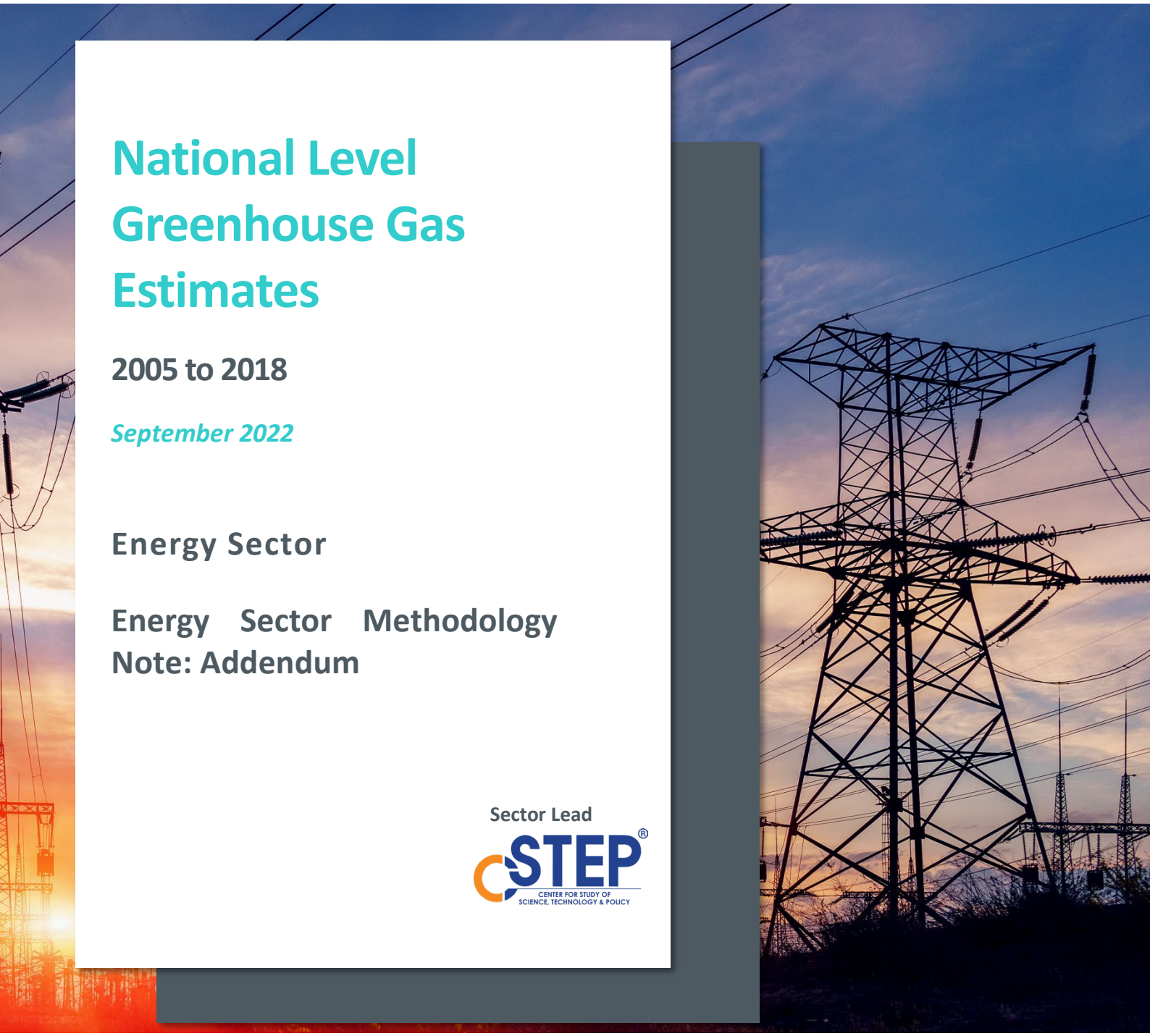
GHG Platform INDIA



National Level Greenhouse Gas Estimates

2005 to 2018

September 2022

Energy Sector

Energy Sector Methodology Note: Addendum

Sector Lead

CSTEP CENTER FOR STUDY OF SCIENCE, TECHNOLOGY & POLICY

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Executive Summary

Key Highlights

- GHG Platform India (GHGPI), is a collective civil-society initiative providing an independent estimation and analysis of India's greenhouse gas (GHG) emissions across key sectors.
- The Platform aims to provide continuous time-series estimates for India's GHG emissions. In the earlier phases of the project, the GHG inventories at state and national levels were prepared for the period 2005-2015.
- The current project phase extended the GHG estimation period further—from 2015 to 2018—expanding the overall time period covered in all phases (2005–2018). The Center for Study of Science, Technology and Policy (CSTEP) has made the emission estimates at the state and national levels for the energy sector.
- Within the energy sector, electricity generation was the largest greenhouse-gas- or GHG-emitting category during 2005–2018. It accounted for 68.1% of the total emissions from the energy sector (excluding industrial energy use[1]) in 2018, followed by the transport sector (which accounted for 18.6% of emissions).
- Coal (followed by diesel) contributed the most to emissions from the energy sector during the 2005–2018 period, growing at a cumulative annual growth rate (CAGR) of 0.5% during this period and constituting 66.2% of the emissions in 2018.
- The transport sector emissions grew rapidly at a CAGR of 7.5% during 2005–2018, followed by electricity generation at 5.7%.

ES 1. Background information on GHG emission estimates

Fuel combustion and fugitive emissions were primarily responsible for GHG emissions in the energy sector. GHG emissions were estimated for three gases: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The carbon-dioxide-equivalent (CO_2e) emissions for CH_4 and N_2O were calculated on the basis of their global warming potential (GWP), as reported in the Second Assessment Report (SAR) of the Intergovernmental Panel for Climate Change (IPCC). These are given in Table ES 1.

Table ES 1: A snapshot of GHG estimates (gas-wise) for the energy sector

IPCC ID	Key Source Category	GHG Emissions for 2018			
		Million tCO_2	Million tCH_4	Million tN_2O	Million tCO_2e
1A	Fuel combustion	1538	2.9	0.05	1613
1A1	Energy industry				
1A1a	Main activity electricity and heat production				
1A1ai	Electricity generation	1093	0.01	0.01	1098
1A3	Transport	292	0.06	0.02	299
1A4	Other Sectors	152	0.98	0.01	177
1B	Fugitive emissions	0.0	1.84	0.00	39

[1] While the IPCC methodology recommends reporting emissions from the industrial energy and captive power plants to be reported in the energy sector. For the ease of data gathering emissions from industrial energy were estimated by the GHGPI partner (CEEW) along with the Industrial Process and Product Use (IPPU) emissions. The energy sector emission estimates with the industrial energy use emissions and captive power plant emissions are provided in the economy-wide assessment sheet (see GHG Platform India website).

ES 2. Summary of GHG trends

Public electricity generation, transport, 'other sectors' (residential, commercial, agriculture, and fisheries), and fuel production are the source categories that contribute significantly to energy-based GHG emissions. The energy sector accounted for 806 $MtCO_2e$ and 1613 $MtCO_2e$ of emissions in 2005 and 2018, respectively, based on the GWP reported in SAR. During the 2005–2018 time period, emissions from the energy sector had grown at a CAGR of 5.5%. The emission intensity of GDP for the energy sector decreased from 13.6 $kgCO_2e$/1000 INR to 11.5 $kgCO_2e$/1000 INR during 2005–2018[2].

Table ES 2: GHG estimates for base year and current year in million tCO_2e

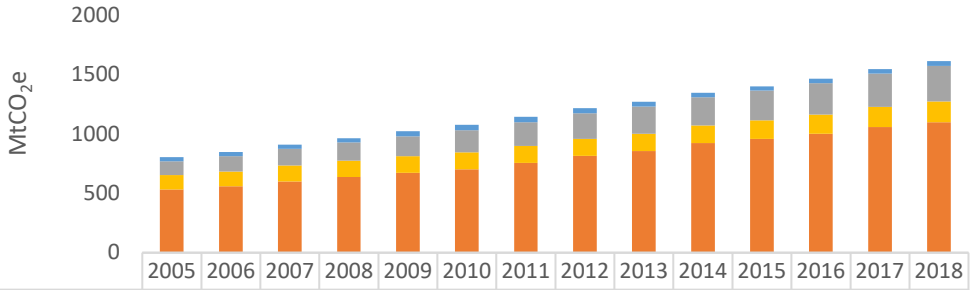
IPCC ID	Source Category	GWP – SAR			GWP – AR6		
		2005	2018	% change[3]	2005	2018	% change
1A1ai	Public electricity generation	533	1098	105%	534	1098	105%
1A3	Transport	116	299	157%	116	299	157%
1A4	Other Sectors	121	177	47%	128	183	43%
1B	Fugitive emissions	36	39	9%	47	51	9%

Among the source categories, electricity generation accounted for the highest share of emissions in the 2005–2018 time period. The key contributor to GHG emissions (from electricity generation) are coal-based power plants. However, emissions increased only marginally (from 66.3% to 68.1%) during this period. This can be attributed to the efforts to decarbonise India's electricity generation sector through various policy measures that accelerated deployment of new renewable energy capacity. Between 2005 and 2018, transport sector emissions increased by 2.5 times. The share in overall energy emissions increased from 14.4% in 2005 to 18.6% in 2018 due to increased transport demand and use of private vehicles.

The share of overall emissions from the residential, commercial, agriculture, and fisheries sectors, together categorised as 'Other Sectors', decreased from 15% in 2005 to 11% in 2018. This was mainly due to the shift to cleaner fuels—such as liquid petroleum gas (LPG) and piped natural gas (PNG)—from diesel, furnace oil, and coal, within the sector. Among 'Other Sectors', residential sector contributed the highest to the emissions. Fugitive emissions (emissions during fuel production) recorded the lowest CAGR of 0.6%. The share of fugitive emissions in overall energy emissions declined from 4.4% in 2005 to 2% in 2018. This can be attributed to the shift from underground mining to open-cast mining of coal, and low growth in natural gas and oil production. Figure ES 1 provides the time-series GHG emission estimates across key source categories in the energy sector.

[2] Emission intensity of gross domestic product (GDP) was estimated using the GDP (2011-12 prices) reported in National Account Statistics (Ministry of Statistics and Programme Implementation, 2021)

[3] % change in values of 2018 (from 2005 values). Percentage change = $\frac{Emissions\ in\ 2018 - Emissions\ in\ 2005}{Emissions\ in\ 2005}$ x 100



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fugitive Emissions	36	35	36	37	43	47	45	42	40	38	37	36	37	39
Transport	116	129	141	153	169	186	201	215	228	235	250	263	282	299
Other Sectors	121	126	133	136	139	141	144	145	147	150	156	164	169	177
Public Electricity Generation	534	559	600	639	674	704	755	814	855	923	958	1000	1057	1098

Figure ES 1: Emissions from energy sector

1. Introduction and Background

1.1 Context

GHG Platform India (GHGPI) is a collective civil-society initiative providing an independent estimation and analysis of India's greenhouse gas (GHG) emissions across key sectors. The Platform aims to provide continuous time-series estimates for India's GHG emissions. It relies on the guidance provided by the 2006 Intergovernmental Panel on Climate Change Guidelines for National GHG inventories[4] (2006 IPCC Guidelines) for national-level GHG emission estimates and covers the period from 2005 to 2018. The Platform aims to support the existing efforts of the Indian Government in activities such as the process of submitting the National Communications to the United Nations Framework Convention on Climate Change (UNFCCC). It also aims to address the existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and increasing the volume of analytics and policy dialogue on India's GHG emissions sources, profile, and related topics. A detailed state-level emission estimate was calculated and aggregated further to evaluate the national-level emissions.

The GHG emission estimates in this report include emissions from carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). For the study, we considered the GWP values as per IPCC's SAR and Sixth Assessment Report (AR6) (given in Table 1.A). These values were used to convert and report emissions in each sector and sub-sector in terms of their carbon dioxide equivalent (CO_2e).

Table 1.A: Global warming potential as per IPCC assessment reports[5]

Name of the Gas	Formula	Global Warming Potential (GWP)	
		SAR	AR6
Carbon dioxide	CO_2	1	1
Methane	CH_4	21	28
Nitrous oxide	N_2O	310	273

[4]As per the Paris Agreement (Article 13 paragraph 7[a]), countries party to the agreement should use the IPCC methodology for preparing their emission estimates.

[5]https://www.ghgprotocol.org/sites/default/files/ghgp/Global-Warming-Potential-Values%20%28Feb%2016%202016%29_1.pdf

1.2 Key economic sectors covered

Emissions in the energy sector are mainly caused by the conversion of primary energy sources into usable energy forms in refineries and power plants, transmission and distribution of fuels, and use of fuels in stationary and mobile applications.

The key source categories covered in this study are as follows:

- IA: Fuel combustion activities
    - 1A1- Energy Industries
        - 1A1a Main activity electricity and heat production
            - 1A1ai- Electricity generation
    - 1A3- Transport
        - 1A3a- Civil aviation
            - 1A3aii Domestic aviation
        - 1A3b- Road transportation (fuel-based; covering sub-sectors 1A3bi to 1A3bvi)
        - 1A3c- Railways
        - IA3d-Water-borne navigation
            - 1A3dii- Domestic water–borne navigation
    - 1A4- Other Sectors
        - 1A4a- Commercial/Institutional
        - 1A4b- Residential
        - 1A4c- Agriculture/Forestry/Fishing/Fish Farms

- 1B: Fugitive Emissions From Fuels
    - 1B1- Solid fuels
        - 1B1a- Coal mining and handling (all sub-sectors from 1B1ai to 1B1aii)
    - 1B2- Oil and piped natural gas (PNG) (all sub-sectors from 1B2a to 1B2b)

1.3 Boundary of GHG estimates

This study assesses India's GHG emissions. The emission estimates were analysed at the state level and aggregated to the national level. In terms of sectoral boundaries, this exercise looks at the energy sector.

1.4 Reporting period

In the earlier phases of the GHGPI project (Phase I to III), the GHG inventories at state and national levels were prepared for the period 2005-2015. The current project phase—Phase IV—extended the period of GHG estimates beyond 2015, to 2018, thus expanding the overall time period covered under all phases (viz. 2005 to 2018). We have considered 2005 as the base year, in accordance with the base year for India's Nationally Determined Contribution (NDC) commitments to the UNFCCC (Ministry of Environment, Forest and Climate Change, 2015).

1.5 Outline of GHG estimates

This exercise entailed making a time-series emission estimate for sectors mentioned in Section 1.2 at the state (sub-national) level. In the current phase of the GHGPI initiative, the state-level emissions from energy sector were estimated for 2016, 2017, and 2018. The estimations were based on literature review, and followed the 2006 IPCC Guidelines for National GHG Inventories and other internationally acceptable guidance. Emissions were estimated on the basis of fuel sources, sub-

sectoral activities, and emission factors. Section 2 provides the sectoral trends of GHG emissions and the key drivers of emission, and Section 3 provides the overview of the energy sector, and methodology updates in Phase IV (from Phase III). The detailed sectoral methodology, source of activity data, and fuel emission factors are provided in the Phase III Methodology Note. Section 4 broadly compares the estimated emissions for 2007, 2010, 2014, and 2016, with the emissions reported by Ministry of Environment, Forest and Climate Change (MoEFCC) for these years.

1.6 Institutional information

The Center for Study of Science, Technology and Policy (CSTEP) is responsible for carrying out the current project. The details of the team involved in Phase IV emissions estimation work are given below:

Roshna Nazar is a Senior Associate in the climate, environment and sustainability domain. She is the energy sector lead for the GHGPI project and has worked on the power and fugitive emission sectors within the project.

Trupti Deshpande is a Senior Associate in the climate, environment and sustainability domain. She has anchored the transport sector emissions inventory in the project.

Kaveri Ashok is a Senior Associate in the climate, environment and sustainability domain. She has worked on the emission estimates of 'Other Sectors', which include residential, commercial, agriculture, and fisheries.

Dr S. S. Krishnan is an Advisor at CSTEP. He supervised and reviewed the project methodology employed and the emission estimates obtained.

Dr Pratima Singh is a Research Scientist in air pollution studies domain at CSTEP. She supervised and reviewed the project methodology and emission estimates.

1.7 Data collection process and storage

In this phase, reports and datasets for the energy sector were obtained in the form of soft copies. CSTEP has not purchased any data in the current phase. Where deemed necessary, the transaction fees were paid, especially for Right to Information (RTI) filing to obtain data from government agencies.

The details of activity data sources used in the previous phases are provided in the Energy Sector Phase III Methodology Note. The details of the data collated in the current phase for state-level sectoral estimates are provided below.

Electricity Generation:
Fuel-wise electricity generation data from 2005-06 to 2010-11, and from 2012-13 to 2018-19 were obtained from Central Electricity Authority (CEA) reports for public electricity generation (utility based) (CEA, 2022). Emissions from combined Heat and Power Generation (CHP) (1A1ai) are required to be reported under 1A1a Main Activity Electricity and Heat Production, as per the 2006 IPCC Guidelines. Bagasse-based cogeneration (biomass-based CHP), however, is reported by CEA under Renewable Energy Systems. Being a CO_2-neutral source, biomass acts both as a source and as a sink. Therefore, emissions from biomass-based CHP electricity were not considered under this exercise.

Data on state-wise fuel consumption, which included state- and private-owned power plants from CEA's General Review Books were directly used for emission estimates (CEA, 2016, 2017, 2018, 2019). For estimating the state-wise fuel consumption of central plants located in a given state, fuel-wise electricity-generation data and regional fuel-consumption data were used. The detailed methodology followed for allocating the regional fuel-consumption data to states has been explained in the Phase III Methodology Note.

Transport Sector:
The 2006 IPCC Guidelines recommend using vehicle-wise activity data to estimate emissions from this sector (1A3). Here, owing to lack of data, an alternative strategy had to be adopted. Fuel consumption data was collected mode-wise (road, rail, air, and water), as reported by the Ministry of Petroleum and Natural Gas (n.d.).

The light diesel oil (LDO) and furnace oil (FO) data for the road transport sector, and the LDO consumption in railways were not available publicly. Looking at their decreasing consumption trend, marginal numbers, and unavailability of uniform data, the consumption of LDO and FO in road transport is assumed to be extinct. For the missing data on LDO consumption in railways, an RTI application was made; based on the response from the railway department, the use of LDO in railways is also considered to be zero.

Data on aviation turbine fuel (ATF) used in the aviation sector has been sourced from statistics published by Ministry of Petroleum and Natural Gas (2014, 2016, 2017, 2018, 2019). This was validated against reports published by the Ministry of Civil Aviation and no deviations were observed.

Other Sectors:
Data on energy consumption at the household level and in commercial/institutional establishments is required to calculate emissions from these sectors. National Sample Survey Office (NSSO) data sets were used to determine household-level fuel consumption (coal, charcoal, coke, and fuelwood). These data sets provide data separately for urban and rural households. The Statistics Handbook of Ministry of Petroleum and Natural Gas (MoPNG), which has been used to collate activity data, such as natural gas for the commercial sector, provides details on the quantity of fuel consumed (such as kerosene) by the residential sector too (MoPNG, 2017, 2018, 2019).

The residential sector fuel-activity estimation vis-à-vis coal, charcoal, and coke was challenging due to the scant and non-uniform availability of data. We have modified the methodology to fill the data gaps, which is explained in Section 3.

Energy consumption in the agriculture sector is categorised into stationary combustion (IA4ci) of diesel for pumping, and mobile combustion (IA4Cii) of diesel in farm mechanisation. Diesel consumed by pump sets and tractors has been considered for this sector as well. Activity data for agriculture sector was collated primarily from the information obtained under the RTIs filed. Emissions from the fisheries sector are accounted for by collating diesel and kerosene consumption in fishing fleets (Department of Fisheries, 2016, 2018, 2020).

Fugitive Emissions:
Fuel production (IB) estimates include production data for coal, oil, and natural gas. These data sets were obtained from reports published by the Coal Controller's Organization (2022) and MoPNG (2020). The data on state-wise open cast (OC) and underground (UG) production of coal were not available. The OC and UG production data for Coal India Limited's Subsidiaries and Singareni Collieries Limited (SCCL) were collated from the provisional coal statistics reports of Ministry of Coal. Based on the geographical location of mines (found using Google maps) and state-wise total production from

the provisional coal statistics reports, the OC and UG production has been allocated to different states using a trial-and-error method to match the totals.

2. Trends in GHG Emissions

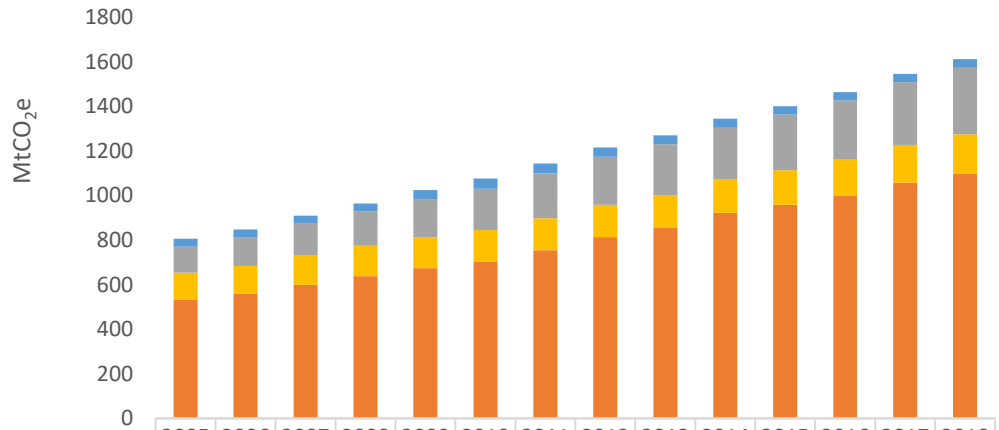
2.1 Trends in aggregated GHG emissions

The energy sector accounted for 807 $MtCO_2e$ and 1613 $MtCO_2$ e of GHG emissions in 2005 and 2018 respectively. Between 2005 and 2018, these emissions grew at a rate of about 5.5% annually (increasing by two times over the 2005 levels in 2018). Among the key source categories, electricity generation (EG) accounted for the highest share of emissions in both 2005 and 2018, increasing marginally from 66.3% to 68.1%. In fact, the contribution of emissions from electricity generation reduced in 2018, as compared to that in 2015. This indicates the fruition of efforts to decarbonise India's electricity generation sector through various policy measures such as the National Solar Mission (NSM), Renewable Energy Purchase Obligations (RPO), and subsidy and incentive schemes for new renewable energy capacity.

The transport sector saw the highest annual growth rate (13% per annum in registered vehicles (Ministry of Road Transport & Highways, 2018), increasing its share in energy emissions from 14.4% to 18.6%. During this period, transport emissions increased by 2.5 times from 116 $MtCO_2e$ to 299 $MtCO_2e$, on account of increased transport demand and greater use of private transport.

The share of overall emissions from the residential, commercial, agriculture, and fisheries sectors, categorised as 'Other Sectors', decreased from 15% in 2005 to 11% in 2018. However, the absolute emissions from 'Other Sectors' grew at about 3% between 2005 and 2018 (from 121 $MtCO_2e$ to 177 $MtCO_2e$ respectively). The shift towards cleaner fuels, especially in the residential sector helped in limiting the emissions to a lower growth rate.

Emissions due to fuel production (fugitive emissions) did not observe any significant growth. This was mainly due to a shift from underground mining to open-cast mining. The sector recorded the lowest growth (less than 1%). In fact, its share in overall energy emissions declined from 4.4% in 2005 to 2% in 2018. The trends in emissions (absolute emissions in $MtCO_2e$) from the various categories are shown in Figure 2.1.A.



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Fugitive Emissions	36	35	36	37	43	47	45	42	40	38	37	36	37	39
Transport	116	129	141	153	169	186	201	215	228	235	250	263	282	299
Other Sectors	121	126	133	136	139	141	144	145	147	150	156	164	169	177
Public Electricity Generation	534	559	600	639	674	704	755	814	855	923	958	1000	1057	1098

Figure 2.1.A Trend in emissions from energy sector

2.2 Trends in GHG emissions (by GHG type)

2.2.1 Energy

CO_2 constituted around 95% of the total GHG emissions from the energy sector in 2018. In the transport sector, CO_2 accounted for nearly 98% of GHG emissions and N_2O for around 2%.N_2O emissions accounted for 1% of the total GHG emissions from the energy sector, with transport sector as the major contributor. Fuel production (fugitive sector) emits only methane (CH_4), which constituted 4% of the overall energy emissions. There was a marginal emission of CH_4 from the transport sector as well. Table 2.A shows the composition of each of these gases in key source categories for 2018

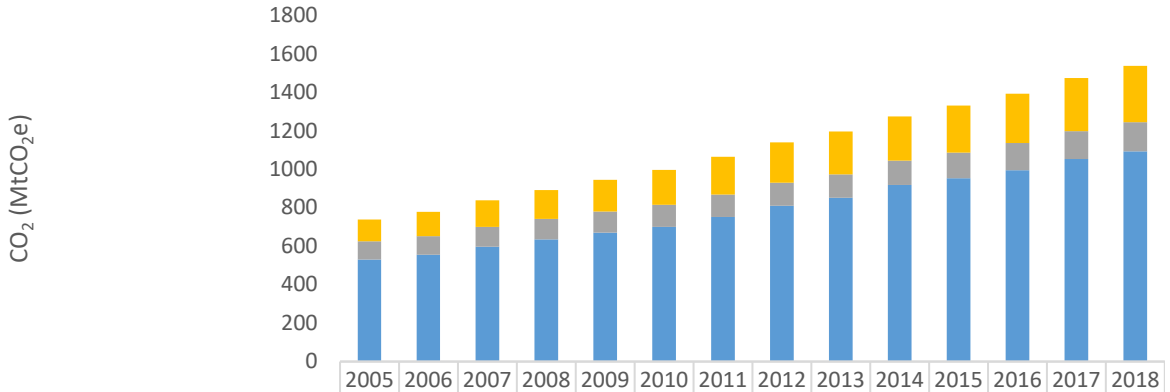
Table 2.A: Energy: Composition of emissions in key source categories for 2018

IPCC ID	Key source category	%CO_2	%CH_4	%N_2O
1A1ai	Electricity Generation	99.5%	0.01%	0.4%
1A3	Transport	97.7%	0.4%	1.8%
1A4	Other Sectors	93.41%	4.06%	1.7%
1B	Fugitive Emissions	0%	100%	0%

Sector-wise CO_2, CH_4, and N_2O emissions from the energy sector are given in Figure 2.2.A, Figure 2.2.B, and
Figure 2.2.C, respectively. The CO_2 emissions (in terms of $MtCO_2e$) increased from 738 $MtCO_2e$ in 2005 to 1538 $MtCO_2e$ in 2018 (CAGR of 5.8%). It is important to note that the growth rate of CO_2 emissions was higher than the growth rate of total GHG emissions during this period. This higher CO_2 emissions growth rate was caused by a relatively higher growth in 'Public Electricity Generation;' and 'Transport' sectors than in sectors with a higher non-CO_2 component such as 'Other Sectors' and 'Fugitive Emissions'.

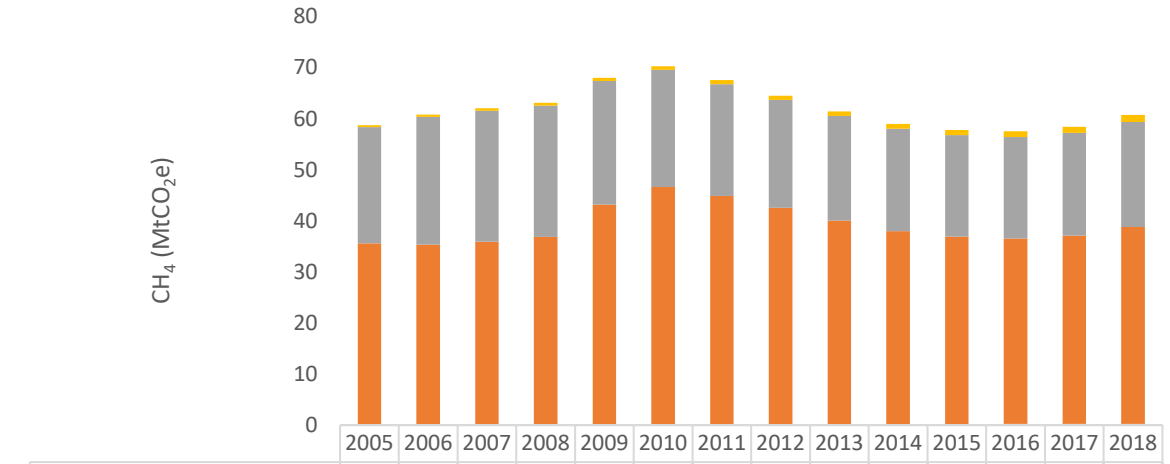
CH_4 emissions during the 2005—2018 period saw only a marginal growth (CAGR of 0.26%), owing to a lower growth in fugitive emissions. In case of N_2O emissions, moderate growth with a CAGR of 3.48%

is observed. N_2O emissions from 'Other Sectors', which accounted for 50% of total N_2O emissions in 2005, saw a fall due to the shift towards cleaner fuels and energy-efficient processes.



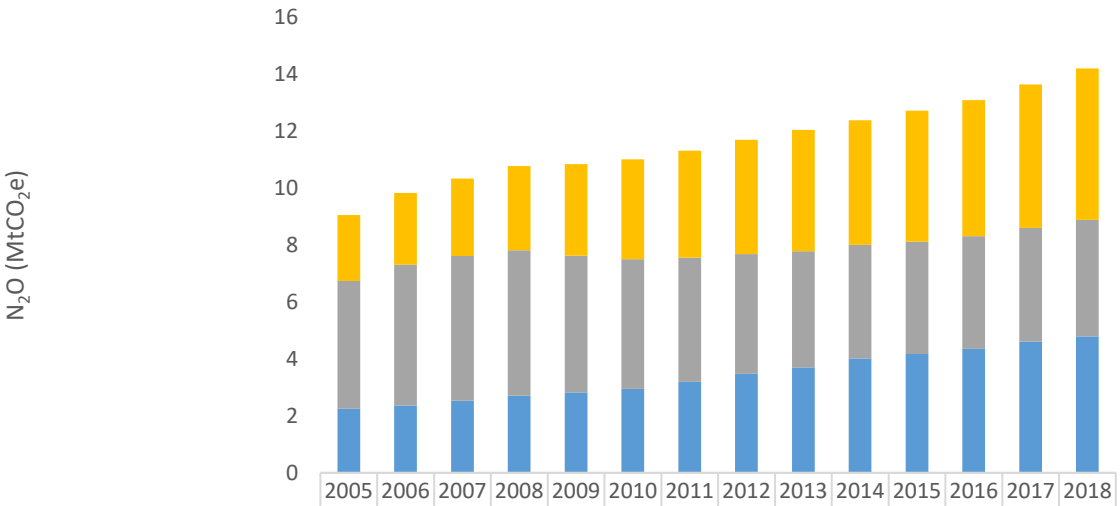
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Transport	113	126	138	150	165	182	196	210	223	230	244	257	276	293
Other Sectors	94	96	103	106	110	114	117	120	122	126	132	141	145	152
Fugitive emission	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Public Electricity Generation	531	556	597	636	671	701	752	811	851	919	954	996	1053	1093

Figure 2.2.A: CO_2 Emissions from energy sector



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Transport	0.4	0.4	0.5	0.5	0.6	0.7	0.8	0.8	0.9	0.9	1.0	1.1	1.2	1.3
Other Sectors	22.7	25.0	25.6	25.7	24.2	22.9	21.9	21.1	20.5	20.0	19.9	19.9	20.1	20.6
Fugitive emission	35.5	35.2	35.8	36.7	43.1	46.5	44.7	42.4	39.9	37.8	36.7	36.3	36.9	38.6
Public Electricity Generation	0.1	0.1	0.1	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2

Figure 2.2.B: CH_4 emissions from energy sector



	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Transport	2.3	2.5	2.7	3.0	3.2	3.5	3.8	4.0	4.3	4.4	4.6	4.8	5.0	5.3
Other Sectors	4.5	5.0	5.1	5.1	4.8	4.6	4.4	4.2	4.1	4.0	4.0	4.0	4.0	4.1
Fugitive emission	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Public Electricity Generation	2.3	2.4	2.5	2.7	2.8	3.0	3.2	3.5	3.7	4.0	4.2	4.4	4.6	4.8

Figure 2.2.C: N_2O emissions from energy sector

2.3 Key drivers of emission trends in various sectors

2.3.1 Public electricity generation

Emissions from electricity generation are driven by coal-, gas-, lignite-, and naphtha-based power plants. Electricity consumption in the residential, commercial, and industrial sectors has been increasing. To meet this increased demand, the capacity of electricity generation has also undergone an increase. The key drivers of increased electricity generation, thus, are population growth, urbanisation, and industrialisation. The growth in public-electricity-generation-based emissions saw a lower CAGR (of 4.6%) post 2015, as compared to that in the pre-2015 period (6%). This is majorly attributed to an increase in RE deployment in the post-2015 period.

2.3.2 Transport

Increasing disposable income and expanding road transport infrastructure has resulted in a steady increase in the demand for two- and four-wheelers (Gupta et al., 2018). Consequently, the consumption of motor spirit and high-speed diesel oil (HSDO) has also increased. Motor spirit consumption had tripled by 2018, in comparison with the 2005 consumption data, with road transport contributing nearly 88% of the overall emissions from the transport sector.

2.3.3 Other Sectors

The use of LPG, PNG, diesel, fuelwood, and kerosene mainly drives emissions in the residential sector. The consumption of diesel, PNG, and LPG, in particular, has shown an upward trend, while fuelwood and kerosene consumption has declined during the study period. The *Pradhan Mantri Ujjwala Yojana* and the National Biomass Cookstoves Programme[6] have helped in reducing the amount of biomass consumption. These schemes focussed on improving the efficiency of biomass consumption and increasing the penetration of LPG. In the agriculture sector, diesel consumption contributed to over 90% of emissions (on an average from 2005 to 2018-19), triggered by the expanding farm

[6] https://mnre.gov.in/national-biomass-cookstoves-programme

mechanisation for higher productivity. The emissions in the fisheries sector is mainly due to diesel- and kerosene-fuelled fishing vessels. The share of emissions from diesel use has been increasing in the sector, which reflects the increasing mechanisation of the vessels.

2.3.4 Fugitive emissions

The demand from electricity generation and industries sectors primarily drives the increase in coal production. Natural gas production saw a decrease in production in 2018, as compared to 2005. For the same period, oil production increased at a CAGR of 0.9%. The low/reduced growth in natural gas and oil production can be mainly attributed to the ageing wells (that have become less productive over time).

3. Methodology Update

The methodology explained in the Phase III Methodology Note was followed for the entire energy sector, except for the residential sector under 'Other Sectors'.

3.1. Methodology followed for residential sector in Phase III

Limited data points are available for the 2005–2018 for coal, charcoal, and coke fuel activity in the residential sector. Monthly per capita consumption data for 2004-05 and 2011-12 from NSSO (for all states except islands, small states, and UTs); and for 2005-06, 2006-07, and 2009-10 from TERI Energy & Environment Data Diary and Yearbook (TEDDY), were collated. To fill in the data gaps (in the previous methodology), state-wise extrapolation was done using the CAGR estimated for the 2009-10 and 2011-12 data points. The CAGR-based method, when applied beyond 2016, resulted in exponential growth in fossil-based fuels in the residential sector, which was counterintuitive and against the actual trend. During Phase III, the NSSO and TEDDY data were used in conjunction with each other to fill in the data gaps. The data disparity between the two sources[7] in some of the states contributed to unreliable growth trends when extrapolated (Figure 3. 1 A).

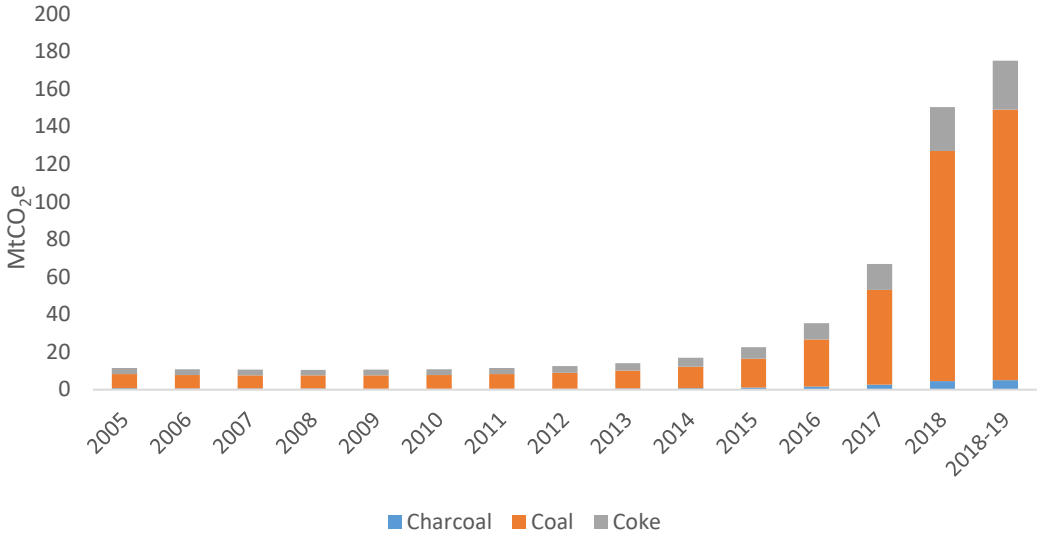


Figure 3. 1 A: Emissions from coal, coke, and charcoal in residential sector (1A4b) (based on Phase III methodology)

3.2. Revised methodology followed for residential sector in Phase IV

In this phase, to address the issue of exponential growth in fossil-based fuels arising from data disparity in sources—when CAGR-based method was used for extrapolation—a linear extrapolation is done for NSSO data for the states for which data is available (2004-05 and 2011-12), and TEDDY data for the remaining states (2005-06 and 2009-10). The GHG emissions from residential sector—employing the new methodology—is shown in Figure 3. 2 A.

[7] For instance, consider the monthly per capita consumption of coal by Punjab (coal-urban). As per TEDDY it was 0.001 kg/month/capita in (2009-10) and as per NSSO it was 0.017 kg/month/capita in (2011-12). Since both the data sources are not available for the same year, this sudden jump in data is unreliable.

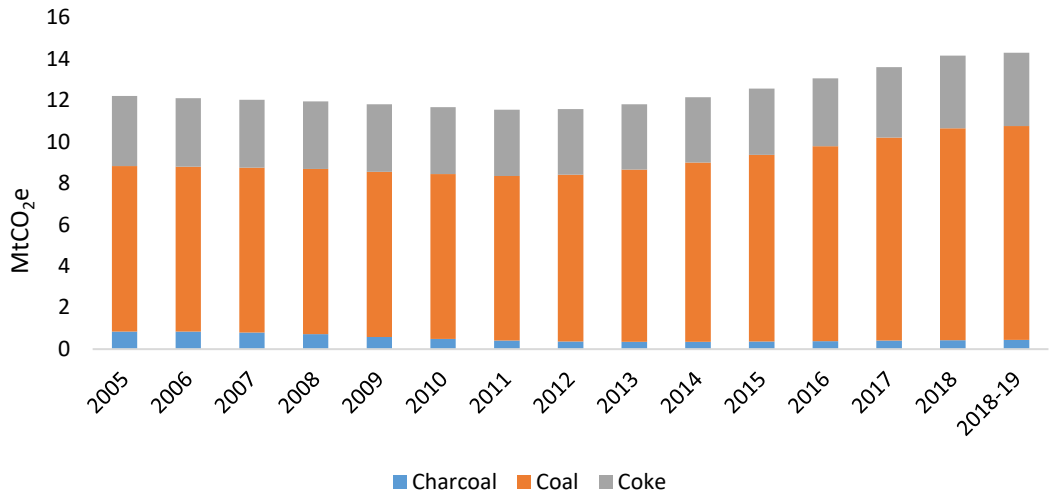


Figure 3. 2 A: Emissions from coal, coke, and charcoal in residential sector (1A4b) (based on revised Phase IV methodology)

A comparison between the two methodologies and the deviation in emission estimates from the Biennial Update Reports (BUR) is provided in
Table 3.2. A. With the use of new methodology for estimating GHG emissions, the deviation from the official estimates for the residential sector has reduced considerably.

Table 3.2. A: Comparison of residential sector (1A4b) emissions obtained by Phase III and Phase IV methodology with BUR estimates

Year	Study	Emissions ($MtCO_2e$)	Deviation (%)[8]
2010	BUR I	85	
	GHGPI Phase III	110	23%
	GHGPI Phase IV	110	23%
2014	BUR II	101	
	GHGPI Phase III	123	18%
	GHGPI Phase IV	113	11%
2016	BUR III	127	
	GHGPI Phase III	170	25%
	GHGPI Phase IV	120	-6%

[8] Deviation % = $\frac{GHG\ Platform\ India\ estimate - BUR}{BUR}$ x 100

4. Comparison with National Inventories

The emission estimates for 2007, 2010, 2014, and 2016 were compared with the national estimates published by the Government of India (Ministry of Environment, Forest and Climate Change, 2010, 2015, 2018). Table 4.A provides a comparison of emission estimates and indicates the percentage deviation.

Table 4.A: Energy: Source-category-wise details of deviation in GHG estimates between GHGPI and official inventories published by the Government of India

Key Source Category	2007			2010			2014			2016		
	INCCA	GHGPI Phase IV	Deviation (%)[9]	BUR I	GHGPI Phase IV	Deviation (%)	BUR II	GHGPI Phase IV	Deviation (%)	BUR III	GHGPI Phase IV	Deviation (%)
IA1a Public Electricity Generation	719	600	-17%	820	704	-14%	1083	923	-15%	1122	1000	-11%
1A3 Transport	142	141	-1%	188	186	-1%	250	235	-6%	274	263	-4%
1A3a Aviation	10	13.7	37%	12	15	28%	14	17	24%	16	20	26%
1A3b Road	124	119	-4%	164	159	-3%	225	207	-8%	243	232	-5%
1A3c Railways	7	7.1	1%	7	8.4	20%	8	10	19%	10	10	0%
1A3d Water-Borne Navigation	1	0.94	-6%	4	2.3	-43%	3	1	-67%	4	1	-69%
IA4 Other Sectors	174	131	-25%	93	141	52%	129	151	17%	213	164	-23%
IA4a Commercial/Institutional	2	6	200%	5	8	60%	25	10	-60%	69	12	-83%
IA4b Residential	138	103	-25%	85	104	22%	101	106	5%	127	115	-9%
IA4c Agriculture/Fisheries	34	20	-41%	3	29	857%	2	34	1600%	2	37	1750%
IB Fugitive Emissions from Fuel Production	36	35.7	-1%	49	46	-6%	38	38	0%	37	36	-3%

[9] Deviation % = $\frac{GHG\ Platform\ India\ estimate - Official\ estimate}{Official\ estimate}$ x 100

The emissions from electricity generation reported in the official inventories include emissions from utilities and non-utilities. Since the energy sector estimates of GHGPI include emissions from utility-based power generation only, official inventories were higher than GHGPI estimates.

Total emissions in the transport sector for all the compared years show minimal deviation. However, when evaluated at the sub-sectoral level, civil aviation and navigation show the highest levels of deviation, as shown in Table 4.A. This is mainly due to changes in the reporting structure of these estimates. In the navigation sub-sector, disaggregated estimates of HSDO were unavailable, which led to deviations from the official estimates. In the aviation sector, the difference in estimates within official sources could be the reason for deviation. These sectors constitute a minor share in the overall emissions compared to road transport, which is the highest emitter.

Deviations in residential sector emissions from official estimates reduced considerably in GHGPI Phase IV as compared to GHGPI Phase III estimates. This was due to the new methodology adopted in the current phase.

The deviations in commercial sector emissions, as per GHGPI Phase IV estimates and the official inventories, were quite significant in all the cases examined. However, since neither detailed activity data nor a methodology note is available for the official inventories, it was challenging to ascertain the exact cause of deviation. The best guess is that the methodology followed for diesel calculation was very different in the commercial sector or that other fuels that the GHGPI exercise categorised elsewhere were included within this sector in official estimates.

The deviation in GHGPI calculations for agriculture/fisheries sector emissions—when compared to official inventories—was quite significant in all the years examined. Since diesel consumption data in agriculture (pump sets, etc.) was not available in the required disaggregated manner/format, many assumptions had to be made, based on literature and consultation. Similarly, owing to paucity of reliable data, fisheries sector emissions calculations were also based on assumptions, and interpolation and extrapolation of existing data. Again, due to the lack of transparency in accounting methods in the Indian network on climate change assessment (INCCA) and BUR reports, it was difficult to ascertain the exact source of deviation. It is possible that either the diesel accounting methods were different or certain activities (such as tractor use) were included in a different sector.

The slight difference in fugitive emissions may be due to the assumptions made for natural gas leakage and distribution, and depth of mines for coal production.

Different reporting formats and incompleteness of data compelled the team to make various assumptions and interpolate data to arrive at the time-series of activity data. Therefore, it is possible that the assumptions made by the GHGPI team and MoEFCC vary, and this could have resulted in inconsistencies in results. GHGPI has considered publicly available data and has used official sources for obtaining activity data (to the maximum extent possible). Neither application-wise nor sector-wise activity data was provided in any of the MoEFCC documents for these sectors. Therefore, any further conjecture on the observed differences is not feasible.

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