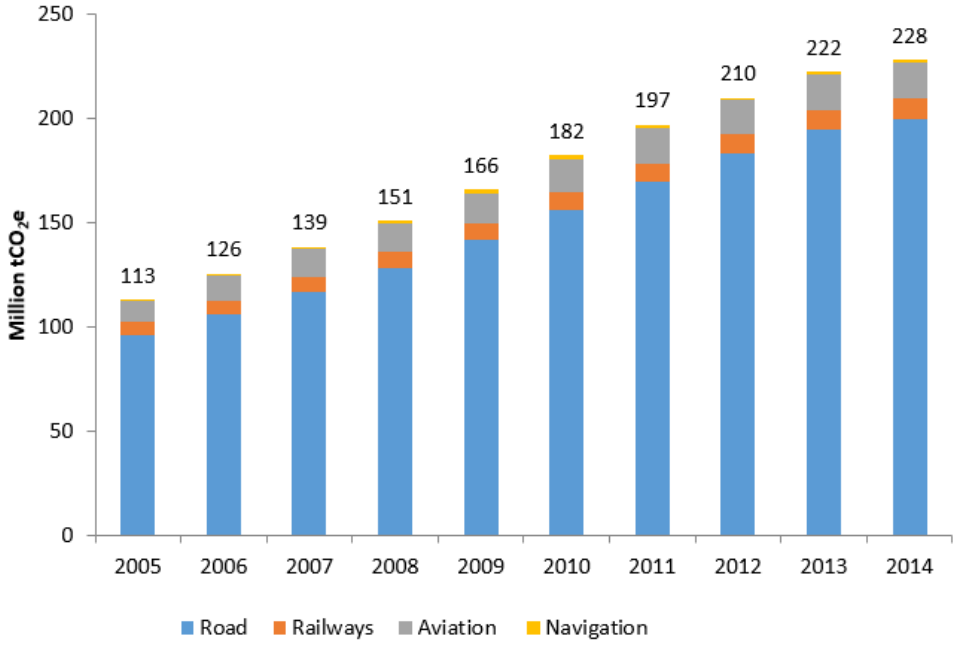

Figure 9: Emission from Transport (2005-2014)

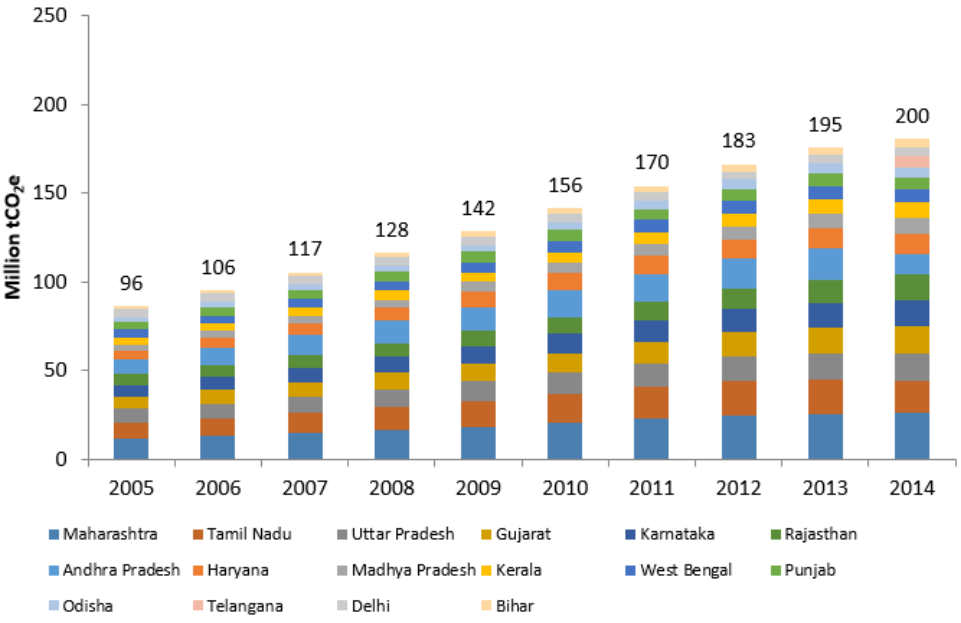

Figure 10: Emissions from Road Transport (2005-2014)

1 ENERGY

Overview of the Sector

The energy sector emissions are broadly classified into two categories: 1A Fuel Combustion Activities and 1B Fugitive Emissions from Fuel Production. Furthermore, 1A examines emissions from energy industries (1A1), Transport (1A3) and Other Sectors (1A4). The total emissions from the energy sector were estimated to be 1617.62 Million tCO_2e in 2014. The associated GHG emissions from all the aforementioned sub-sectors, in 2014, are tabulated below.

Table 5: GHG Emissions in reporting year (2014)

IPCC ID	GHG Source categories	Million tCO_2	Million tCH_4	Million tN_2O	Million tCO_2e
1	Energy				
1A	Fuel Combustion Activities				
1A1	Energy Industries	1542.01	2.83	0.44	1615.02
1A1ai	Electricity Generation	1190.94	0.01	0.027	1196.64
1A3	Transport	223.08	0.04	0.01	228.09
1A4	Other Sectors	129.53	0.01	0.01	154.09
1B	Fugitive Emissions from Fuels				
1B1	Solid Fuels	-	1.00	-	21.03
1B2	Oil & Natural Gas	-	0.80	-	16.87

Boundary of the GHG estimates

The emissions generated in energy sector is estimated and reported within the national boundary of the Republic of India. The total geographic land area is 3,287,469[2] sq.km, as per the 2011 census, with a population of 1210193422 and population density of 382 persons per sq. km. Between 2001 and 2011, the decadal growth rate of population was estimated to be 17.64%[3]. In 2011-12, the Gross Domestic Product at constant 2004-05 prices was accounted to be 5,351,831 crores. The contributions of agriculture, industry, mining and quarrying, and other services were 739,495, 1,442,498, 108,249, and 3,061,589 respectively[4]. State level emissions are estimated within the physical boundary of the state.

Overview of Source Categories and Methodology

The energy sector includes emissions from fuel combustion (1A) and fugitive emissions from fuel production (1B). The sub-sectors within 1A include electricity generation (both public and auto producers) (1A1ai), transport (1A3) and other sector (1A4). The key sources of GHG emissions are both stationary and mobile combustion of fuels (solid, liquid and gaseous fuels) in aforementioned sectors. The methodology for estimating emissions from energy sector is consistent with a combination of tier 1 and tier 2 approaches specified by 2006 IPCC guidelines for national GHG inventories. Each sector explained below will provide in-depth explanation on the process adopted to estimate emissions, including emission and conversion factors, as applicable. The following sections provide category and sub-category wise details on the activity data and emission factors.

1.A.1 Energy Industries

1.A.1a Electricity Generation

Category Description

Emissions in this sector pertain directly to the amount of fossil fuels such as coal, oil and gas (and other petroleum products) used for generating electricity in utility-based and auto producers (non-utility) power plants of 1 Mega-Watt (MW) or above. The activity data were sourced from CEA All India Electricity statistics books.

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
1.	Energy			
1A	Fuel Combustion			
1A1A	ELECTRICITY GENERATION	SECONDARY	HIGH	CEA All India Electricity statistics

[2] Office of the Registrar General and Census Commissioner of India

[3] http://censusindia.gov.in/2011-prov-results/data_files/india/table_1.pdf

[4] https://data.gov.in/visualize/?inst=197d689e4c81c5698a48f09a0a98cecd&vid=499#

The Emission Factor (EF)[5] for CO_2 (MoEF, 2010), CH_4 and N_2O (IPCC, 2006) gases pertaining to different fuels for generating electricity in Utility and Non-utility power plants are described below.

Table 6: Emission Factors of Fuels

Fuel	CO_2 EF (t/TJ) (MoEF, 2010)	CH_4 EF (kg/TJ) (IPCC, 2006)	N_2O EF (kg/TJ) (IPCC, 2006)
Non-coking coal	95.81	1.00	1.40
Lignite	106.15	1.00	1.40
Diesel/LDO[6]	74.10	3.00	0.60
Fuel oil	77.40	3.00	0.60
Light distillates/ Naphtha	74.10	3.00	0.60
Compressed Natural Gas (CNG)	56.10	1.00	0.10
LSHS[7]	73.30	3.00	0.60

Methodology

A mix of Tier 1 and Tier 2 approach of the 2006 IPCC guidelines for national GHG inventories methodology is followed to calculate greenhouse emissions in electricity generation sector. Tier 2 approach is followed for fuels like coal and lignite as India specific emission factors are available. For the remaining fuels, Tier 1 approach is followed using internationally available emission factors as summarised above.

IPCC ID	GHG source & sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1.	Energy						
1A	Fuel Combustion						
1A1	Energy Industries						
1A1a	Electricity Generation	T1, T2	D, CS	T1	D	T1	D

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Utilities

- Year-wise activity data is obtained from CEA All India Electricity statistics Reports 04-05 to 14-15 (CEA, 2006; CEA, 2007; CEA, 2008; CEA, 2009; CEA, 2010; CEA, 2011; CEA, 2012; CEA, 2014; CEA, 2015; CEA, 2016).

Non-Utilities

- Year-wise data on electricity generation from auto producers was obtained from CEA All India Electricity statistics books.
- To estimate quantity of fuel use, heat rates in industrial plants were assumed to be five percent higher than utilities for each fuel type, based on International Development Finance Corporation's (IDFC) India Infrastructure Report (IDFC, 2010). This translates to lower the capacity of boiler, in MW, higher the station heat rate. Typically, industrial plants operate at low capacity of 10-15 MW; and thus, a conservative five percent increase in heat rate is applied
- Data on heat rates from utility plants was obtained from CEA All India Electricity statistics reports (for coal), CEA CO_2 baseline studies (for diesel) (CEA, 2016) and report published by CSE (for gas) (Bhushan, 2010)

[5] ppac.org.in/WriteReadData/userfiles/file/conversion_factor.xls

[6] High Speed Diesel (HSD), in this context Diesel and Light Diesel Oil (LDO) are two main grades of diesel fuel that are available in markets in India. The HSD is a 100% distillate fuel, hence referred as diesel, while the LDO is a blend of distillate fuel with select proportion of residual fuel. Gas turbines uses HSD, while LDO is used in diesel engines that are stationary

[7] Low Sulphur Heavy Stock (LSHS) and Hot Heavy Stock (HHS) are used in lieu of furnace oil in boilers/air preheaters. LSHS has higher pour point and low sulphur content.

Electricity Generation sector follows a bottom up approach where activity demand of different fuels at state level is specified and it is summed to form the national activity demand. This national fuel-wise activity demand is then multiplied by their respective Net Calorific Value (NCV) and gas specific Emission Factor (EF) to obtain the emission value. The formula used to calculate GHG emissions is described below:

$$\text{Emissions}_{Gas} = \text{Activity Data}_{Fuel} \times \text{NCV}_{Fuel} \times \text{Emission Factor}_{Gas}$$

A sample set of calculations are provided in Appendix I to illustrate the emission estimations using the equation above. The NCV used for different fuels as per GHG Inventory report published by MoEF in 2010 (MoEF, 2010) are listed below.

Fuel	NCV (TJ/kt) (MoEF, 2010)
Non-coking coal	19.63
Diesel/LDO	43.00
Naptha	43.00
Fuel oil	40.40
CNG	48.00
LSHS	40.20

The Central sector thermal power plants for Utilities have been apportioned to the respective states based on the share of net generation of power plants in that specific state for the primary fuels (Coal, Lignite, Naptha and Natural Gas). For other supporting fuels, such as Furnace oil, LSHS/HHS and LDO, the emissions are apportioned based on the Generation Capacity of power plants in that specific state. For example, Haryana is a state in Northern region (NR) as specified by CEA. The ratio of state net generation and regional net generation is multiplied with the regional fuel consumption to estimate fuel consumed in that state, as indicated in equation below.

$$Fuel\ Consumption_{State-Coal} = \frac{Net\ Generation\ (Coal\ based)_{State} * Fuel\ Consumption_{Region-Coal}}{Net\ Generation\ (Coal\ based)_{Region}}$$

Since activity data were available in financial year (FY) format, the data were apportioned by taking the weighted average of three-fourth of preceding year and one-fourth of the succeeding year, to convert into calendar year (CY) format.

$$\text{CY Emissions}_{t} = (1/4 \times \text{FY Emissions}_{t}) + (3/4 \times \text{FY Emissions}_{t+1})$$

Uncertainty

The activity data is obtained from data collected by government agencies from several power plants that are located across India. These activities take into account of fuels used to generate electricity, in addition to operating hours. Uncertainty in electricity generation arises due to inconsistencies while aggregating numbers and measurement reporting errors. Other reasons for uncertainty could be unit conversion errors associated with reporting data.

IPCC Source Category	Sector	Gas	Activity data uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
Electricity production	Energy	CO_2	10	5	11.18

Source Category specific QA/QC

CSTEP Researchers are well aware of data sources and patterns exhibited by published data on yearly basis. Several measures were undertaken towards quality control process of the estimates. Firstly, to ensure highest level of accuracy, each activity data point was compared with other alternative publications. For instance, in case of electricity generation, fuel consumption data is primarily obtained from CEA. These numbers are compared with other sources such as ministerial reports, and journal articles. Other variables such as heat

rate, fuel consumption rate and electricity generated are employed as proxy variables to determine the natural range of the data point.

In select cases, due to lack of activity data, we resort to interpolation methods. Upon calculation, the derived numbers were compared with other sources to ensure that the deviation range is not significant (more than 5%). Despite these control measures, it is important to note that all values are subjected to errors – owing to methods of reporting at the site. This is represented as uncertainty in previous section.

Typically, activity data is reported in a combination of units across different fuels. In such cases, we compute the conventional mass based units, from volumetric units, using suggested conversion factors and physical parameters. All these measures are broadly applied to ensure transparency in data collation, effective representation of activity data and application of data to estimate emissions.

Recalculation

This is the first exercise for state level estimates as compared to National level estimates wherein we already had 2007-12 data. Therefore, recalculation may not be applicable.

Verification

The GHG estimates were calculated within the national boundary of India. The emissions were calculated using the methodology provided in 2006 IPCC guidelines for national GHG inventories and the methodology was applied consistently in the calculations. The activity data are sourced from credible sources and have been referenced appropriately in the document. The official estimates provide aggregate emissions from electricity generation in the country. The emissions from utility-based and auto producers are not separately provided.

Emissions (Million tCO_2e)	INCCA 2007	CSTEP 2007	% deviation	BUR 2010	CSTEP 2010	% deviation
Total	719	763.90	6.25%	820	922.74	12.53%

The deviation indicates the assumptions (installed capacity used as an indicator to derive emissions from regional level data to state level data) undertaken to estimate the activity data for each state, in addition to the conversion factor applied to estimate emissions in calendar year format.

Planned improvements

The activity data for 2011-12 will be obtained from CEA officials, based on availability. Further, assumptions on heat rates will be revised depending on the availability of individual plant data (industries).

1.A.3 Transport

Category Description

Emissions from the transport sector are reported under four modes: Road Transportation, Railways, Civil Aviation and Water –borne Navigation. Within each of these modes, emissions from different fuels are separately estimated. The activity data are sourced from Ministry of Petroleum and Natural Gas (MoPNG), Ministry of Statistics and Program Implementation (MoSPI), Ministry of Railways (MoR) and the Emission Factors for each fuel has been sourced from 2006 IPCC Guidelines for National Greenhouse Gas Inventories (IPCC, 2006) . The activity data for the transport sector covers the following sub sectors: 1A3aii (Domestic Civil Aviation), 1A3b (Road Transportation (Fuel based-covering sub sectors 1A3bi to 1A3bvi)), 1A3c (Railways) and 1A3dii (Domestic Water borne navigation)

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
1.	Energy			
1A	Fuel Combustion			
1A3	Transport			
1A3a	Civil Aviation	Secondary	High	MoPNG, MoSPI
1A3b	Road Transportation	Secondary	High	PPAC, MoPNG
1A3c	Railways	Secondary	High	Ministry of Railways, PPAC, MoPNG

1A3d	Water-borne Navigation	Secondary	High	PPAC

Methodology

IPCC ID	GHG source & sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor
1.	Energy						
1A	Fuel Combustion						
1A3	Transport						
1A3a	Civil Aviation	T1	D	T1	D	T1	D
1A3b	Road Transportation	T1	D	T1	D	T1	D
1A3c	Railways	T1	D	T1	D	T1	D
1A3d	Water-borne Navigation	T1	D	T1	D	T1	D

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

2006 IPCC guidelines for national GHG inventories methodology has been followed for calculating emissions from the transport sector. The reporting structure followed is similar to INCCA report (MoEF, 2010). Emissions are obtained by multiplying activity data for a specific fuel or fuel type with its associated Emission Factor (EF).

Emissions = Activity Data * Emission factor

The GHGs accounted for are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). Fuel calorific values are obtained from INCCA report (MoEF, 2010). In case of liquid and gaseous fuels, density assumptions are taken from the Ministry of Petroleum and Natural Gas (MoPNG). The CO_2 emissions (000 Tonnes) from transport sector are calculated based on the formula given below for each fuel type:

$$Emission_{Coal} = \frac{Coal\ consumption\ (000\ Tonnes) * NCV_{Coal}\left(\frac{Tj}{Kt}\right) * CO_2EF_{Coal}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{Diesel} = \frac{Diesel\ consumption\ (000\ Tonnes) * NCV_{Diesel}\left(\frac{Tj}{Kt}\right) * CO_2EF_{Diesel}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{CNG} = \frac{CNG\ consumption\ (MCM) * Density_{CNG}\left(\frac{Kg}{SCM}\right) * NCV_{CNG}\left(\frac{Tj}{Kt}\right) * CO_2EF_{CNG}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{LPG} = \frac{LPG\ consumption\ (000\ Tonnes) * NCV_{LPG}\left(\frac{Tj}{Kt}\right) * CO_2EF_{LPG}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{ATF} = \frac{ATF\ consumption\ (000\ Tonnes) * NCV_{ATF}\left(\frac{Tj}{Kt}\right) * CO_2EF_{ATF}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{Gasoline} = \frac{Gasoline\ consumption\ (000\ Tonnes) * NCV_{Gasoline}\left(\frac{Tj}{Kt}\right) * CO_2EF_{Gasoline}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{Fuel\ Oil} = \frac{Fuel\ Oil\ consumption\ (000\ Tonnes) * NCV_{Fuel\ Oil}\left(\frac{Tj}{Kt}\right) * CO_2EF_{Fuel\ Oil}\left(\frac{t}{Tj}\right)}{10^3}$$

$$Emission_{LDO} = \frac{LDO\ consumption\ (000\ Tonnes) * NCV_{LDO}\left(\frac{Tj}{Kt}\right) * CO_2EF_{LDO}\left(\frac{t}{Tj}\right)}{10^3}$$

Similarly, for calculating the CH_4 and N_2O emissions the same equations for each fuel is considered. The emission factors for CO_2 and the specific emission factors with respect to road transportation, railways, water- borne navigation, and civil aviation for CH_4 and N_2O are given in detail in the table below:

Emission Factors										
Net Calorific Value (NCV) & CO_2 Emission Factor (MoEF, 2010)			Road Transportation (IPCC, 2006)		Railways (IPCC, 2006)		Water –borne Navigation (IPCC, 2006)		Civil Aviation (IPCC, 2006)	
	NCV (TJ/kt)	CO_2 EF (t/TJ)	CH_4 EF (kg/TJ)	N_2O EF (kg/TJ)	CH_4 EF (kg/TJ)	N_2O EF (kg/TJ)	CH_4 EF (kg/TJ)	N_2O EF (kg/TJ)	CH_4 EF (kg/TJ)	N_2O EF (kg/TJ)
Coal	19.63	93.91			2.00	1.50				
Diesel	43.00	74.10	3.90	3.90	4.15	28.60	3.90	3.90	3.90	3.90
CNG	48.00	56.10	92.00	3.00						
LPG/Auto LPG	47.30	63.10	62.00	0.20	62.00	0.20				
ATF	44.10	70.00							0.50	2.00
Gasoline/Motor Spirit	44.30	69.30	33.00	3.20						
Fuel Oil	40.19	77.40	3.00	0.60	3.00	0.60	7.00	2.00		
LDO/HSDO	43.00	74.10	10.00	0.60	10.00	0.60	10.00	0.60		

Road Transportation

- Fuels used: For the state-wise emission estimation due to lack of activity data, Motor Spirit (Petrol), High Speed Diesel Oil (HSDO), Auto LPG, LDO, FO was considered. About 97% of total fuel consumption in road transportation is pertaining to Motor Spirit & HSDO, the other fuels (CNG) have not been considered owing to lack of disaggregated data at state level.
- The main source for state-wise activity data for Motor Spirit consumption estimates was from Petroleum Planning and Analysis Cell (PPAC)[8]. The time series data was available from 2004-05 till 2015-16. As more than 99.5% of Motor Spirit consumption is in transport sector (Nielsen, 2013), the fuel consumption was considered for road transportation directly.
- For HSDO, only direct sales are reported in the MoPNG statistics and the retail shares are reported under 'miscellaneous' and retail category at National level for the time series 2004-05 to 2014-15. For the state-wise HSDO consumption, total consumption by all the sectors was available from PPAC. There is no disaggregate or percentage allocation for each sector specific consumption or mode specific consumption of HSDO at state level. To allocate the share of HSDO for retail consumption only (and not direct sales) in road transportation, the All India Sectoral Demand of Diesel and Petrol report (Nielsen, 2013) by PPAC was considered.
- The share for the diesel sold through retail outlets sector-wise was considered from PPAC report (Nielsen, 2013), which was based on primary surveys at retail outlets state-wise. Primary data was collected from over 2000 retail outlets in 150 districts in over 16 states, spanning 18 months. This data provides information on the diesel consumption patterns across various sectors, segments on a state, zonal and all India basis.
- The percentage contribution of HSDO for transport (road transportation specifically), reported state-wise and nationally, were used to estimate HSDO consumption. Since the report (Nielsen, 2013) was divided into 3 time zones, July - September 2012 percentage shares were allocated for years prior to 2011-12, April-June 2013 percentages shares were allocated to 2012-13 onwards while average national values were used for 2011-12.
- For the states not covered in the report (Nielsen, 2013), a combination of average zonal numbers and average value of the closest state has been considered to derive percentage share. For example, states like Uttarakhand, the the percentage share has been derived from Uttar Pradesh. Similar is the case with Chandigarh (derived from Punjab), Jharkhand (derived from Bihar), etc. For other states, zonal average percentage share has been considered.
- Due to lack of data source for state-wise share of HSDO direct consumption, it has not been considered for the analysis.

[8] RTI Application number PPACL/R/2017/50011

- For auto LPG, LDO, FO state wise consumption data was considered from PPAC[9].

Railways

- Fuels Used: HSDO, LDO, FO and other fuels such as LPG, and coal (traction) were not considered due to lack of state-wise data.
- HSDO accounts for ~99.8% of total railways sector fuel consumption, other fuels LPG, LDO, FO and coal (for traction) contributes to the remaining share.
- The main source for the state-wise fuel consumption estimates was the Petroleum Planning and Analysis cell under Ministry of Petroleum and Natural Gas' (MoPNG)
- HSDO consumption data was available only till 2013-14; hence data for 2014-15 has been linearly extrapolated.

Civil Aviation

- Fuels Used: Aviation Turbine Fuel (ATF) & HSDO
- ATF & HSDO are the two prominent fuels consumed in aviation sector, the share of ATF was ~99.9% and due to lack of state-wise data availability, HSDO has not been considered for the GHG estimation
- The main source for the state-wise fuel consumption estimates was the Petroleum Planning and Analysis cell under Ministry of Petroleum and Natural Gas' and MoPNG statistics for the time series data from 2004-05 till 2015-16. The numbers from 2010-11 onwards were cross verified from "Indian Petroleum & Gas Statistics Reports" 2010-11 to 2015-16.

Water – borne Navigation

- Fuels Used: HSDO, LDO, and FO
- LDO and FO data was available state wise from PPAC and HSDO was not considered due to lack of data availability at the state level.

Since activity data were available in financial year format, the data were apportioned by taking the weighted average of three-fourth of preceding year and one-fourth of the succeeding year, to convert into calendar year format. The following equation has been used:

$$CY\ Emissions_t = (1/4 \times FY\ Emissions_t) + (3/4 \times FY\ Emissions_{t+1})$$

Uncertainty

Uncertainty could have arisen due to lack of completeness in activity data, especially of fuels such as HSDO retail which has a dominant share of fuel consumption in road transportation sector. In order to minimise the uncertainty, activity data has been compiled from multiple sources (Nielsen, 2013) (MoPNG, 2011) (Anand, 2012). Other reasons include measurement error, misreporting (HSDO retail versus HSDO) and missing data points in the activity data.

IPCC Source Category	Sector	Gas	Activity data uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
Road Transport	Energy	CO_2	5	0	5

Source Category specific QA/QC

Activity data for transport sector was obtained from MoPNG statistics, and other peer-reviewed journal papers and reports. It was evident that the datasets were inundated with gaps and aberrations. Having worked in this sphere, we resorted to alternative sources of publications to iron out aberrations and inconsistencies. In addition, with the use of Right to Information act, we filled request to data for activities that required additional validation. Upon receipt, gaps in HSDO consumption in Railways, for example, was resolved and verified with Indian Railways Statistics Publications (MoR, 2014-15). Similar verification processes were undertaken to validate activity data and assumptions from PPAC (Nielsen, 2013) and MoPNG.

In select cases, like civil aviation, CO_2 emissions estimates were validated with the Civil Aviation's Carbon footprint of Indian Aviation report (Director General of Civil Aviation, 2013) and similarly IPCC default

[9] RTI Application number PPACL/R/2017/50011

emission factors for mobile combustion were validated with International Civil Aviation Organisation's Guidance Material for the Development of State Action Plan report (2011) (International Civil Aviation Organisation, 2011). These validations played a significant role in asserting quality control on the emissions estimates, due to heavy reliance on activity data.

Recalculation

This is the first exercise for state level estimates as compared to National level estimates wherein we already had 2007-12 data. Therefore, recalculation is not applicable.

Verification

Activity data and emission factor data has been considered from government reports that are available in public domain and the reference for each report was given along with the assumptions considered.

The total emissions for 2007 and 2010 were compared with government estimates in INCAA and BUR. CSTEP's 2007 aggregate emission estimates are almost 2% lesser than official numbers. In 2010, estimates were lower by 3% than the official numbers. From the tables above, it is evident that road transport sector is the highest contributor to the total emissions.

Emissions (Million tCO_2e)	INCCA 2007	CSTEP 2007	% deviation	BUR 2010	CSTEP 2010	% deviation
Road	124	117	-6%	164	156	-5%
Aviation	10	14	34%	12	15	-33%
Rail	7	7	4%	8	8	106%
Navigation	1	1	-34%	4	2	-38%
Total	142	139	-2%	188	182	-3%

Planned improvements

The latest primary survey conducted by PPAC on HSDO retails is available only for 2012-13. The data from the survey has been used for calculating the activity data for 2013. This data can be updated based on the new primary surveys conducted after 2012-13. Any revisions in activity data is credible, if and when revised fuel consumption estimates get published by government agencies or peer-reviewed journals.

1.A.4 Other sectors

Category Description

Other sectors include energy consuming activities in residential, commercial, agricultural and fisheries sectors. The activity data for this sector represents the fuel consumption used for specific applications such as cooking, lighting, heating, use of small (< 1 MW) Diesel Generator (DG) sets, drying of field produce, operation of tractors, diesel pump-sets, other farm implements, and fishing fleet. The main sources considered for the activity data in other sectors were from MoPNG and MoSPI.

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
1.	Energy			
1A	Fuel Combustion			
1A4	Other Sectors			
1A4a	Commercial/ Institutional	Secondary	High	MoPNG, MoSPI
1A4b	Residential	Secondary	High	MoPNG, MoSPI
1A4c	Agriculture/ Fishing[10]	Secondary and Tertiary	High	MoPNG, MoSPI

The emission factors and Net Calorific Value (NCV) are obtained from INCAA report (MoEF, 2010) and 2006 IPCC guidelines for national GHG inventories (IPCC, 2006).

[10] Energy related aspects of agriculture and fishing, e.g. use of diesel/ electricity in agricultural pumps and use of diesel for mobile combustion related to fishing.

Fuel type	NCV (TJ/kt)	Emission Factors		
		CO_2 EF (t/TJ)	CH_4 EF (kg/TJ)	N_2O EF (kg/TJ)
Coking coal	24.18	93.61	300.00	1.40
Diesel/LDO	43.00	74.10	10.00	0.60
Charcoal	29.50	112.00	200.00	1.00
Kerosene	43.80	71.90	10.00	0.60
Fuel oil	40.40	77.40	10.00	0.60
CNG	48.00	56.10	5.00	0.10
LPG	47.30	63.10	5.00	0.10
LSHS	41.91	74.68	10.00	0.60
Wood/Biomass	15.67	0.00	300.00	4.00

In select fuels, density is used to determine the quantity (activity data) in desired unit, and these factors are provided in the below table.

Fuel type	Density	Unit	Source
Diesel	1.21	kL/t	PPAC[11]
PNG	0.76	kg/SCM	PPAC[12]

Methodology

IPCC ID	GHG SOURCE & SINK CATEGORIES	CO_2		CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
1.	Energy						
1A	Fuel Combustion						
1A4	Other Sectors						
1A4a	Commercial/ Institutional	T1	D	T1	D	T1	D
1A4b	Residential	T1, T2	D, CS	T1	D	T1	D
1A4c	Agriculture/ Fishing	T1	D	T1	D	T1	D

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

2006 IPCC guidelines for national GHG inventories methodology has been followed for calculating emissions from the sectors mentioned above. The reporting structure followed is similar to INCCA (2010) report. Emissions are obtained by multiplying activity data for a specific fuel or fuel type with its associated Emission Factor (EF). The GHGs accounted for are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). The emissions were converted into its equivalent terms of GWP and GTP. Fuel calorific values are obtained from INCCA (2010) report. In case of liquid and gaseous fuels, density assumptions are taken from the Ministry of Petroleum and Natural Gas (MoPNG).

$$\boldsymbol{Emissions_{CO2}(t) = Activity\ Data(TJ) * Emission\ factor_{CO2}(\frac{t}{TJ})}$$

$$\boldsymbol{Emissions_{CH4}(t) = \frac{Activity\ Data(TJ) * Emission\ factor_{CH4}(\frac{kt}{TJ})}{1000}}$$

$$\boldsymbol{Emissions_{N2O}(t) = \frac{Activity\ Data(TJ) * Emission\ factor_{N2O}(\frac{kt}{TJ})}{1000}}$$

$$\boldsymbol{Emissions_{Co2e}(GWP) = Emissions_{CO2} + GWP_{CH4} * Emissions_{CH4} + GWP_{N2O} * Emissions_{N2O}}$$

$$\boldsymbol{Emissions_{Co2e}(GTP) = Emissions_{CO2} + GTP_{CH4} * Emissions_{CH4} + GTP_{N2O} * Emissions_{N2O}}$$

[11] http://petroleum.nic.in/docs/readyrecknor_May14.pdf

[12] ppac.org.in/WriteReadData/userfiles/file/conversion_factor.xls

Residential and Commercial

LPG, Kerosene

- Data for FY 2004-05 to 2014-15 were obtained from PPAC.

Fuelwood, Coke Coal and Charcoal

- State-wise Per Capita Monthly Consumption (PCMC) of fuelwood, coke, coal, and charcoal for rural and urban households were obtained from NSSO's 61st (2004-05), 62nd (2005-06), 63rd (2006-07)[13], 66th (2009-10) and 68th (2011-12) rounds (NSSO, 2007; NSSO, 2012; NSSO, 2015).
- State-wise PCMC for 2007-08 and 2008-09 were linearly interpolated. The difference in value between 2006-07 and 2009-10 were divided equally for the years 2005-06 and 2007-08.
- State-wise PCMC for 2012-13, 2013-14 and 2014-15 were extrapolated using CAGR (2009-10 to 2011-12). CAGR was calculated using the following formula:

$$\boldsymbol{CAGR} = \left(\frac{\boldsymbol{Ending\ Value}}{\boldsymbol{Beginning\ Value}}\right)^{\frac{1}{\boldsymbol{no\ of\ years}}} - \mathbf{1}$$

- The state wise PCMC was converted to aggregate absolute fuel consumption by multiplying the state-wise PCMC with state-wise population (Ministry of Rural Development, 2016). The state sector wise population data from Census 2001 and 2011 rounds were interpolated as well as extrapolated using the CAGR calculated between the 10 years. The urbanization rates of each state between these years were also calculated using the same approach.

  For example, the total consumption of fuelwood consumed in residential sector for each state is calculated as shown below:

  $$Fuelwood_{RURAL} = PCMC_{FUELWOOD\_RURAL} * Rural\ Population * No\ of\ months\ in\ a\ year$$

  $$Fuelwood_{URBAN} = PCMC_{FUELWOOD\_URBAN} * Urban\ Population * No\ of\ months\ in\ a\ year$$

  $$Total\ Fuelwood\ Consumption\ (kg) = Fuelwood_{RURAL} + Fuelwood_{URBAN}$$

  $$Total\ Fuelwood\ Consumption\ (TJ) = TotalFuelwood\ Consumption\ (kg) * NCV_{FUELWOOD}\ (TJ)/1000$$

  The same formula is applied to calculate the total consumption of coke, coal, and charcoal too.

Natural Gas

- The state-wise domestic PNG connection data was obtained from the Petroleum Planning Analysis Cell (PPAC). The national level PNG consumption data was divided among every Indian state based on its share of PNG connection data.

Diesel

Diesel consumption from Diesel Generator (DG) sets is not directly available. A study conducted by Nielson for PPAC observes that 4.3%of diesel retails account for the DG sets in residential and commercial sector in the major Indian states (Nielsen, 2013).

The quantities of diesel consumed by DG sets of different capacity categories (1-19 kilo-Watt (kW), 19-75 kW, and 75-800 kW) in 2012-13 were obtained from a study by ICF International (ICF International, 2014).

Based on expert consultation, DG sets in the categories up to 75 kW are assumed to operate in households; higher sizes are used in commercial enterprises. The percentage share of diesel sold to DG sets up to 75kW (33.9%) was taken as a thumb rule to calculate the diesel used in residential sector. The remaining percentage was accounted to calculate the diesel consumption in commercial sector. The shares of diesel in residential

[13] Raw data from Household Consumer Expenditure, NSS 62nd and 63rd rounds were procured from National Sample Survey Office and were analyzed for the following state wise household cooking and lighting fuels: LPG, Firewood and chips, Kerosene, Coke, Coal and Charcoal

(33.9%) and commercial sectors (66.1%) were calculated from the values reported in study by ICF International for various capacities of DG sets (ICF International, 2014)

There are very few studies available in the public domain on the diesel consumption in DG sets. Hence, the growth in market size of DG sets between 2009-10 and 2012-13 (i.e., 10.06%) (ICF International, 2014) has been used as representative of growth in diesel consumption, across the years.

Agriculture

LSHS, HSDO, LDO, Furnace Oil and LPG

- Data for FY 2004-05 to 2014-15 were obtained from PPAC.

Diesel (from retails)

- The share of diesel consumed in majority of the Indian states by tractors, agricultural pump sets and implements through retail sale in 2012-13 was provided in a study conducted by Nielson for PPAC (Nielsen, 2013). The total diesel consumed in agricultural sector for FY 2008-09, 2009-2010 and 2010-11 were reported by National Institute of Public Finance Policy (NIPFP) (Anand, 2012). The percentage share of diesel (retails) consumed in agriculture sector were calculated for the remaining years.

$$Share\ of\ diesel\ consumed\ from\ retails\ (\%) = \frac{Share\ of\ diesel\ consumed\ in\ agriculture\ sector\ *\ share\ of\ diesel\ consumed\ from\ retails_{2012-13}}{Share\ of\ diesel\ consumed\ in\ agriculture\ sector_{2012-13}}$$

Fisheries

Kerosene and diesel

- The state-wise diesel (2010-11 to 2014-15) and kerosene (2004-05 to 2014-15) consumption by fishing fleets in Karnataka were obtained from Department of Fisheries and Food Civil Supplies & Consumer Affairs in Karnataka.
- The state-wise diesel (2004-05 to 2010-11) and kerosene (2010-11) consumption by fishing fleets in Kerala were obtained from an academic journal paper (N. Aswathy, 2013) The numbers from the graph were extracted using Graph Digitizer software.
- The kerosene supplied for the fisheries sector by Public Distribution System and Matsyafed (Kerala State Co-operative Federation for Fisheries Development Ltd) in Kerala was obtained from Civil Supplies Department, Kerala for the period 2011-12 to 2014-15. Since, this contributes only a part of the total kerosene consumption by fishing fleets in Kerala, this primary data was not considered in the emission calculation.
- The quantity of subsidized diesel and kerosene supplied to fisheries sector in Tamil Nadu was provided in the policy notes published by Department of Fisheries, Tamil Nadu (GoTN, 2005; GoTN, 2006; GoTN, 2007; GoTN, 2008; GoTN, 2009; GoTN, 2010; GoTN, 2011; GoTN, 2012; GoTN, 2013; GoTN, 2014) (GoTN, 2015). Since the data is not available for the total consumption of diesel and kerosene in Tamil Nadu, these values were not used for calculating the emission estimates.
- The state wise-number of motorized and mechanized fishing fleets in 2005, 2010 and 2016 were obtained from the Marine Census (DAHD, 2014) (The World Bank, 2010) and from Department of Fisheries, Karnataka.
- The number of fishing fleets for the intermediate years was calculated using linear interpolation by applying the CAGR between 2005 and 2010 and 2010 and 2016 and the total kerosene and diesel consumption obtained at the national level is distributed among each state based on the share of motorized and mechanized fishing fleets in India, respectively.

In cases where activity data were unavailable for intermediate years, linear interpolation of data was used to calculate the activity data. The difference in the data between two years was equally distributed in the intermediate years. Since, activity data were available in financial year format, the data were apportioned by taking the weighted average of three-fourth of preceding year and one-fourth of the succeeding year, to convert into calendar year format.

Uncertainty

Given the average quantity of LSHS consumed in the other sector, the implications LSHS will have on emissions will be insignificant. However, it is imperative to state that LSHS is used only in the agricultural sub-sector. Charcoal and natural gas are used in residential and commercial establishments for cooking activity, and uncertainty in these fuels represents a small fraction of emissions from residential sector. Other reasons may include aggregation errors and measurement inaccuracy.

IPCC Source Category	Sector	Gas	Activity data uncertainty (%)	EF uncertainty (%)	Combined uncertainty (%)
Residential, Agriculture & Fisheries	Energy	CO_2	25	5	25.49
Residential	Energy	CH_4	10	150	150.33

Source Category specific QA/QC

The quality of data is maintained by the reliability of the source of the data. The activity data, emission factors and assumptions made are collected from reports published by government departments, peer-reviewed international statistics documents, individual peer-reviewed and published academic research works and information disseminated by technology suppliers. The data were validated from other available sources in public domain. For example, kerosene consumption data in residential sector for 2006-07 was validated from a report published by International Institute for Sustainable Development (IISD) (Clarke, 2014). Owing to limitations in availability of select fuels like charcoal and kerosene (household) data, interpolation method was applied to bridge identified gaps. These data points are validated with experts' solicitation through interviews and other literature.

Recalculation

This is the first exercise for state level estimates as compared to National level estimates wherein we already had 2007-12 data. Therefore, recalculation is not applicable.

Verification

The GHG estimates were calculated within the national boundary of India. The emissions were calculated using the 2006 IPCC guidelines for national GHG inventories methodology and the methodology was applied consistently in the calculations. The activity data are sourced from credible sources and have been referenced appropriately in the document.

The emissions reported in 2007 INCAA and 2010 BUR were compared with the calculated emission estimates for the residential, commercial, agriculture and fisheries sectors. It can be seen that the emissions from residential and agriculture/fisheries sector have reduced by 27% and 56%, respectively from 2007 to 2010. Given that non-electric energy consumption in these sectors has increased over the years based on official documents, it can be inferred that the reduction reported between 2007 and 2010 can be attributed to change in accounting and/or reporting method. The emissions from commercial sector have increased by 42% during this period, whereas the overall emissions have reduced by 47%.

Emissions (Million tCO_2e)	INCCA 2007	CSTEP 2007	% deviation	BUR 2010	CSTEP 2010	% deviation
Residential	138	100	-27%	85	104	22%
Commercial	2	5	215%	5	7	57%
Agriculture/Fisheries	34	23	-33%	3	26	803%
Total	173	128	-26%	92	138	49%

Planned improvements

Since, the latest NSSO 'Consumer Expenditure' survey on fuel used in household cooking and lighting was conducted in 2011-12, PCMC of fuelwood, coke, coal and charcoal were extrapolated using CAGR between 2009-01 and 2011-12. The PCMC of these fuels for the time period after 2011-12, will be updated based on the next round of NSS 'Consumer Expenditure' survey.

Similarly, latest PNG sales data for domestic and commercial sectors will be updated based on the data that will be published by PPAC.

1.B Fugitive emissions from fuels

Category Description

Fugitive (Fuel Production) emissions are estimated from mining, transportation, storage and processing of solid, liquid and gaseous fuels. The activity data were sourced from Ministry of Coal and MoPNG.

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
1.	Energy			
1B	Fugitive emissions from fuels			
1B1	Solid fuels	Secondary	High	Ministry of Coal
1B1a	Coal mining and handling			
1B2	Oil & Natural Gas	Secondary	High	Ministry of Petroleum and Natural Gas
1B2a	Oil			
1B2b	Natural Gas			

Activity wise emission factors are obtained from a government report published in 2010 (MoEF, 2010). This includes emissions from both solid (coal) fuels and oil and natural gas production, as listed below:

Type of Fuel		Activities		Emission factor	Unit (CH_4)
Solid Fuels	Underground Mines	Mining	Deg I	2.91	m^3/T
			Deg II	13.08	
			Deg III	23.64	
		Post-Mining	Deg I	0.98	
			Deg II	2.15	
			Deg III	3.12	
	Surface Mines	Mining		1.18	
		Post-Mining		0.15	
Oil & Natural Gas	Oil	Number of Wells		0.003	Gg/well
		Oil Production		0.000334	Gg/'000 T
		Refinery Throughput		6.75904×10^{-5}	Gg/MT
	Natural Gas	Gas Production		0.003556	Gg/MMCM
		Gas Processing		0.010667	Gg/MMCM
		Gas Distribution		0.010667	Gg/MMCM
		Leakage		0.006482	Gg/MMCM
		Flaring		0.000641	Gg/MMCM

To convert one volume of methane from coal mining to ton (weight), a conversion factor of 0.0006802[14] is applied, as per the US Environmental Protection Agency Interactive Units Converter Coalbed Methane Outreach Program (CMOP).

Methodology

IPCC ID	GHG source & sink categories	CO_2		CH_4		N_2O	
		Method Applied	Emission Factor	Method Applied	Emission Factor	Method Applied	Emission Factor

[14] http://www.mdpi.com/2071-1050/4/9/1966/htm

1.	Energy						
1B	Fugitive emissions from fuels						
1B1	Solid fuels	T1	D	T1	D	T1	D
1B2	Oil & Natural Gas	T1	D	T1	D	T1	D
1B3	Other emissions from energy productions	T1	D	T1	D	T1	D

Notes: T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default

Solid Fuels

- Data for total coal mined from Underground (UG) and Open Cast (OC) mines, in addition to the share of UG and OC coal, are obtained from the Provisional Coal Statistics report published by Ministry of coal (Coal Controller's Organisation, 2016).
- CAGR of production was employed as a proxy to estimate coal production, during 2005-05 and 2005-06, especially for select Coal India Limited (CIL) and other small mines.
- In totality, fugitive emissions from coal production occur in twelve states – Telangana, Arunachal Pradesh, Assam, Chhattisgarh, Jammu & Kashmir, Jharkhand, Madhya Pradesh, Maharashtra, Meghalaya, Odisha, Uttar Pradesh, and West Bengal.
- As per the activity list obtained from INCCA report (MoEF, 2010), emissions occur at two stages while coal is produced – (a) during coal mining and (b) post-mining within the boundary of coal mines.
- To estimate emissions from coal mining in OC mines, the share of coal produced from OC mines is multiplied with the emission factor (mining and post mining as two different activities) to obtain volume of methane emissions generated. This value is further converted to weight, in tons, using a conversion factor of 0.0006802 (referred in category description).
- It is important to note that coal production from UG mines is not available at various depths, Typically, coal production from UG mines occur at three levels of depth, and emission factors are provided at three levels – in this case referred as 'degree of gassiness'. Therefore, we have assumed a share of 33.33% at each level to account for total coal produced from UG mines. The same can be noted in these formulae given below:

$$Emissions\ from\ UG\ Coal\ Mining_{CH4}(t) = \sum_{i=0}^{3}(Activity\ Data(tons) * EF\ Mining_{i_{CH4}}\left(\frac{m^3}{tons}\right) * 0.0006802 tonsCH4 * Share_i)$$

$$Emissions\ from\ UG\ Coal\ Post\ Mining_{CH4}(t) = \sum_{i=0}^{3}(Activity\ Data(tons) * EF\ Post\ mining_{i_{CH4}}\left(\frac{m^3}{tons}\right) * 0.0006802 tonsCH4 * Share_i$$

$$Emissions\ from\ OC\ Coal\ Mining_{CH4}(t) = \left(Activity\ Data(tons) * EF\ Mining\ _{CH4}\left(\frac{m^3}{tons}\right) * 0.0006802 tonsCH4\right)$$

$$Emissions\ from\ OC\ Coal\ Post\ Mining_{CH4}(t) = \left(Activity\ Data(tons) * EF\ Post\ mining\ _{CH4}\left(\frac{m^3}{tons}\right) * 0.0006802 tonsCH4\right)$$

Liquid and Gaseous Fuels

- Data on the number of wells, oil produced and refinery throughput are obtained from MoPNG's Petroleum and Natural Gas Statistics reports (MoPNG, 2016).
- Share of crude oil production from select states is estimated from the reported refinery throughput of oil refining companies. In this case, the refinery throughput is used as a proxy variable to estimate share of oil production in states such as MP, Punjab and Gujarat.
- Data on the number of wells were scantly available; therefore, for years 2010-11 to 2014-15, CAGR based linear interpolation was applied. In few cases, state-wise data on the number of wells were available for states like Assam, Gujarat and Maharashtra. Hence, share of other states were determined by applying the share of refinery throughput.
- Data on the amount of natural gas produced, flared, processed, and distributed is also derived from MoPNG's Petroleum and Natural Gas Statistics reports (MoPNG, 2016). Natural gas processed is what is available after deducting the portion of gas flared from total production. Own consumption of

natural gas is deducted from this figure to arrive at the amount of natural gas distributed. The leakage rate is 1.65% of the gross production of natural gas, as reported in a memo titled 'Fugitive Methane and Greenhouse Warming' (Muller).

$$Emissions\ from\ Oil\ Extraction_{CH4}(t) = \left(Oil\ Production('000tons) * EF_{CH4}\left(\frac{Gg}{'000tons}\right)\right) + \left(Refinery\ Throughput(MMTA) * EF_{CH4}\left(\frac{Gg}{Milliontons}\right)\right) + \left(Number\ of\ Wells * EF_{CH4}\left(\frac{Gg}{well}\right)\right)$$

$$Emissions\ from\ Natural\ Gas\ Extraction_{CH4}(t) = \left(NG\ Production(MMCM) * EF_{CH4}\left(\frac{Gg}{MMCM}\right)\right) + \left(NG\ Distribution(MMCM) * EF_{CH4}\left(\frac{Gg}{MMCM}\right)\right) + \left(NG\ Consumption(MMCM) * EF_{CH4}\left(\frac{Gg}{MMCM}\right)\right) + \left(Flaring(MMCM) * EF_{CH4}\left(\frac{Gg}{MMCM}\right)\right) + \left(Leakage(MMCM) * EF_{CH4}\left(\frac{Gg}{MMCM}\right)\right)\right)$$

Since activity data were available in financial year format, the data were apportioned by taking the weighted average of one-fourth of preceding year and three-fourth of the succeeding year, to convert into calender year format.

Uncertainty

Uncertainty in fuel production can be attributed to missing data (leakage) and detailed coal production data from UG mines (on the basis of depth). Other sources include aggregation errors (refinery throughput, natural gas leakage, number of wells) and measurement inaccuracies. Furthermore, methane emissions from venting, flaring and coal mines (seam gas) must be collected in different time-intervals to establish additional relationships with activity data and emission factors.

Source Category specific QA/QC

The quality of data is maintained by the credibility of the source of the data. The activity data, emission factors and assumptions made are collected from reports published by government and research institutes/individual academic research works. Barring validations, typical production trends are used to compare and validate data points. For example, a general 1.65% leakage rate was assumed to quantify total amount of natural gas leaked in a year. These numbers were further validated with global estimates to ensure that the resultant values are within the acceptable range.

Recalculation

This is the first exercise for state level estimates as compared to National level estimates wherein we already had 2007-12 data. Therefore, recalculation is not be applicable.

Verification

The GHG estimates were calculated within the national boundary of India. The emissions were calculated using the 2006 IPCC guidelines for national GHG inventories methodology and the same was applied consistently in the calculations. The activity data are sourced from credible sources and have been referenced appropriately in the document. For select years (2007 and 2010), the results are verified with government

estimations, with less than 5% deviation. CSTEP's estimates for 2007 and 2010 are comparable to the national estimates published by GoI (INCCA and BUR). The slight difference may be due to the assumptions considered for natural gas leakage and distribution.

Emissions (Million tCO_2e)	INCCA 2007	CSTEP 2007	% deviation	BUR 2010	CSTEP 2010	% deviation
Fugitive	32	36	13%	49	46	-5%

Planned improvements

Rather than equal apportionment, the real values of production of coal from UG mines for all three degrees must be used, to improve the estimates of emissions from coal production from UG mining and post mining. We hope to integrate this change, depending on the response from coal controllers' organization in Kolkata.

Public Consultation & Outreach

As part of the outreach activity, the following experts were contacted to collect the activity data and relevant assumptions.

Name	Designation and Institution	Date
Mr.S S Love	Joint Director (RTI&S), Petroleum Planning & Analysis Cell (PPAC)	30-05-2017
Ms.Dev Priya Kaushal	Deputy Director (MIS), PPAC	02-06-2017
Dr.Udaya S Mishra	Professor, Centre for Development Studies	08-03-2017
Mr.Balakrushna Padhi	PhD student, Jawaharlal Nehru University	22-03-2017
Dr.C.K Murthy	Joint Director, Department of Fisheries, Karnataka	13-04-2017
Mr.Vinu Balakrishnan	Sr. Manager Marketing, GAIL Gas Ltd, Bangalore	17-04-2017
Dr.Leela Edwin	Principal Scientist, Central Marine Fisheries Research Institute	18-04-2017
Sri M.C.Gangadhara	Senior Deputy Director (Procurement and Distribution), Office of the Commissioner, Food Civil Supplies & Consumer Affairs, Karnataka	27-04-2017
Dr.Gopalakrishnan	Director, Central Marine Fisheries Research Institute	05-05-2017
Dr.Kaushik Basu	Assistant Professor, National Law School of India University	05-05-2017
Dr.Indrajit Bairagya	Assistant Professor, Institute for Social and Economic Change	05-05-2017
Mr.P.P.Surendran	Dy. G.M. (Commercial Operations), Matsyafed, Kerala	24-05-2017
Dr.Narasimhugari T L Reddy	Director of Civil Supplies, Kerala	24-05-2017
Mr.A.V. Srinivasan	Former Consultant-Engine and Genset manufacturing (Cooper Corporation)	30-05-2017

Apart from individual meetings with experts, CSTEP researchers organized (refer S.no. 1 in table below) and participated in stakeholder consultations organized by partner institutions in the GHG India Platform.

S.No	Title	Organiser	Date	Venue
1	Workshop on GHG Platform – India: Energy	CSTEP and CEEW	Jan 24, 2017	Hotel Taj Vivanta, Bangalore
2	Workshop on GHG Platform – India: Waste and Industrial Emissions	ICLEI	Feb 3, 2017	Hotel Kenilworth, Kolkata
3	Workshop: GHG Platform India (Energy, IPPU, Waste and AFOLU)	WRI	Mar 17, 2017	WRI India Office, Mumbai
4	Roundtable Consultation of "GHG Emission Estimations Experts"	Vasudha Foundation	April 6, 2017	Amaltas Hall, India Habitat Center, New Delhi

Recommendations

Though government reports provide data required for building emission inventory, there are various data gaps in activity data and country specific emission factors. In order to build a robust database, the following recommendations are made.

a. In order to increase the reliability of data on national emissions, MoEFCC should consider developing 'country-specific' emission factors using real-time measurements, across all the sectors. At present, most of the factors employed are either defaults or global estimates.
b. The activity data specific to diesel consumption in the transport sector needs to be disaggregated, instead of aggregating into 'miscellaneous' header. Thus, it is recommended that when the related ministry collects data, the aggregated numbers must be broken down based on sectoral consumptions such as transport, telecom, commercial, fisheries, etc.
c. CNG and PNG consumption across different sectors needs to be captured and cited diligently in assessment reports (BUR, INCCA), since the usage of alternative fuels is gaining traction within the economy. At present, all gaseous fuels are listed as one item – Natural Gas City sector in MoPNG reports.
d. In order to estimate reliable sector-specific emissions, the respective ministries should consider providing the absolute quantity of subsidized fuels. For example, in fisheries sector, the quantity of subsidized kerosene and diesel consumed by fishing fleets is unavailable in the public domain.
e. MoPNG should consider making available in their reports the total quantity of natural gas (in MMCM) leaked during extraction and distribution.
f. Refinery throughput and number of wells in operation at all drilling sites across the states must be recorded and published by MoPNG

Few of the activity data in commercial, residential, agriculture and fisheries sector were calculated using secondary and tertiary data sources. In order to improve the emission estimates from these sectors, it's recommended that the following data are collected by its corresponding ministries on a monthly basis.

Agency	Data type	Frequency of data collection
Ministry of Petroleum and Natural Gas	State wise PNG sales of domestic and commercial sector	Monthly
Ministry of Petroleum and Natural Gas	State wise accounting of number of DG sets, its capacity, operating hours of DG sets and quantity of diesel consumption in generator sets in domestic and commercial sector	Monthly
Ministry of Petroleum and Natural Gas	Quantity of diesel from retails consumed in agriculture sector by tractors, pumpsets and agriculture implements.	Monthly
Ministry of Petroleum and Natural Gas/ Department of Animal husbandry, dairy and fisheries	State wise sales of kerosene for fishing fleets through public distribution system and other agencies	Monthly
Ministry of Petroleum and Natural Gas/ Department of Animal husbandry, dairy and fisheries	State wise sales of diesel for fishing fleets	Monthly

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Appendix I

Sample Calculation

Andhra Pradesh (2005)

Electricity Generation

$$Emission_{Coal} = \left(Coal\ consumption\ (000\ Tonnes) * NCV_{Coal}\left(\frac{Tj}{Kt}\right) * CO_2EF_{Coal}\left(\frac{t}{Tj}\right)\right)$$

CO_2 $Emission_{Coal}$ = 31,494 (000 Tonnes) * 20 (Tj/Kt) * 95.81 (t/Tj)

= 5,92,32,350 Tonnes

Transport – Road

$$Emission_{Gasoline} = \left(Gasoline\ consumption\ (000\ Tonnes) * NCV_{Gasoline}\left(\frac{Tj}{Kt}\right) * CO_2EF_{Gasoline}\left(\frac{t}{Tj}\right)\right)$$

CO_2 $Emission_{MotorSpirit}$ = 589 (000 Tonnes) * 44.3 (Tj/Kt) * 69.3 (t/Tj)

= 18,07,602 Tonnes

Residential

$$Emission_{LPG} = \left(LPG\ consumption\ (000\ Tonnes) * NCV_{LPG}\left(\frac{Tj}{Kt}\right) * CO_2EF_{LPG}\left(\frac{t}{Tj}\right)\right)$$

CO_2 $Emission_{LPG}$ = 774 (000 Tonnes) * 47.3 (Tj/kT) * 63.1 (t/Tj)

= 23,10,481 Tonnes

Commercial

$$Emission_{LPG} = \left(LPG\ consumption\ (000\ Tonnes) * NCV_{LPG}\left(\frac{Tj}{Kt}\right) * CO_2EF_{LPG}\left(\frac{t}{Tj}\right)\right)$$

CO_2 $Emission_{LPG}$ = 12 (000 Tonnes) * 47.3 (Tj/kT) * 63.1 (t/Tj)

= 35,472 Tonnes

Agriculture

$$Emission_{LDO} = \left(LDO\ consumption\ (000\ Tonnes) * NCV_{LDO}\left(\frac{Tj}{Kt}\right) * CO_2EF_{LDO}\left(\frac{t}{Tj}\right)\right)$$

CO_2 $Emission_{HSDO}$ = 2 (000 Tonnes) * 43 (Tj/kT) * 74.1 (t/Tj)

= 7,748 Tonnes

Fisheries

$$Emission_{Kerosene} = \left(Kerosene\ consumption\ (000\ Tonnes) *\ NCV_{Kerosene} \left(\frac{Tj}{Kt}\right) * CO_2EF_{Kerosene} \left(\frac{t}{Tj}\right)\right)$$

CO_2 $Emission_{Kerosene}$ = 35 (000 Tonnes) * 43.8 (Tj/kT) * 71.9 (t/Tj)

= 1,08,656 Tonnes

Fugitive Emissions

$$Emissions\ from\ Oil\ Production_{CH4}(t) = \left(Oil\ Production('000\ tonnes) * EF_{CH4} \left(\frac{tonnes}{'000 tonnes}\right)\right)$$

CH_4 $Emission_{Oil}$ = 219 (000 Tonnes) * 0.334 (tonnes/'000 tonnes)

= 73 Tonnes