TREND ANALYSIS

of GHG Emissions in India

2005 to 2013

An Indian civil society initiative to understand greenhouse gas emissions from India's Energy, IPPU, AFOLU and Waste sectors.

The platform seeks to add value to the various ongoing GHG estimation efforts by helping address existing data gaps and data accessibility issues, extending beyond the scope of national inventories, and by increasing the volume of analytics and policy dialogue on India's Greenhouse Gas emissions sources, profile, and related policies.

GHG Platform INDIA

GHG Platform-India (2017). Trend Analysis of GHG Emissions in India from 2005 to 2013. Retrieved from www.ghgplatform-india.org/publications

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1. Introduction

This analysis looks at the trends of Greenhouse Gas emissions estimated under this Platform for the period 2005 to 2013 at national and state level for India. The greenhouse gases covered under this exercise are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). Based on the Intergovernmental Panel on Climate Change, 2006 Reporting Format, the study assesses greenhouse gas emission and removal estimates from the following main sectors:

I. Energy
II. Industry
III. Agriculture, Forestry, and Other Land Use (AFOLU)
IV. Waste

In the year 2013[1], major contribution of emissions in India were from the Energy sector followed by the Industry[2] sector (Figure 1). Combined, these sectors form almost 89% of the overall emissions of India. The energy sector contributes 63% to the overall emissions while the Industry sector contributes to almost 26% to the overall emissions. AFOLU sector forms almost 7% (with LULUCF) of the total emissions while the waste sector contributes 4% to the national level estimates.

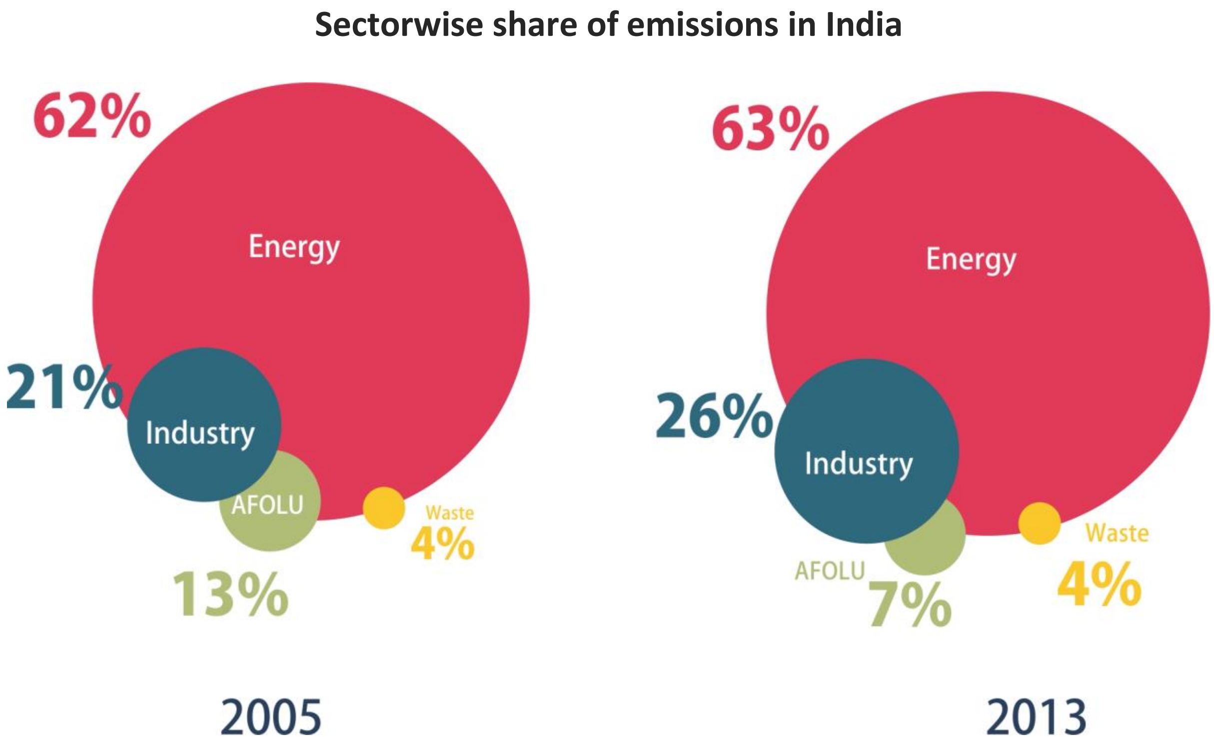

Figure 1. Comparison of Sector Wise Emission Estimates

From the year 2005 to 2013, overall emissions have been rising steadily at an annual growth rate of 5.57%, compounded annually. Emissions had increased from ~1546 Million tonnes CO_2e in 2005 to ~2417 Million tonnes CO_2e in 2013. Figure 2 depicts the emission trends sector by sector. Notably, all the sectors except AFOLU observed an annual growth rate of approximately 3 - 9%. It is also notable that while the emissions from the agriculture sector (excluding LULUCF) were increasing from 2005

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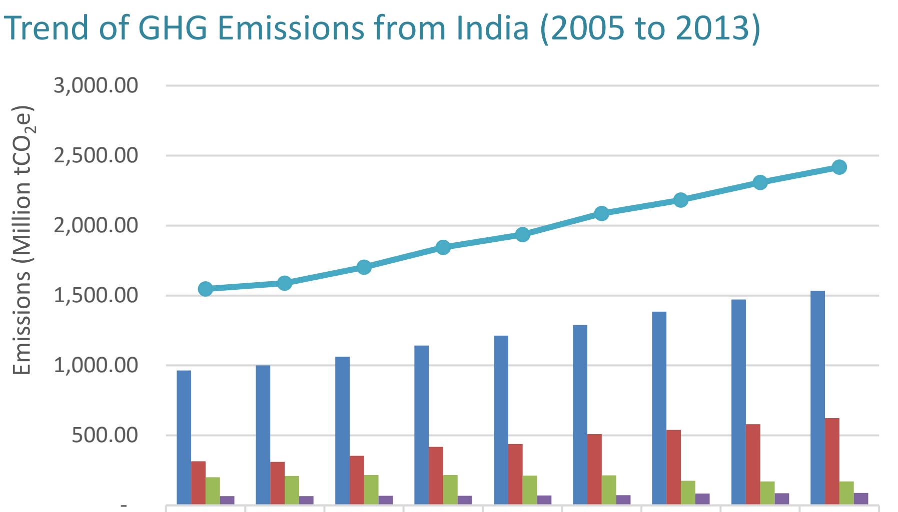
[1] Please note: All the values considered under this study, unless specified, are from GHG Platform India (*GHG platform India 2007-2012 National Estimates - 2016 Series)*

[2] *Industry Sector includes emissions from IPPU sector and Fuel combustion emissions from the Industries.* However, emissions from captive power plants (non-utilities) that are attached to industrial units, are accounted in Energy sector.

(335 Million tonnes CO_2e) to 2011 (352 Million tonnes CO_2e), there was a decline in the year 2012 (348 Million tonnes CO_2e) and emissions from AFOLU have declined thereafter mainly due to a stagnation in the growth of population of cattle and increase in removals from the forestry sector. The compounded annual decline in emissions from AFOLU in the reporting period were 1.9%.



	2005	2006	2007	2008	2009	2010	2011	2012	2013
Energy	964.50	1,000.5	1,062.9	1,142.2	1,214.2	1,288.6	1,383.8	1,472.3	1,533.0
Industry	315.19	311.29	354.73	417.22	439.40	509.17	539.44	579.27	623.15
Agriculture, Forestry and Other Land Use	201.72	209.99	215.86	215.90	212.90	214.55	175.00	171.39	172.30
Waste	65.62	66.65	67.75	68.80	69.95	73.18	83.61	85.73	89.14
Grand Total	1,546.8	1,588.5	1,701.3	1,844.1	1,936.5	2,085.7	2,182.3	2,308.5	2,417.1

Figure 2 . Trend for economy wide emissions (2005 to 13)

Census of India reports the population of India to be 1029 million and 1211 million in years 2001 and 2011 respectively. The population of India grew at a compound annual rate of 1.64% from 2001 to 2011. Using a linear trend, India's population in the year 2005 was estimated to be approximately 1100 million[3] which grew to approximately 1250 million persons in year 2013.

Per capita emissions in India increased from ~1.40 tCO_2e in 2005 to ~1.93 tCO_2e in 2013. Significantly, though the population grew at compound annual rate of 1.64%, per capita emissions grew at a rate of 4.07% compounded annually (refer Figure 3). This, however, is only to be expected as the economy grows and the population becomes more prosperous. Sectorally, maximum per capita emissions arise from Energy sector (~1.23 tCO_2e) in 2013 followed by Industry sector (~0.50 tCO_2e). An observed growth rate of 4.29% and 7.04% compounded annually for Energy and Industry sectors respectively shows that the per capita emissions growth rate from these sector is higher than the economy wide per capita emissions growth rate. Per capita emissions from AFOLU sector have declined from 0.18 tCO_2e in 2005 to 0.14 tCO_2e in 2013 with a negative growth compound annual rate of 3.49% while for the waste sector, per capita emissions have increased at a CAGR[4] of 2.27%. The decline in per capita emissions from AFOLU sector can mainly be attributed to increase in the forest biomass and soil organic carbon and hence, sequestration of greenhouse gases in India. Also, the population of livestock (mainly cattle) have also stagnated from 2005 to 2013, further reducing the proportion of the emissions from AFOLU sector to India's gross as well as per capita emissions.

[3] Using Census of India 2001 and 2011 values, population for the intermediate years has been calculated using linear trend. Increment Ratio was calculated and applied to the intermediate years. For 2012 and 2013, population was calculated using CAGR.

[4] Compound Annual Growth Rate

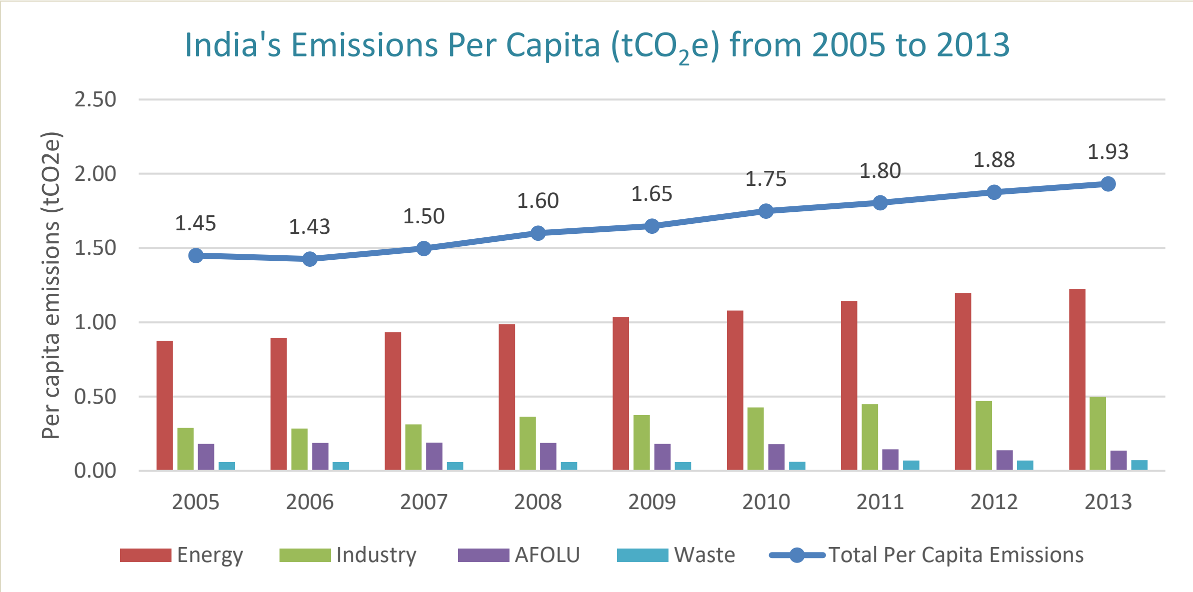


Figure 3. Trend for per capita economy wide emissions (2005 to 2013)

The analysis also covers trends of greenhouse gases from 2005 to 2013 for all Indian States and Union Territories. This analysis could help in further strengthening actions taken by state for mitigating greenhouse gas emissions.

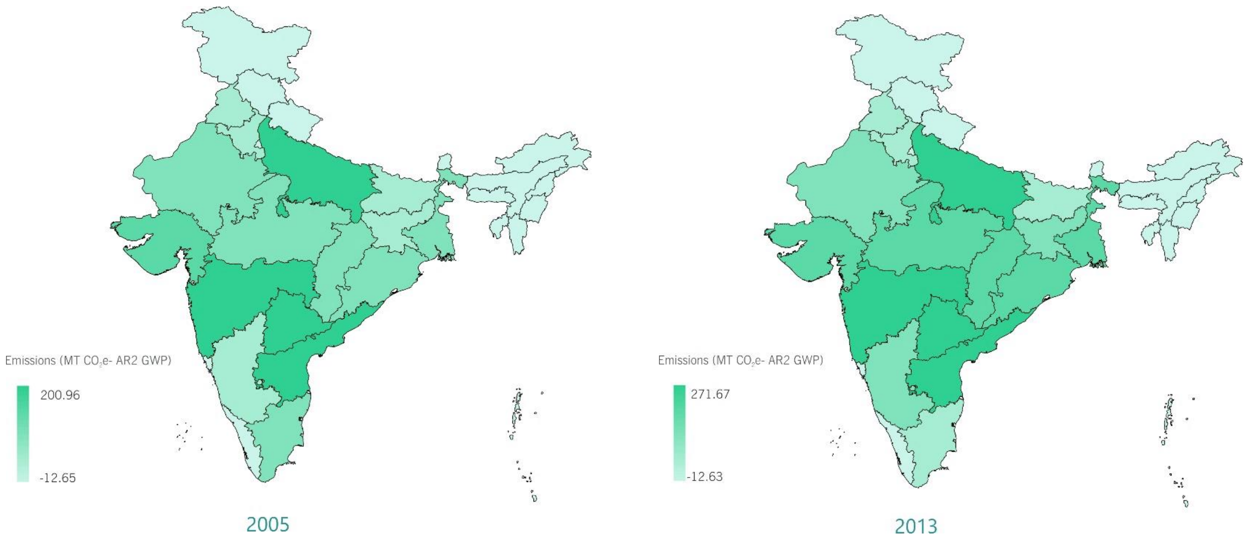


Figure 4. India's state-wise emissions profile (2005 and 2013)

Sector by sector details of the state level is discussed in subsequent chapters. Figure 4 shows the increasing emissions from Indian states. Maximum emissions in 2013 arise from the states of Uttar Pradesh, Andhra Pradesh, Maharashtra, Gujarat, and Odisha.

As far as the per capita emissions of the states are concerned, in 2005, five Indian states viz. Arunachal Pradesh, Manipur, Meghalaya, Mizoram and Sikkim, and the Union territory of Andaman and Nicobar Islands had per capita net negative emissions (refer fig 5 below). Most other states had per capita emissions ranging from 0-2 tonnes of CO_2 equivalent per capita, except for five states viz. Andhra Pradesh[5], Chhattisgarh, Gujarat, Odisha and Punjab that had per capita emissions ranging from 2-4 tonnes of CO_2 equivalent per capita. None of the states had per capita emissions higher than 4 tonnes of CO_2 equivalent per capita in 2005.

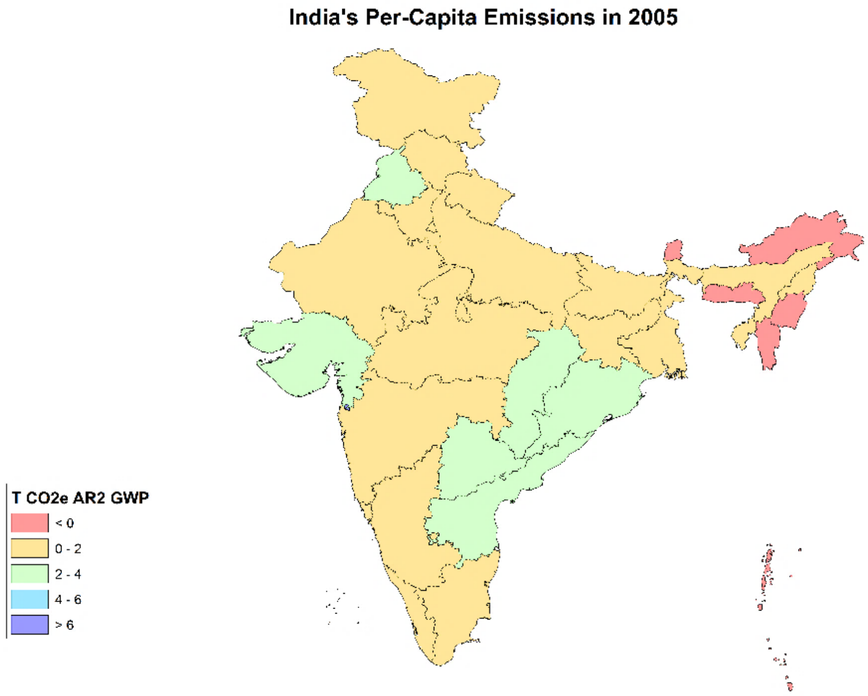


Figure 5. India's per capita emissions profile in 2005

In 2013, however, the situation had changed considerably (refer to fig 6 below). To start with, both Chhattisgarh and Odisha had jumped into the above 4 tonnes of CO_2 equivalent per capita emissions, with Chhattisgarh moving into the above 6 tonnes of CO_2 equivalent per capita emissions category. Further, 4 states viz. Haryana, Madhya Pradesh, Maharashtra, and Jharkhand had graduated from the category of 0-2 tonnes of CO_2 equivalent per capita into 2-4 tonnes of CO_2 equivalent per capita emissions. In addition, while Meghalaya and Mizoram had become net positive emitters by graduating from the category of less than zero tonnes of CO_2 equivalent per capita into 0-2 tonnes of CO_2 equivalent per capita emissions, the states of Kerala and Jammu and Kashmir, had reduced their per capita emissions to become net removers of CO_2 per capita in 2013.

[5] Andhra Pradesh refers to the unified geographical and administrative entity before it was bifurcated into Telangana and Seemandhra in 2014

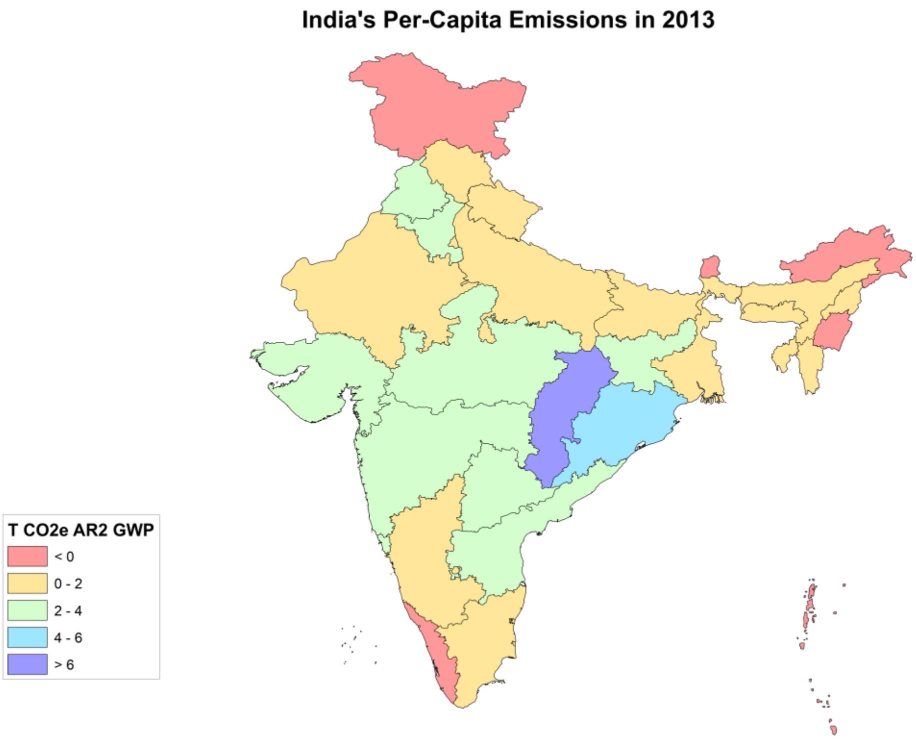


Figure 6. India's per capita emissions profile in 2013

While most of the state level per capita emission trends appear normal, the steep increase of emissions of Jharkhand and Odisha perhaps reflect the economic strategy that these states have pursued over the reporting period. The reduction of per capita emissions from Kerala and Jammu and Kashmir need further, deeper analysis, and might provide clues on how to pursue an economic development strategy that is not necessarily linked to inevitably higher GHG emissions.

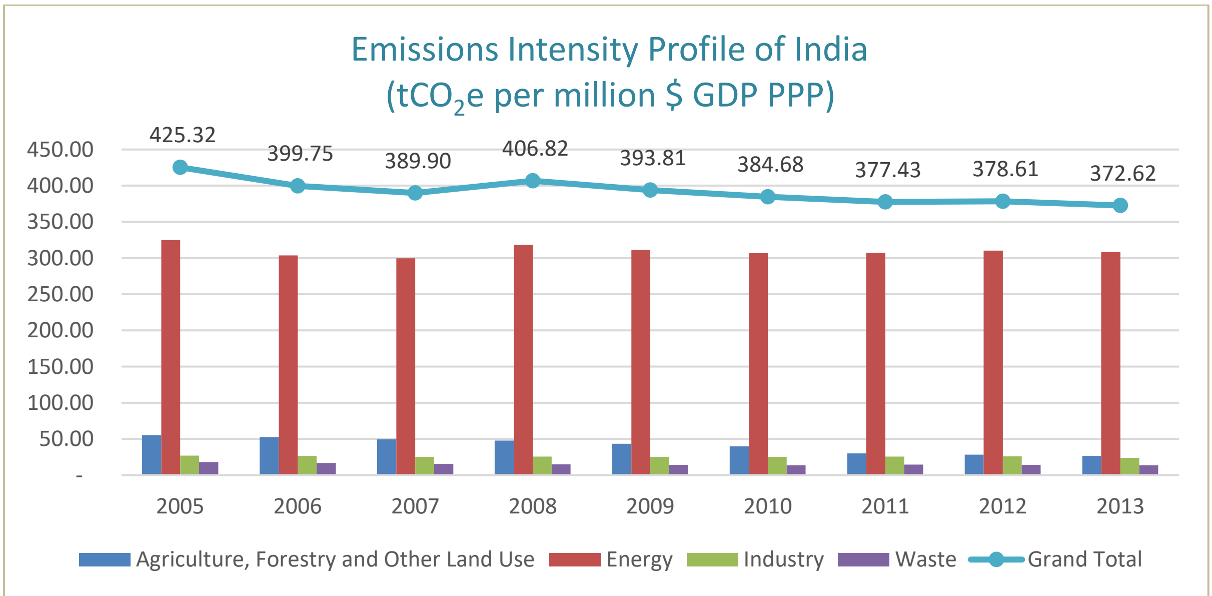


Figure 7 Emissions Intensity Profile of India (tCO_2e per million $ GDP PPP)

Emissions intensity of India is depicted in the graph above. This is based on the GDP PPP values at constant 2011 international dollar from the World Bank[6]. Emission intensity of India in 2005 was 425.32 tCO_2e per million $ GDP PPP while in year 2013, it dropped down to 372.62 tCO_2e per million $ GDP PPP. While the GDP of India increased by 78% in the reporting period, the emissions intensity has declined by 12% between 2005 to 2013. This translates into a 1.64% CAGR decline per annum of emissions intensity of India.

The following chart also represents India's emission intensity based on data available from the Databook for Planning Commission; 22nd December, 2014[7]. This is based on GDP values at constant 2004-05 prices (in Rs. Crore[8]).

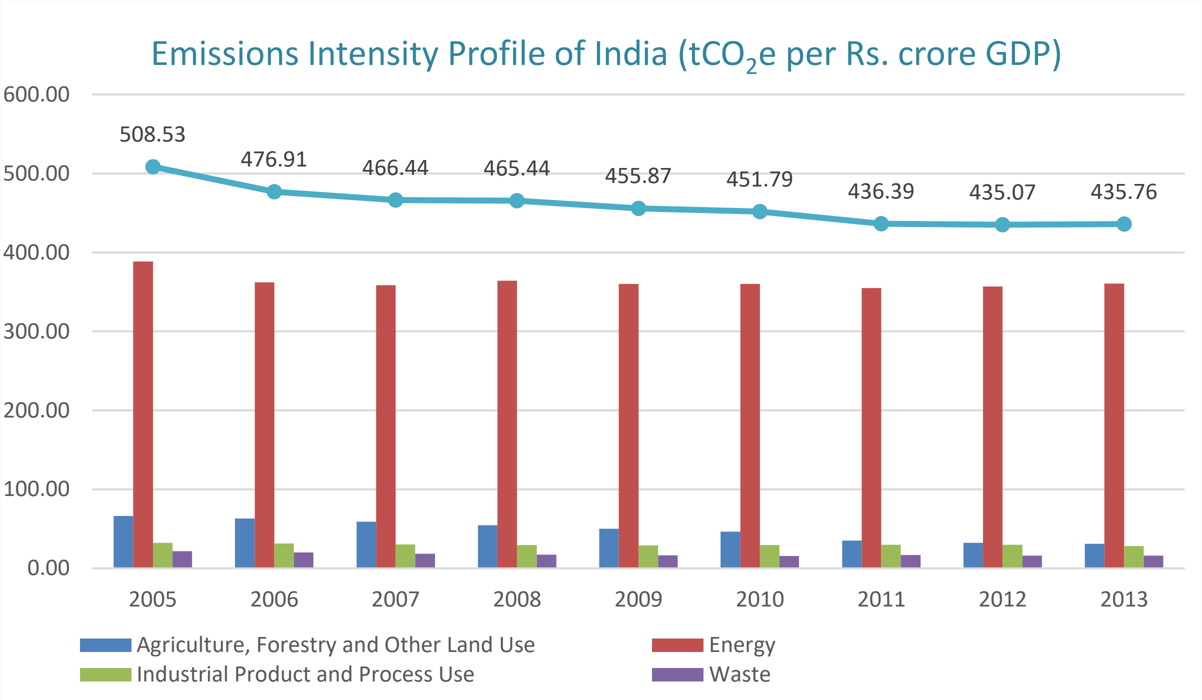


Figure 8 Emissions Intensity Profile of India (tCO_2e per Rs. crore GDP)

According to this, India's emission intensity declined from 508 tCO_2e to 435.76 tCO_2e from 2005 to 2013. Thus, the decline in emissions intensity during the reporting period based on official GOI data was 14%. There is however a difference in decline in the emission intensity, in this case, as compared to the decline in emission intensity (i.e. 12%) computed from World Bank database.

Detailed sector wise trend analysis of GHG emissions of India and its states is explained in the subsequent chapters. In addition, existing policy interventions important to mitigate the impacts of these GHG gases are also available in detail in each of the sector specific chapters that follow.

[6] http://databank.worldbank.org/data/reports.aspx?source=2&series=NY.GDP.PCAP.PP.KD&country=IND#
[7] http://planningcommission.nic.in/data/datatable/data_2312/DatabookDec2014%2012.pdf
[8] 1 Crore is equal to 10 million

Energy Sector

C-STEP Analysis

1. Introduction

The Inter-Governmental Panel for Climate Change (IPCC) has classified the reporting structure of Electricity Generation (1A1a), Transport (1A3), Other Sectors (1A4) and Fugitive Emissions (1B) under the Energy sector (IPCC, 2006). Emission estimates for the energy sector have been generated using the IPCC 2006 revised methodology. According to official emission inventories, the above sectors contributed to 56% and 54% of total emissions in 2007 and 2010, respectively (MoEF, 2010) (MoEFCC, 2015). Therefore, these sectors are of critical importance for identifying and implementing mitigation options. In this section, a disaggregated time-series accounting of emissions between 2005 and 2013 from each sub-sector is provided.

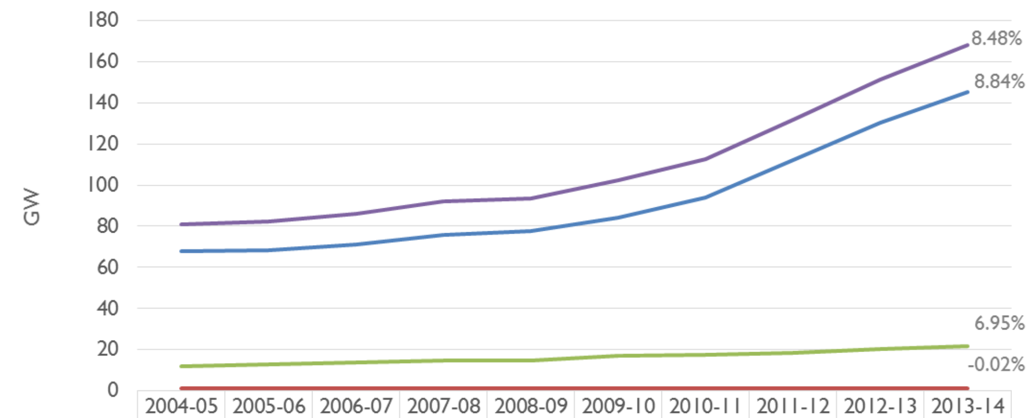
Sector	Electricity	Transport	Others	Fugitive
Subsector	Utility power plants	Road	Residential	Coal Mining and post-mining
	Non-utility (Industries) power plants	Railways	Commercial	Oil and Natural Gas Extraction, Refining and Distribution
		Aviation	Agriculture	
		Navigation	Fisheries	

2. Trend Analysis

This sub-section provides the trends in activity levels and corresponding GHG emissions from the sub-sectors under ENERGY sector.

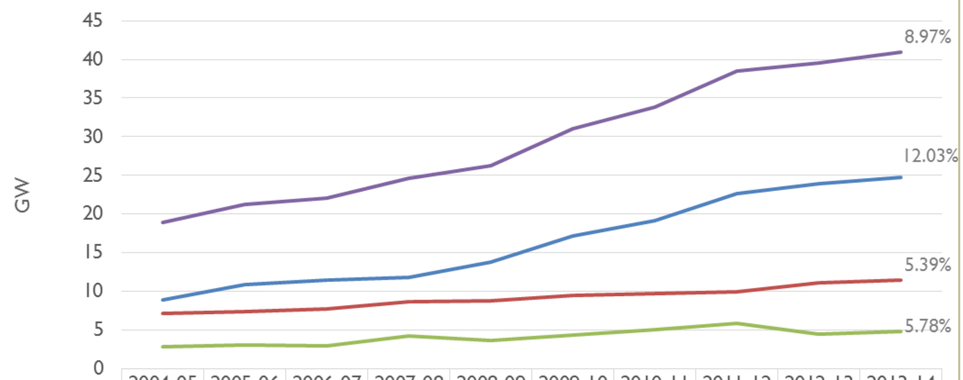
a) Electricity Generation

Electricity generation has been the single largest emitting category in India's emissions portfolio, accounting for 42% and 44% emissions in 2007 and 2010, respectively, as per official inventories. Figure 9 and Figure 10 shows that the installed capacity of the utility-based generators and Captive Power Plants (CPP) of 1 MW or above has grown at approximately 9% during the period 2005 and 2013. However, generation from CPP grew by 10%, compared to 6% growth in utilities. This is of concern since CPPs tend to have lower generation efficiency and hence emit more per unit of electricity generated than utility-based power plants.



	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Coal	67.79	68.52	71.12	76.02	77.65	84.20	93.92	112.02	130.22	145.27
Diesel	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20	1.20
Gas	11.90	12.69	13.69	14.69	14.88	17.06	17.71	18.38	20.11	21.78
Total	80.89	82.41	86.01	91.91	93.73	102.45	112.82	131.60	151.53	168.25

Figure 9: Installed Capacity of Utilities



	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13	2013-14
Coal	8.90	10.82	11.40	11.76	13.82	17.18	19.11	22.62	23.89	24.75
Diesel	7.13	7.42	7.72	8.65	8.75	9.46	9.66	9.96	11.15	11.43
Gas	2.87	3.03	2.98	4.21	3.62	4.37	5.05	5.88	4.50	4.75
Total	18.90	21.26	22.10	24.62	26.19	31.01	33.82	38.46	39.54	40.93

Figure 10: Installed Capacity of Non-Utilities

Figure 11, depicts the dominant share of electricity generated using coal across both utilities and non-utilities. In 2013-14, around 73% of electricity was generated by combusting coal.

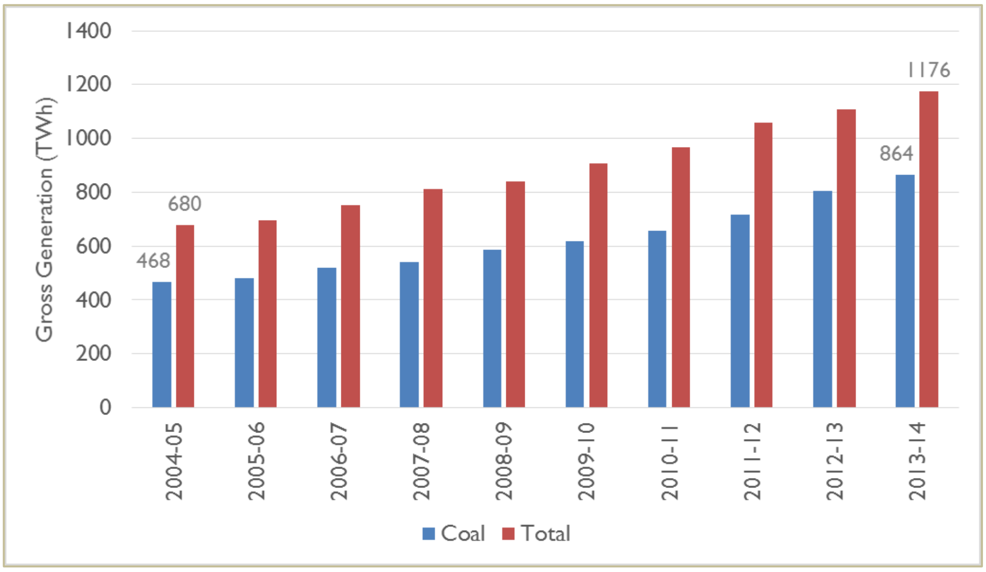


Figure 11: Gross Generation Trends (2005 to 2013)

National Estimates

The emissions released while burning fossil fuels for generating electricity have increased at a Compound Annual Growth Rate (CAGR) of 6.6% from 2005 to 2013, with CO_2 accounting for almost 99% of the emissions. The annual emission growth rates from utility and captive power plants were 6.2% and 9.1%, respectively (Figure 10). There has been an increasing trend of emissions from coal and lignite based power plants. On the contrary, a decreasing trend of emissions was seen in the power plants using furnace oil, diesel, naptha, gas and Low Sulphur Heavy Stock (LSHS)/Hot Heavy Stock (HHS).

Emissions from coal based power plants (public and captive) registered a growth of 7.4% CAGR between the years 2005 and 2013. Lignite also registered a positive growth of around 1.5% in emissions while the emissions from other fuels declined in this period. Emissions from Gas-based power plants peaked to 56 Million tonnes CO_2eq in 2010 due to increased availability of natural gas from domestic sources. Other fuels such as furnace oil and diesel are used in initial stages of thermal power plants. Due to strict environmental regulations and policies, the rate of construction of these power plants have slowed down, which has resulted in decline of these fuels. Emissions from coal-based captive power plants increased to 126 Million tonnes in 2013 as compared to just 51 Million tonnes CO_2eq in 2005; registering a growth of 12% annually. Emissions from gas-based captive power plants increased moderately with a CAGR of 2.5% and diesel based emissions declined at a CAGR of 4.14% over the same period. Owing to the dominating role of coal in electricity generation, in 2013, around 93% of emissions from electricity generation can be attributed to combustion of coal (Figure 13).

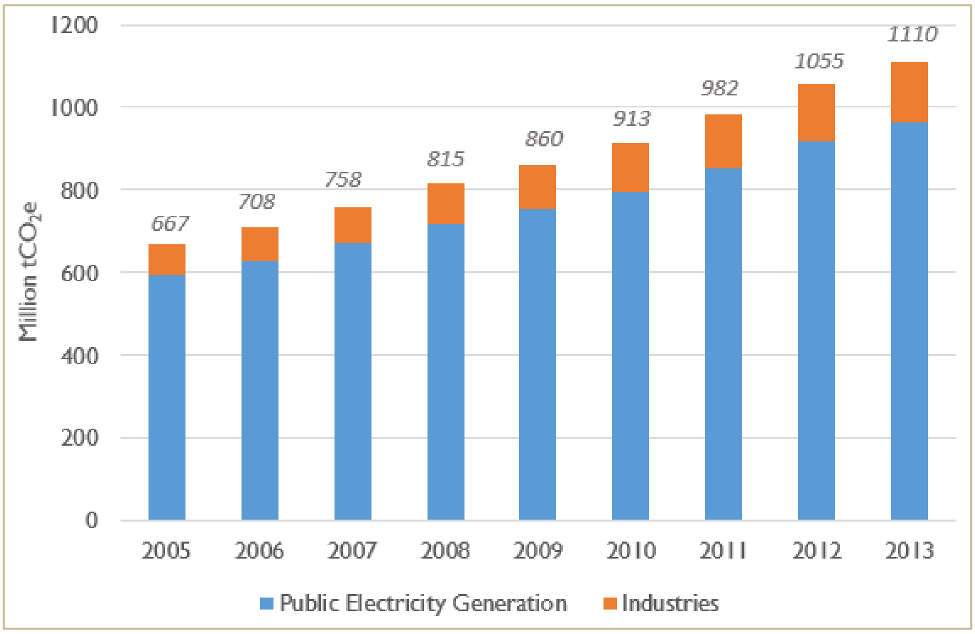


Figure 12: Emissions from Electricity Generation (2005 to 2013)

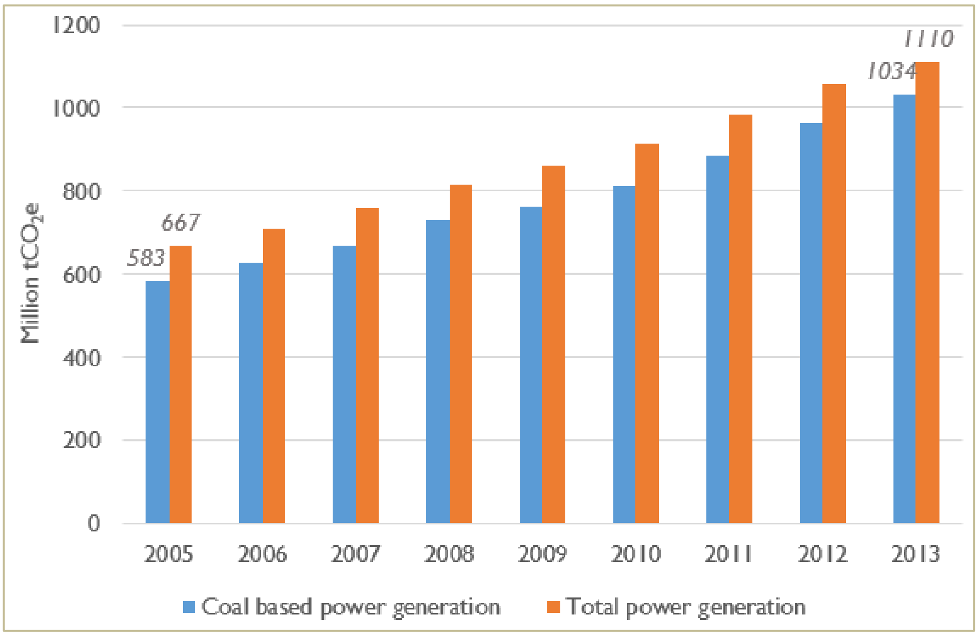


Figure 13: Share of Emissions from Coal based power generation

State Estimates

Maharashtra, West Bengal and Uttar Pradesh are the largest contributors of emissions from coal based power plants. Significant growth can be seen in emissions in these states over the years 2005 to 2013. Lignite is primarily used in only two states in India- Gujrat and Tamil Nadu. The emissions in Gujrat nearly doubled in 2014 as compared to 2005 levels, due to capacity addition of 300 MW in Surat Lignite power plant in 2010. Emissions from furnace oil have declined from

12.8 Million tonnes CO_2eq in 2005 to merely 0.9 Million tonnes CO_2eq in 2014 for Maharashtra, due to decline in new capacity addition in this time period. Other states such as Uttar Pradesh, Karnataka, West Bengal and Tamil Nadu registered increase in furnace oil consumption and hence, higher emissions. There is an overall declining trend in emissions from diesel consumption, generally used in initial kick-off phase of the power plants. Moreover, the old diesel based power plants have been shut down due to strict environmental regulations. Tamil Nadu, Kerala and Andhra Pradesh are the largest contributors to Naptha based emissions in the country. This is possibly because Naptha generates more power in gas-based power plants, as compared to liquefied natural gas (LNG), and is also cheaper. However, Karnataka, Gujarat and Goa witnessed a decline in Naptha consumption and a corresponding decline in emissions as well. Gujarat and Andhra Pradesh were the largest contributors of gas based emissions in 2005 have showed a steep decline in 2013. This is due to unavailability of domestic natural gas for power generation. Other states such as Maharashtra, Tamil Nadu, Delhi, Assam and Tripura have shown increase in emissions from natural gas-based thermal power plant emissions. Low Sulphur Heavy Stock (LSHS)/ Hot Heavy Stock (HHS) have similar application to furnace oil. Gujarat registered the highest decline in consumption of LSHS/HHS.

Chhattisgarh, Gujarat, Karnataka, Odisha and Uttar Pradesh were the largest emitters due to captive generation capacity in 2013. Orissa, Chhattisgarh and Gujarat have also been the largest contributors to emissions from coal based captive generation, which grew at 12% during 2005 to 2013. The overall consumption of diesel in captive power plants has declined due to increase in diesel prices, but Tamil Nadu and Karnataka have registered growth in emissions for this period. Maharashtra has the largest gas-based captive capacity, thus contributing to highest emissions in this category.

Top 3 emitting states under each sub-sector are listed in Table 1, in addition to an illustration of emissions from key states in Figure 14.

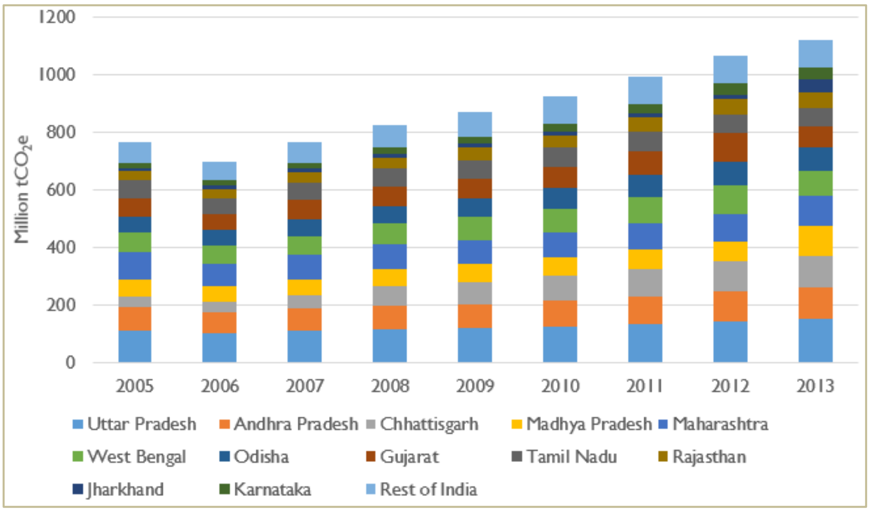


Figure 14: Statewise emissions from Electricity Generation

Table 1: Top emitters in Electricity Generation Sector in 2013

Sub sector	States
Public Electricity Generation	Uttar Pradesh, Andhra Pradesh, Madhya Pradesh
Industries (captive)	Odisha, Gujarat, Chhattisgarh

b) Transport Sector

The energy consumption in transport sector increased from 1869 Peta Joules (PJ) to 3217 PJ from 2005 to 2013. In 2013, road sector consumed 88% of the total energy in transportation sector. The remaining energy was consumed by railways (3%), aviation (7%) and domestic water borne navigation (1%).

National Estimates

Table 2 shows the fuel consumed by transport sub sectors from 2005 to 2013.

Table 2: Fuel Consumption by Transport Sectors (in PJ)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013
Road	1623	1443	1546	1804	2030	2213	2528	2754	2845
Railways	74	78	86	92	96	101	104	108	112
Navigation	34	35	38	47	51	54	42	31	28
Aviation	138	169	194	198	202	213	235	226	232
Other Transport-ation	0.103	0.109	0.119	0.087	0.074	0.051	0.055	0.059	0.054
Total	1869	1725	1864	2141	2379	2581	2909	3119	3217

Figure 15 shows the time series GHG emission estimates of road, railways, aviation and navigation sectors from 2005 to 2013. The emissions from the transportation sector followed an increasing trend and grew at a Cumulative Annual Growth Rate (CAGR) of 6.90% during this time period. The number of registered vehicles on the road increased at 10% per year, between 2005 and 2013 (MoRTH, 2016).

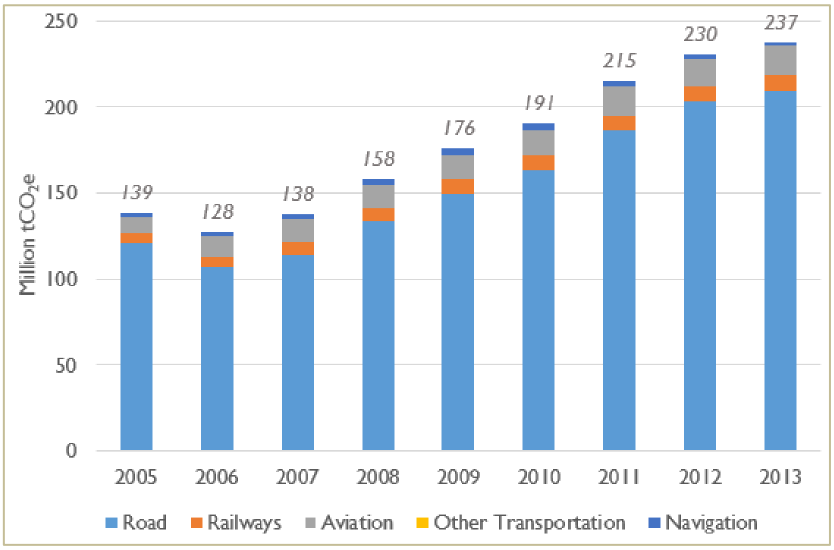


Figure 15: Emission estimates for Transport Sector (2005 to 2013)

State Estimates

The states emitting the highest GHGs from various sub sectors of the transport sector are shown in Table 3. Road emissions were highest in states having high population and economic growth rate. In case of the railways sector, Uttar Pradesh and Rajasthan have the highest route kilometres of railway lines in India (MoR, 2013). In terms of passenger traffic, airports in Delhi, Mumbai and Chennai were the busiest airports in India in 2013-14.

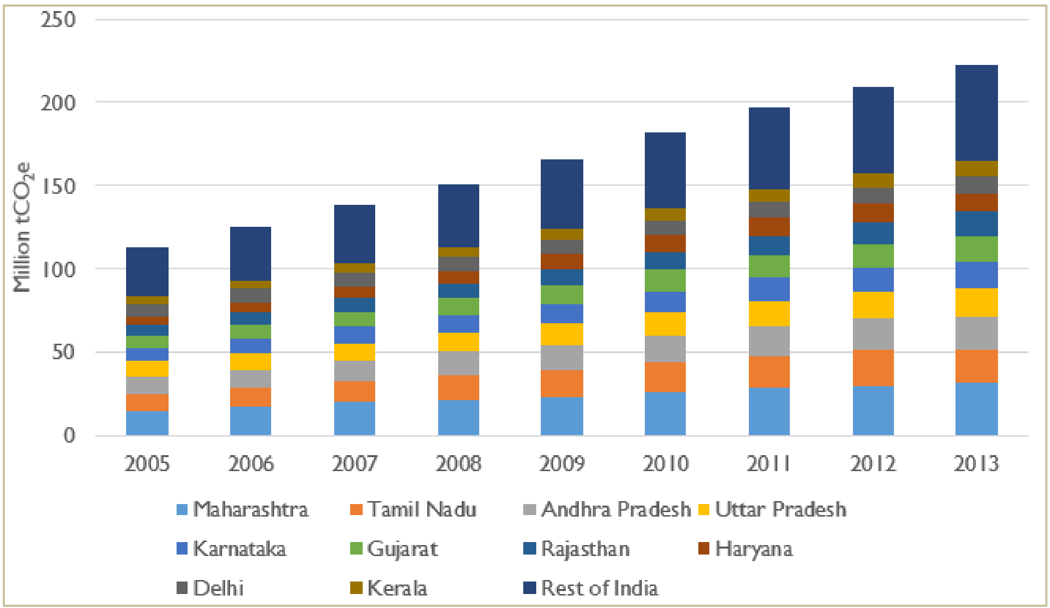


Figure 16: State wise Emission Estimates (2005 to 2013) for Transport Sector

More than 80% of the transport sector emissions are from the 10 states shown in Figure 16.

Table 3: Top emitters in Transport sector in 2013

Sub sector	States
Road	Maharashtra, Tamil Nadu, Andhra Pradesh
Railways	Uttar Pradesh, Karnataka, Rajasthan
Aviation	Delhi, Maharashtra, Tamil Nadu
Navigation	Maharashtra, Kerala, Gujarat

c) 'Other' Sector

The energy demand for household activities has been steadily increasing every year. The major fuel source for household cooking and lighting are firewood, Liquefied Petroleum Gas (LPG), kerosene, Piped Natural Gas (PNG), coke, coal and charcoal. About 83% of the rural population is still dependent on firewood for their household activities. Though the firewood usage in households has not reduced alarmingly, the average per capita consumption of firewood has dropped from 21.21 to 19.04 kg/capita/month in the rural sector. However, the case is different in urban sector where 23% of the households used firewood and 71% of the households used LPG (NSSO, 2015). In urban households, the penetration of LPG increased by 20% between 2004-05 and 2011-12. Kerosene is an important fuel which is mainly used for household lighting. Thanks to efficient policies enabling rural electrification, kerosene usage has seen a declining trend in the past few years. In case of the commercial sector, LPG and kerosene used for cooking and lighting, and diesel used in the Diesel Generator (DG) sets, were the main fuels that generate emissions. Use of DG sets in residential and commercial sectors increased significantly over the past decade (ICF International, 2014). Energy usage in the agricultural sector was mainly due to diesel consumption in irrigation pumps, tractors and other implements. Fishing fleets largely use diesel and kerosene as fuel.

National Estimates

Residential sector emitted more than 70% of the emissions from the 'other' sector. However, with the help of multiple policies framed by the Indian government to improve the penetration of clean cooking and lighting fuel, the overall emission from residential sector increased by less than 1% annually from 2005 to 2013. The emissions generated by burning LPG, PNG and diesel showed an increasing trend while the emissions from fuelwood and kerosene showed a decline during these years.

In case of commercial sector, LPG, kerosene and diesel were the main fuels that generate emissions. The emissions from commercial sector have grown by 11% per annum wherein DG sets account for well over half of these emissions. Table 4 shows the energy used by residential, commercial, agriculture and fisheries sector from 2005 to 2013.

Table 4: Fuel Consumption by Other Sectors (in PJ)

Sector	2005	2006	2007	2008	2009	2010	2011	2012	2013
Residential	4997	5499	5485	5165	4778	591	4460	4300	4168
Commercial	85	98	124	134	171	197	227	240	231
Agriculture	206	217	235	258	287	304	336	373	398
Fisheries	43	46	49	51	54	56	59	62	65
Total	5330	5860	5893	5607	290	5147	5080	4974	4861

The emission from agriculture sector has increased by 8.6% (per annum) from 2005 to 2013. Diesel usage in tractors and pump sets accounts for 99% of its emissions. According to Indian Pump Manufacturers' Association (IPMA), the agricultural pump market is expected to grow at 7-8% per year. Due to government policies on energisation of agricultural pump sets, the rate of direct burning of diesel fuel has reduced. The emissions from fisheries sector have grown at a CAGR of 5.22% between 2005 and 2013. The emissions from kerosene usage have declined by 23% while that from diesel have increased by 74% during this time. Figure 17 shows the time series GHG emission estimates of residential, commercial, agriculture and fisheries sector.

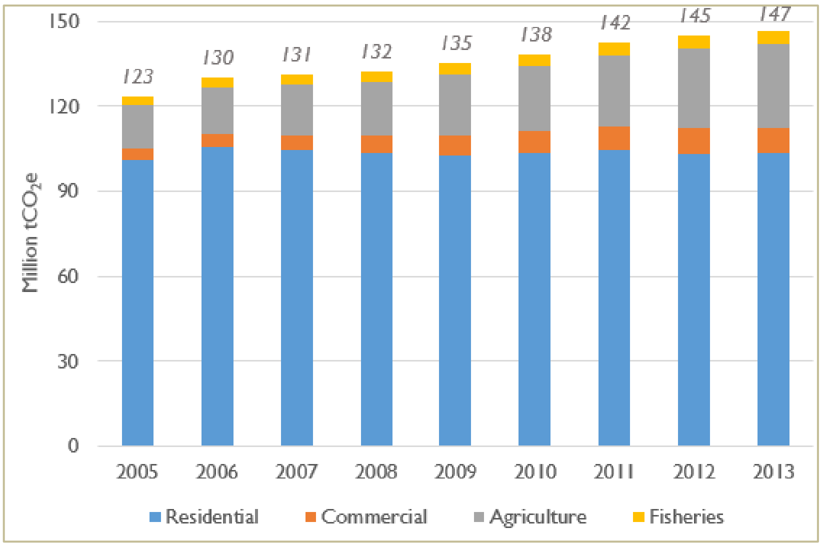


Figure 17: Emission estimates for Other Sectors (2005 to 2013)

State Estimates

In case of 'other' sectors, about 80% of the total CO_2 equivalent emissions were emitted by 13 states. The year on year emission trend of these states are shown in Figure 18. It can be inferred that the most populous states were the most emitting ones. Uttar Pradesh, West Bengal, Maharashtra, Andhra Pradesh and Tamil Nadu were the highest GHG polluting states in the 'other' sectors in 2013. Based on an analysis conducted by CSTEP analysis, the top 3 GHG emitting states in each sub sectors are provided in Table 5.

Table 5: Top emitters in other sectors in 2013

Sub sector	States
Residential	West Bengal, Uttar Pradesh, Maharashtra
Commercial	Maharashtra, Uttar Pradesh, Tamil Nadu
Agriculture	Uttar Pradesh, Punjab, Haryana
Fisheries	Gujarat, Maharashtra, Tamil Nadu

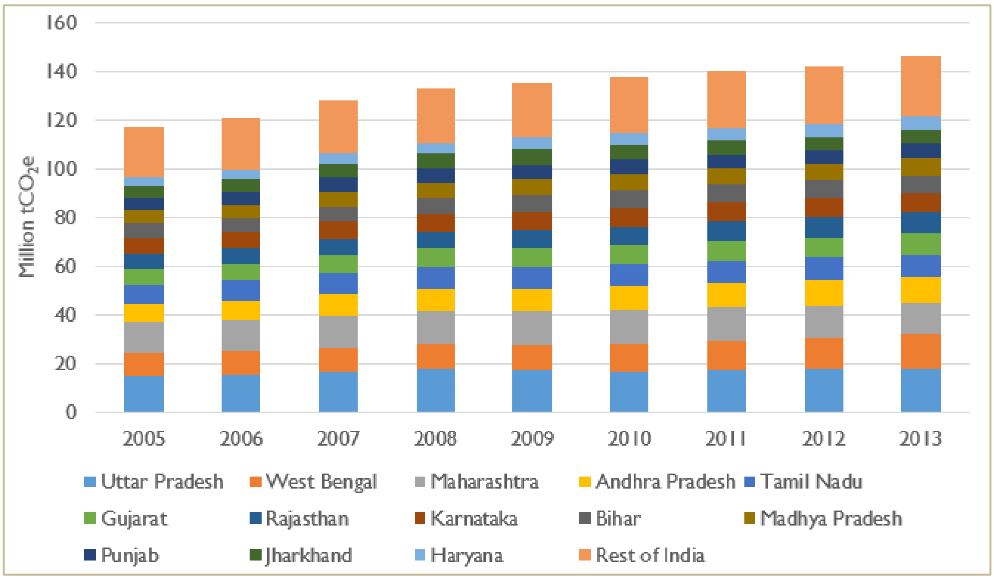


Figure 18: State wise Emission Estimates (2005 to 2013)

d) Fugitive Emissions

Indicating a CAGR of 4.34% between 2005 and 2013, coal production in India increased from 401 Million tons (MT) to 563 MT in India (Coal Controller's Organisation, 2016). Typically, based on operations, coal is mined using two methods: underground mines (UG) and opencast mines (OC), also referred to as surface mines. In the above-mentioned period, coal production from OC mines grew by 5.29% (340 MT to 513 MT) and production of coal from UG mines decreased by 2.45%(61 MT to 50 MT). Technological advancements, geological conditions, safety issues and site characteristics like coal seam continuity, are some of the reasons behind the increased adoption of opencast mining. It is important to note that the degree of gassiness, in case of UG mines, increases with the depth of coal available for extraction; thus, determining the levels of methane emissions in UG mining.

In 2013, around 38 MT of oil was produced in India, compared to 33 MT in 2005 levels (MoPNG, 2014-15). Given the rise in oil production, the number of wells deployed to produce oil increased at 4.91% and the throughput of refinery grew at 6.96%, between 2005 and 2013. The natural gas production was accounted to be 36725 Million Metric Cubic Meter (MMCM) in 2013; an addition of 4633 MMCM compared to 2005. Around 13% of the produced natural gas is typically reinjected for internal use, while 2.18% is flared in the site and 1.65% (Muller, n.d.) can be attributed to leakages; the remaining amount is considered available for consumption.

National Estimates

The fugitive emissions grew at a rate of 1.05% annually from 2005 to 2013, with contributions from coal, oil and gas production estimated as 0.57%, 2.21% and 1.62%, respectively. In 2013, the total emission from fuel production was accounted to be 38.60 MT CO_2eq. Around 53% was attributed to emissions from coal production, while the remaining 47% was due to oil and natural gas production. It is important to note that 87% of the emissions from coal production took place during the mining processes. Figure 19 shows the time series GHG emission estimates for fuel production activities.

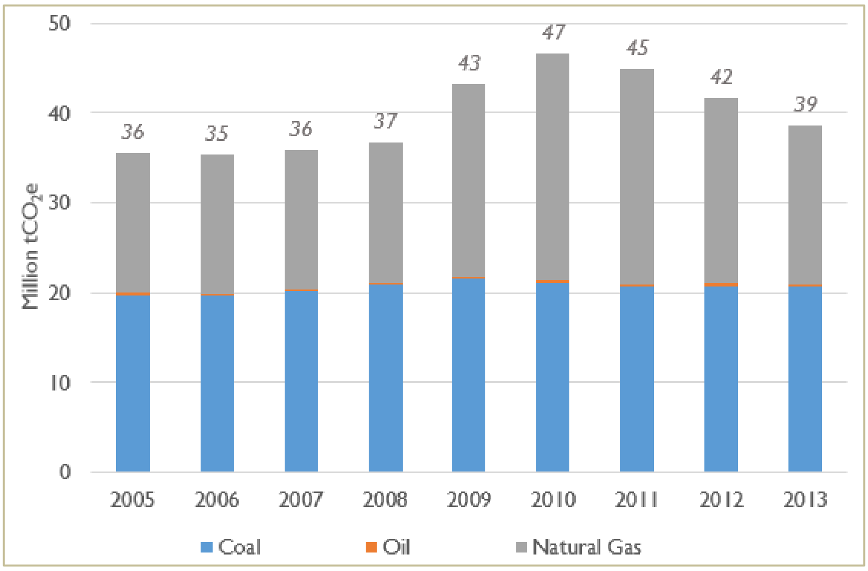


Figure 19: Fugitive Emissions Estimates (National)

State Estimates

Over 81% of the emissions from fuel production can be attributed to six states where coal, oil and natural gas are produced. As depicted in Figure 20, these states include Maharashtra, Chhattisgarh, Andhra Pradesh, Jharkhand, Telangana[9] and Odisha. Top emitting states in coal, oil and natural gas production is shown in Table 6.

Table 6: Top Emitters in Fugitive Sector in 2013

Sub sector	States
Coal	Andhra Pradesh, Chhattisgarh, Jharkhand
Oil	Maharashtra, Gujarat, Rajasthan
Natural Gas	Maharashtra, Andhra Pradesh, Assam

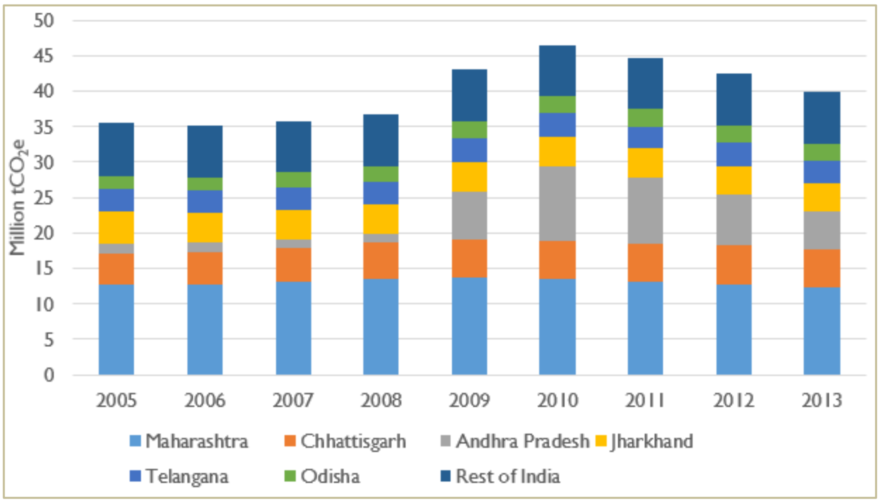


Figure 20: Statewise fugitive emissions

[9] All coal production from Telangana state is from Singareni Collieries Company Limited

3. Conclusion

Electricity Generation: There has been a consistent increase in emissions from electricity generation sector. This can be mainly contributed to 'Power for All' and 'Make in India' missions of the government which has given push to rural electrification and manufacturing in India. We have observed significant growth in coal based electricity generation, which has subdued the impact of higher Renewable Energy (RE) penetration, despite several flagship programs of the government such as National Solar Mission, 175GW RE target, Renewable Purchase Obligations (RPO) and generation based incentives. The emissions from coal based power plants are expected to reduce due to National Electricity Plan 2016 which envisions meeting 39% of this coal based capacity addition by super-critical technology (Central Electricity Authority, 2016). Furthermore, India's Nationally Determined Contribution target of 40% fossil-free capacity by 2030, submitted to UNFCCC, can drive down emissions intensity of electricity generated (MoEFCC, 2015).
Various other initiatives undertaken by Government of India such as improving efficiency of thermal power plants, implementation of strict environmental norms, retiring old and inefficient thermal power plants and Perform Achieve and Trade (PAT) scheme adoption can help reduce greenhouse gas emission from Electricity Generation sector and make electricity supply consistent and reliable.

Transport: The growth in the road transport sector GHG emissions can be attributed to the increase in population, motorization, urbanization, and industrialization rates. With improvements in the road infrastructure, such as National and State Highways, freight transport has also increased significantly. However, adoption of higher Bharat Standards (BS) for fuel, along the lines of Euro Standards, and by phasing out old vehicles, the impact of emissions on transport sector have reduced. Ethanol Blending Programme, introduction of BS VI fuels, promotion of electric vehicles and electrification of railways are some of the alternate fuel related mitigation actions that Government of India has undertaken and are likely to have a significant role in reducing the GHG emissions from the transport sector. In urban areas, growth in mobility demand and private vehicle purchases has led to increase in transport externalities such as air pollution and accidents. In an attempt to address the urban transport issues, the National Urban Transport Policy (NUTP) has aimed at improving the mobility of people rather than mobility of vehicles.
Policies which focus on modal shift strategies such as coastal shipping promotion, promoting inland waterways and metro rail and mono rail projects will have a significant role in GHG emission reduction from transport sector. Other drivers for urban transport emission reduction will be better land use planning, restricting urban sprawl, promoting non-motorised transport and reducing the need to travel.

Others: Several government schemes like Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) (MoP, 2016) and Remote Village Electrification (MNRE, 2016) have helped in reducing the dependency of fossil fuels for lighting, especially in rural India. A similar effect has been seen in case of cooking activity too. Schemes like Pratyaksh Hanstantarit Labh (PAHAL) Scheme (MoPNG, 2016), Pradhan Mantri Ujjwala Yojana (PMUY) (MoPNG, 2016),expansion of PNG network and schemes to improve cook stoves have helped in the penetration of LPG into the households, thereby reducing dependency on fuelwood, coke, coal and kerosene for cooking purpose. Though LPG and PNG are cleaner fuels as compared to coal, their emissions are expected to increase with higher penetration of these fuels in the sector. These fuels help in reducing indoor air pollution, which has been a major cause of mortality and morbidity, particularly in rural India.

Rural electrification also benefited the agriculture sector by helping in electrification of agricultural pump sets. In 2012, agricultural pump sets were using 4.04% of the total diesel sold in the country (Nielsen, 2013). With improved rate of rural electrification and installation of energy efficient pump sets, the emissions from the pump sets will further reduce with reduced dependence on diesel. Owing to the mechanisation/motorisation of boats, the fisheries sector has started emitting more as compared to the period when traditional boats comprised most of the fishing fleet. The coastal states are provided with kerosene subsidy and rebate in diesel oil to promote the mechanisation of fishing fleets (Shyam S Salim, 2012). Recently, the quantity of subsidised kerosene has decreased and the dependence on diesel has increased. These policies have led to the increase in emissions from this sector.

Fugitive Emissions: Economic development coupled with higher electricity requirements are primary reasons for increasing growth in coal production. Over 60% of electricity generated is via thermal power plants fuelled by coal. Furthermore, the energy intensive manufacturing sectors like cement and steel use coal as the primary energy source. In order to realise the developmental aspirations and associated policies it is important to understand that commodities such as electricity, cement and steel play a pivotal role moving forward. Therefore, the fugitive emissions from coal sector may increase two to three-fold, in addition to the ambitious targets of reaching 1.5 billion tonnes coal production by 2022 (U.S. Energy Information Administration, 2016).

The emissions from oil and natural gas production also witnessed a similar trend due to high growth in transport demand and access to modern cooking fuels. In the coming years, the emissions from natural gas production may increase due to policy impetus on cleaner cooking fuels (LPG) to all households (Byravan, et al., 2017). Urbanization, rising per capita incomes and growth in mobility needs may result in increase of private vehicle purchases, which will further drive consumption of petroleum products- thus, leading to growth in fugitive emissions from oil production.

Industry Sector*

CEEW Analysis

(Industrial Process & Product Use and Industrial Fuel Combustion Emissions)

1. Introduction

This section provides a trend analysis of greenhouse gas (GHG) emissions from industrial sector (as per IPCC-2006 classification) resulting from both energy use, and industrial processes and product use (IPPU).

As per the standard IPCC classification, the scope includes *manufacturing industries and construction* (1A2); energy industries for *petroleum refining* and *manufacturing of solid fuels* (1A1b & 1A1ci); mining and hydrocarbon extraction (1A1cii); and, industry process and product use emissions (2A, 2B, 2C, 2D, 2E, 2F, 2G and 2H). However, our estimates excludes any emissions arising from the captive power generation activities - as it is covered under energy (electricity) reporting for the ease of convenience. Further – 2B9, 2D3, 2E, 2F, 2G, and 2H categories[10] of the IPPU emissions are not covered – as little or no information is publicly available for these industrial activities. Many of these activities were not part of India's industry until 2010-11. Together, industry energy use and IPPU account for ~ 25% of the national GHG estimates from India. This analysis covers trends, summary and key takeaways from the detailed emission estimates.

2. Summary of GHG trends

Greenhouse gas emissions (GHG) from the manufacturing activities in India have increased at a secular rate of 9% (CAGR) – rising from ~315 Million Tonnes (MT) of Carbon equivalent (CO_2e) in 2005, to ~623 MT in 2013. This includes emissions from energy use, and industrial process and product use (IPPU). Figure 21 illustrates the share of emissions from various industry sub-sectors, and the overall growth of emissions over a period of 2005 (base year) till 2013 (referred as 'current year' in the document).

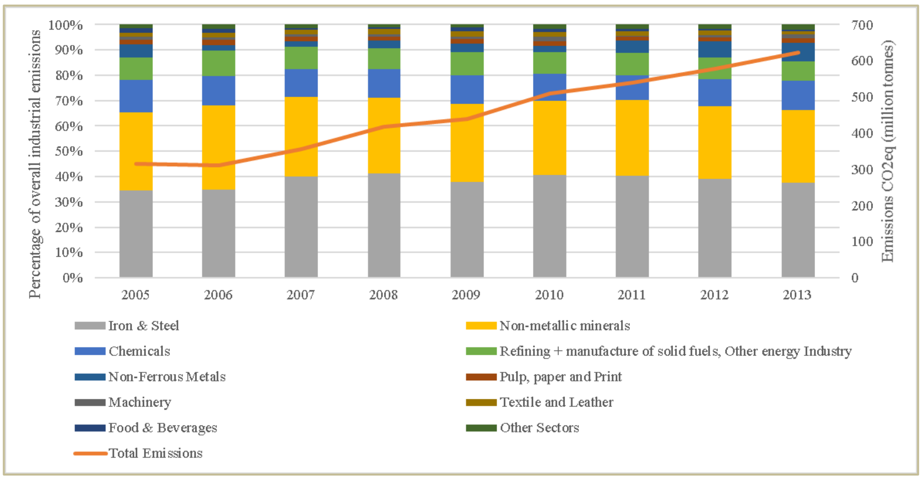


Figure 21: Year on year growth of GHG emissions and dominant sectors

*Industry Sector includes emissions from IPPU and emissions from fuel combustion within industries. However, emissions from captive power plants (non-utilities) that are attached to industrial units, are accounted in Energy sector.

[10] 2A: Mineral Industry, 2B: Chemical Industry and 2B9: Fluorochemical Production, 2C: Metal Industry, 2D: Non-Energy Products from Fuels and Solvent Use and 2D3: Others, 2E: Electronics Industry, 2F: Product Uses as Substitutes for Ozone Depleting Substances, 2G: Other Product Manufacture and Use, 2H: others.

Major source categories

Manufacturing (and processing) of *iron and steel* and *non-metallic minerals* (predominantly cement) are the major contributors to industry related GHG emission. For 2013, they represented 38% and 29% of industrial GHG emission share respectively, as illustrated in Figure 21. High consumption of primary energy dictates the manufacturing (or industry) sector emissions, where coal continues to remain a dominant source of energy (across sectors) over the assessed period

Top emitting states:

In 2013, out of 34 states and union territories[11] considered for this evaluation, 10 states accounted for ~80% of GHG emissions from industry sub-sectors, viz. - Gujarat (14%), Odisha (13%), Chhattisgarh (10%), Jharkhand (9%), Karnataka (8%), Maharashtra (8%), Andhra Pradesh (7%), Tamil Nadu (6%), Rajasthan (5%), and West-Bengal (5%).

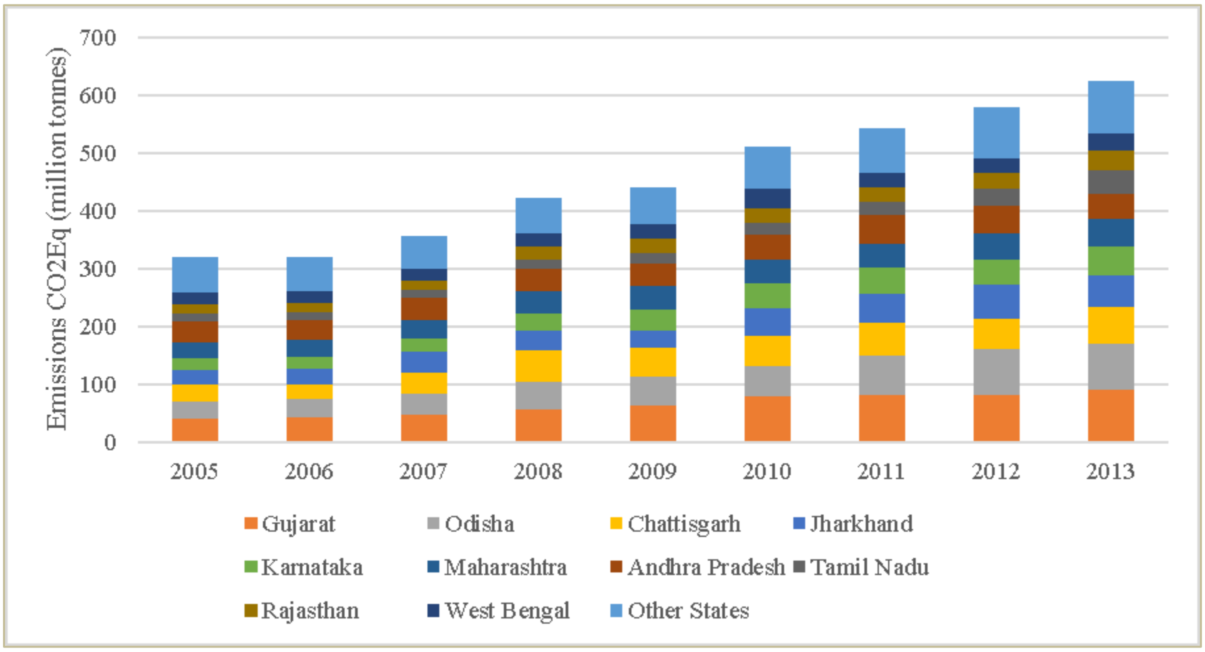


Figure 22: State wise emissions from the manufacturing sector

[11] Mizoram and Lakshwadeep were not considered due to data insufficiency; Telangana and Andhra Pradesh are considered as undivided Andhra Pradesh for an ease of estimation.

Figure 23 and Figue 24 demonstrate state-wise total industrial emissions profile of India.

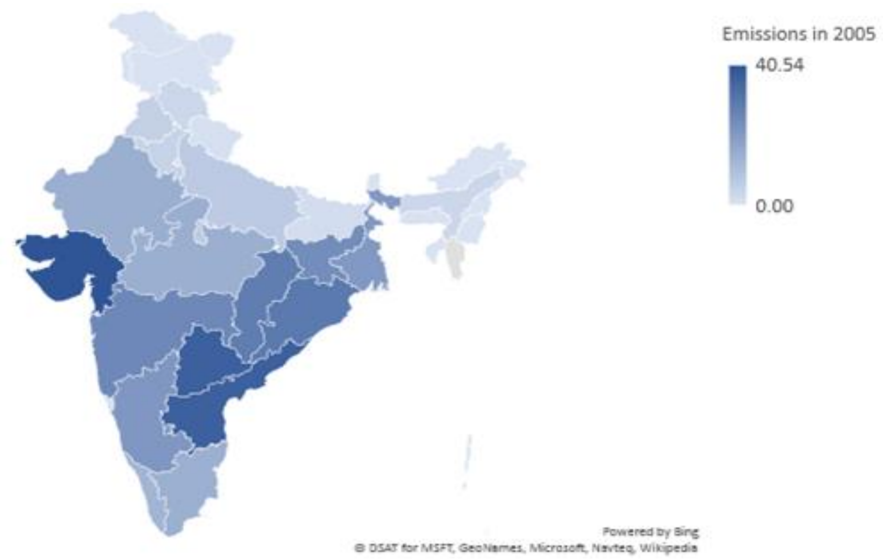


Figure 23: State-wise emissions profile for the year 2005 ***(in Million tonnes CO_2eq)***

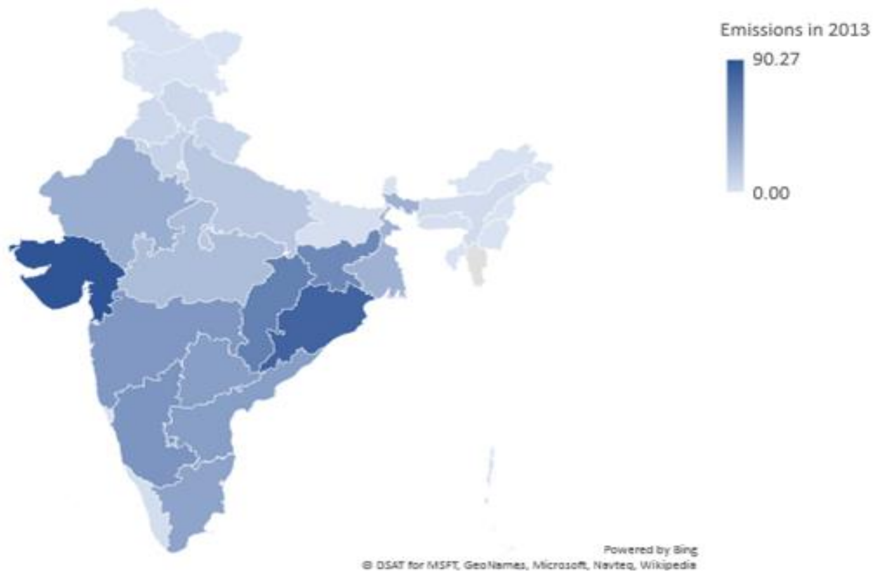


Figure 24 : State-wise emissions profile for 2013 (in Million tonnes CO_2eq)

a) GHG emissions from energy use

Over the analysis period (2005 to 2013), GHG emission due to industry energy use has grown upwards at a rate of 10%, rising from ~217 MT in 2005, to ~ 467 MT in 2013. Also, its share in the total industrial emissions has increased from 65% to 76% in the same period.

Figure 25 showcases energy-use based emission trends from various industrial sub-sectors. Manufacturing of Iron and Steel, and non-metallic mineral sectors together contribute to 70% of total energy use industry GHG emissions.

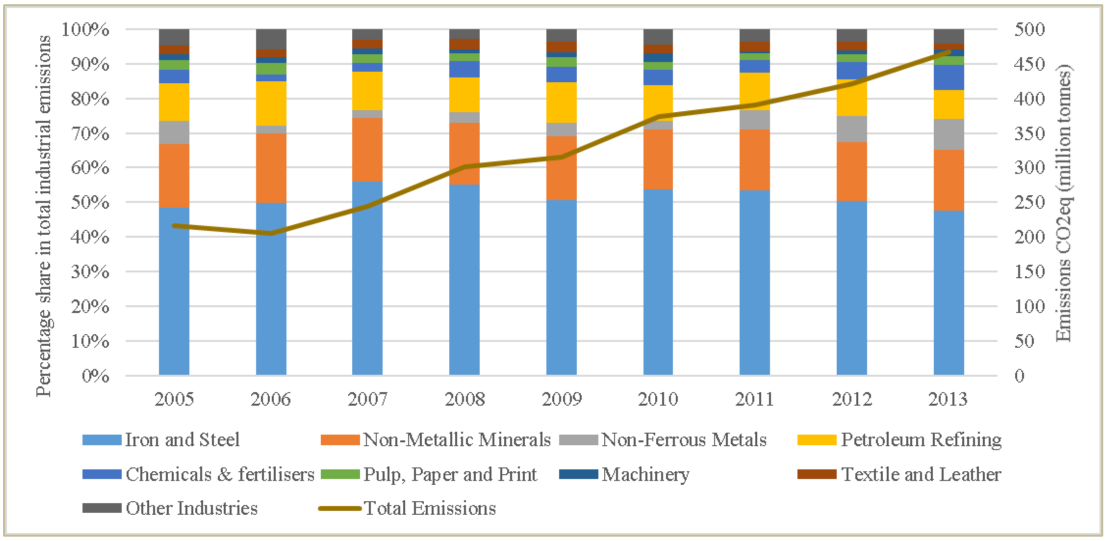


Figure 25: Sectoral emissions of fuel use for 2005 to 2013

b) Trends observed in the state-wise energy related emissions

Odisha (16%), Gujarat (14%), Chhattisgarh (11%), Jharkhand (11%) and Karnataka (9%) are the top five emitter states for latest estimates (2013) – together they represent more than 60% of the energy use based GHG emission by manufacturing sector. Coal is the principle source of emission for most states. Even though Gujarat is not among the top consumers of coal, it is one of the largest emitting states. This is on account of the fact, that Gujarat alone expend 23% and 12% share of natural gas and petroleum fuels demand from the industry sector in India.

Figure 26 and Figure 27 highlight state-wise emission profile of manufacturing activities across India for 2005 and 2013 respectively, which is derived from industry energy consumption.

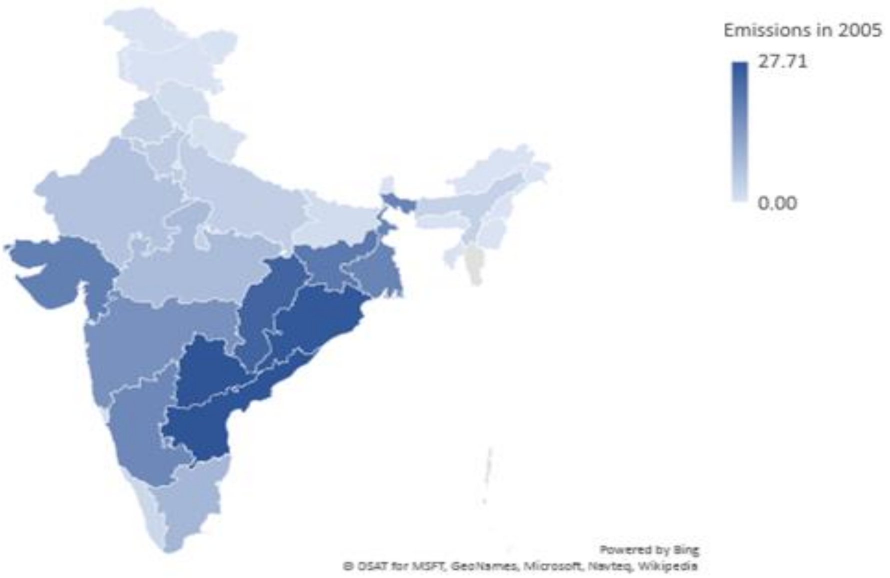


Figure 26: State-wise energy related emissions profile in 2005 *(in Million tonnes CO_2eq)*

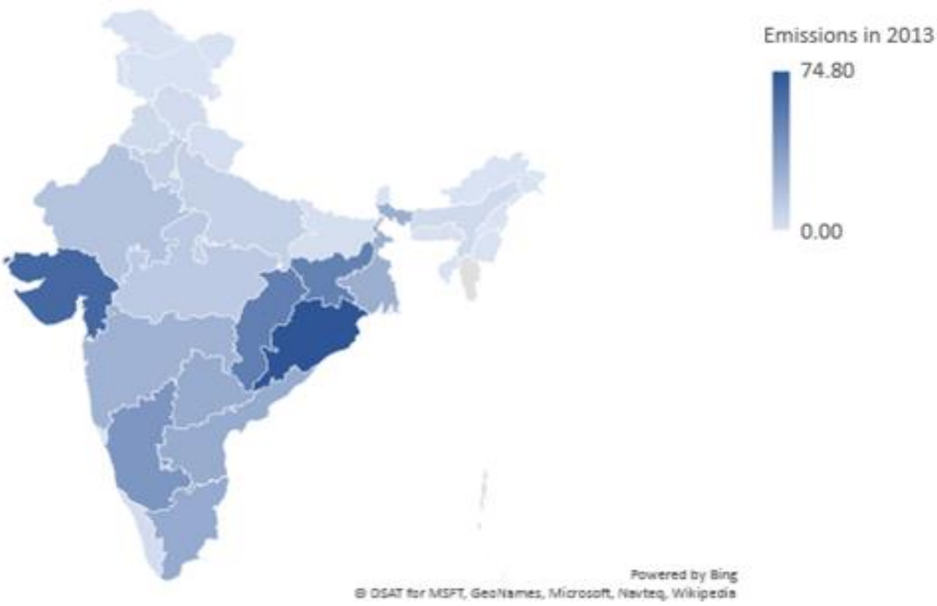


Figure 27 : State-wise energy related emissions profile in 2013 (in Million tonnes CO_2eq)

India's industry sector is a mixed bag of low to high intensive manufacturing activities. Among high energy intensive sectors, iron and steel, cement, aluminium, fertilizer, petrochemical, paper, textile, and food industry, are the noticeable ones. These sectors together correspond to 90% of total industrial energy demand for any given year. Shift in sectoral composition translates to change in energy and emission intensity of industrial activities within a state. Table 7 highlights relative change in terms of percentage value add contribution, within specified states, over the course of assessment period.

Table 7: Percentage change in the industrial value addition share within the states

State	Iron	Cement	Chemicals	Refinery	Aluminium	Textile	Paper
Gujarat	57%	-13%	-7%	18%	33%	-1%	42%
Odisha	24%	2%	46%		-3%		24%
Chattisgarh	59%	38%			-22%		
Jharkhand	-27%	130%					
Karnataka	-61%	-25%	52%	-58%	-20%	-17%	40%
Maharashtra	5%	8%	6%	0%	50%	-18%	-23%
Tamil Nadu	-8%	-13%	26%	-52%	107%	-5%	14%
Andhra Pradesh	-5%	6%	-11%			-9%	21%
West Bengal	-4%		-58%		-46%	-2%	-16%
Uttar Pradesh	55%		16%		-13%	-18%	8%
Rajasthan		14%	2%		20%	6%	
Madhya Pradesh		-13%	10%			1%	-28%

Note: States are arranged in the descending order of their share in industry energy use emission

This structural change has subsequent impact on overall emissions from each state as well. For example, energy intensive sectors like iron steel witnessed strong growth in Gujarat, Odisha and Chhattisgarh. Whereas, these sectors have experienced significant decline in Karnataka and Jharkhand. It is to be noted that energy/emission intensity for a specific sector may also vary across states due to several factors, essentially the choice of technology, quality of fuel/raw material, and efficiency of operation. Hence, this structural shift shall only be taken as an indicator of shifts in emission trends, but not the absolute determinant.

Our analysis of GHG emissions considers only the total primary energy consumption by industry (for process heating), and excludes non-energy use of fuels. Electricity and fuel-use for captive power generation gets accounted separately within Energy Industries (1A1), as per standard IPCC 2006 guidelines.

The top five states, in terms of overall emissions are the same as the top-five states based on total energy consumed, albeit with a slightly different ranking order.

c) Trend of energy mix of the industries across states

Over the last decade, a sharp dip in fuel prices during 2008-09 has been noticed, probably due to recession, and thereafter a steady rise in price trend – except for natural gas (Indexmundi, 2017). Rising energy (fuel) prices have a considerable impact on choice of fuel-mix by industry, which in-turn also gets reflected as a noticeable shift within state(s). Most of such changeovers were recorded for natural gas, replacing conventionally used fuel oil, to power industrial boilers. To understand the impact of rising energy prices on the fuel-mix, we have analysed a relative change in the energy mix between two time-periods, former as 2004 to 2011, and later being 2011 to 2014. This grouping is done to normalise any sudden spike/downfall in a particular year.

It is evident from Figure 28, that the share of petroleum derived fuels (fuel oil, diesel, etc.) is decreasing within industry energy consumption, which gets counterbalanced by the increasing share of natural gas, as well as rising consumption from grid based electricity. Uttar Pradesh is a good reference to this, as illustrated by Figure 29 for all states.

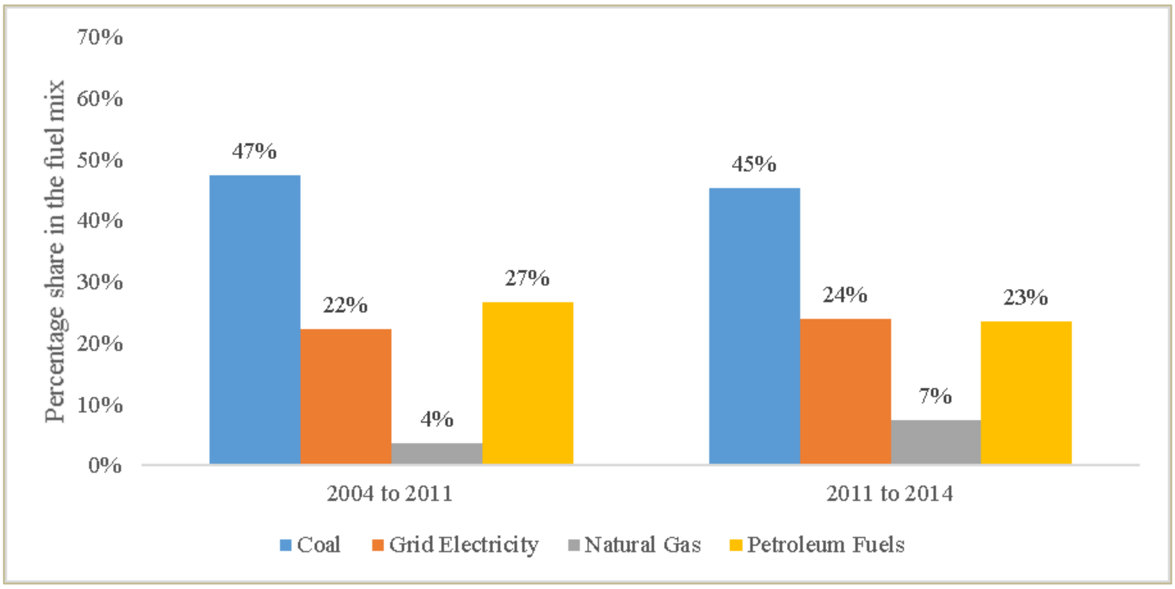
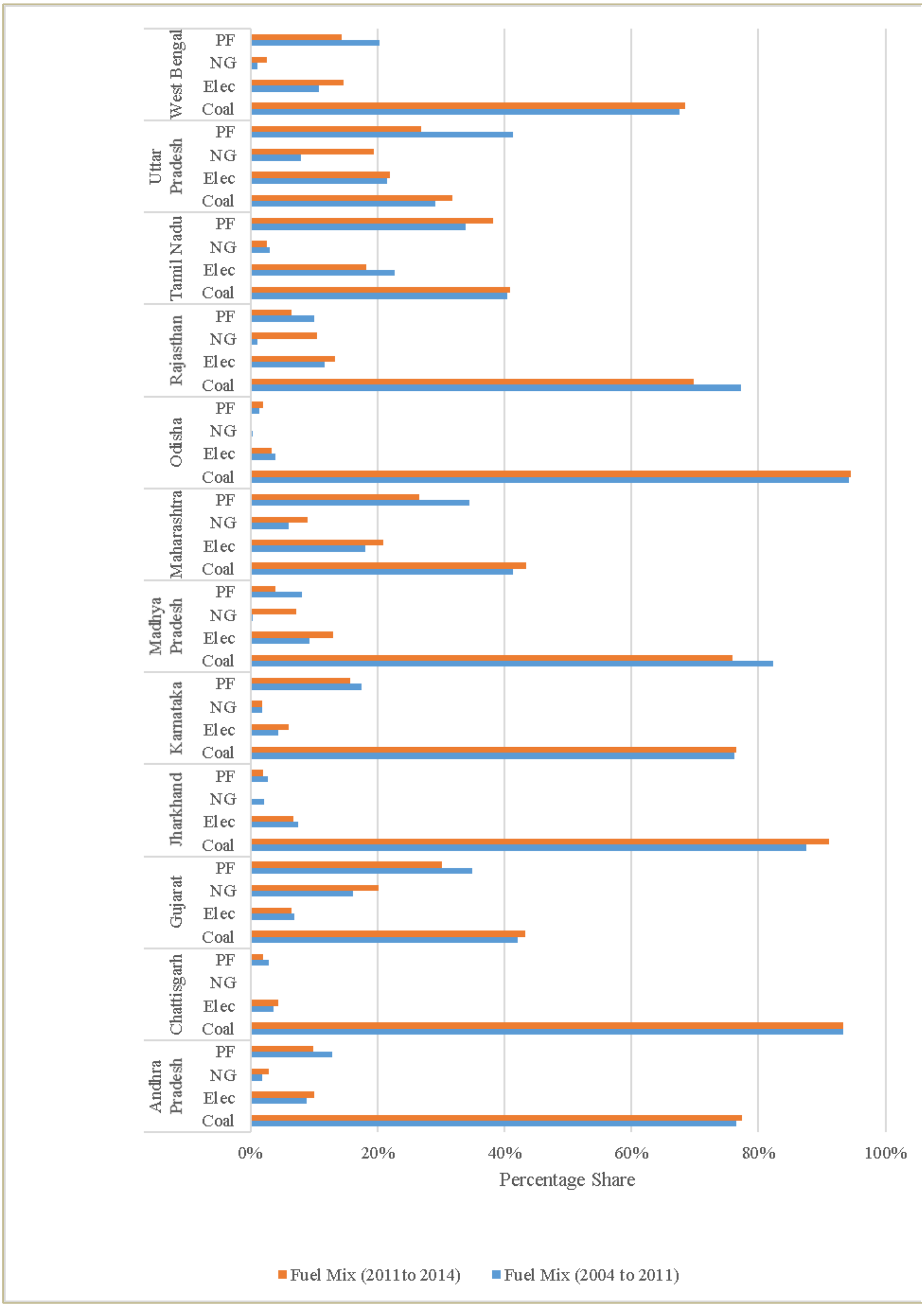


Figure 28: Comparison of the energy mix of industries between the assessment periods

It is observed that between 2011 and 2014, all states, barring Tamil Nadu, were able to achieve a reduction in the share of petroleum fuels in their fuel mix. Industries in Gujarat have the largest share of petroleum fuels, presumably on account of the significant refinery capacity in the state. Industries in Odisha have the lowest share of natural gas within their energy mix.

Among all states/UTs, industries in Uttar Pradesh have the highest share of grid electricity in their fuel mix, while it is lowest for industries in Odisha. In Tamil Nadu, petroleum fuels (mainly diesel) compensates for the falling share of grid electricity in industrial fuel-mix.



Abbreviations- Coal: Coal and Lignite; NG: Natural Gas; Elec: Grid Electricity; PF: Petroleum Fuels

Figure 29: Comparison of fuel mix across various states between the periods

d) Trends in the energy use intensity of the industries across states

Most of the states have shown improvement in their industrial energy intensity, for an average between 2011 to 2014 compared to average of period between 2004 and 2011 (Figure 30). However, the overall impact is marginal because of insignificant reduction from top energy intensive states for their industrial operations.

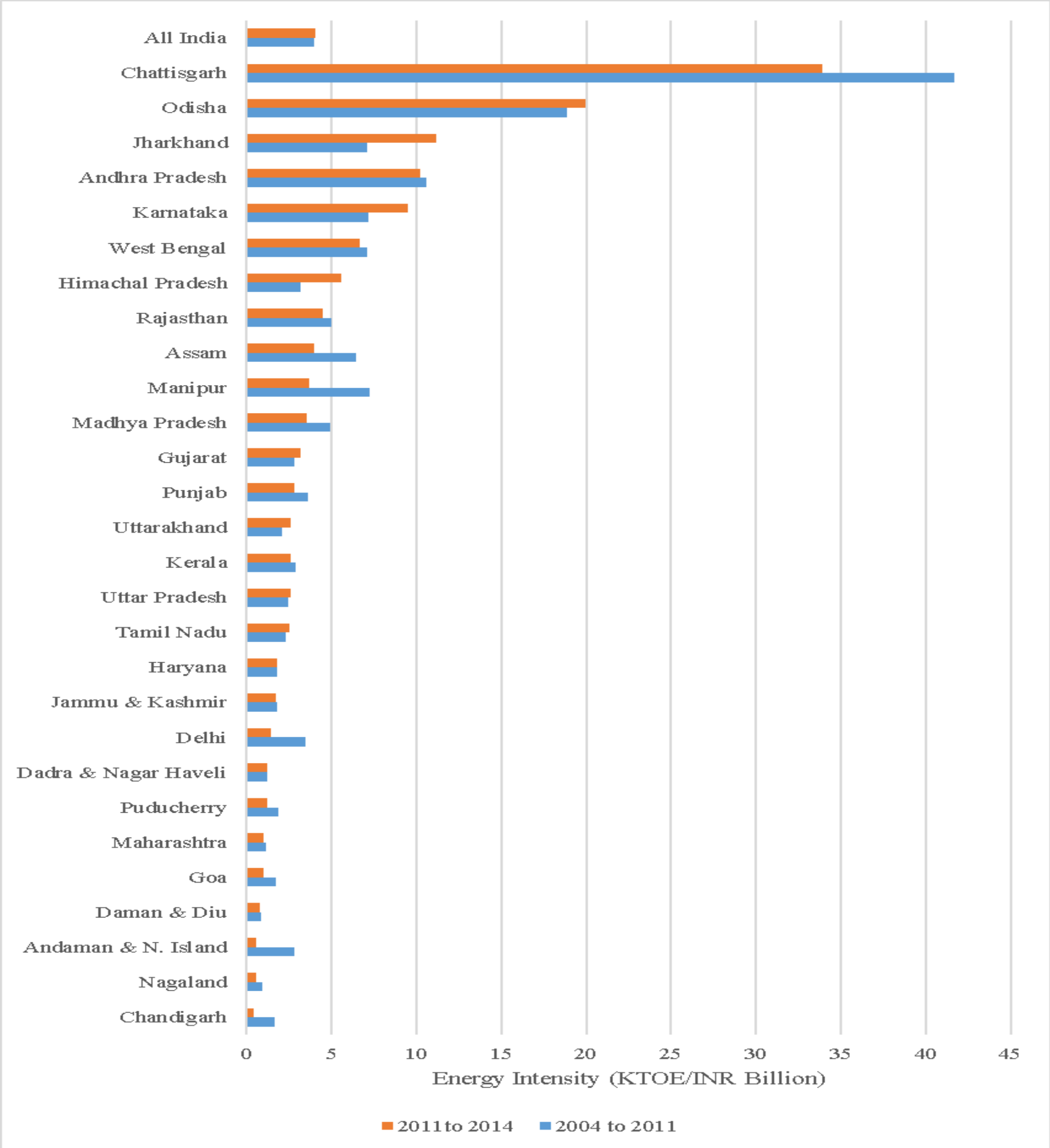


Figure 30: Comparison of energy intensity across various states between the periods

Jharkhand and Odisha have come to be increasingly energy inefficient, which is a big concern, especially in view of India's ambition towards low carbon development strategies. Correlated to this, Chhattisgarh has made significant improvements in energy intensity, however, it is still distinctive as the most energy inefficient state by a huge margin. Having said that, improvements made by certain states is still far from the best of industry standards, and we need an accelerated improvement.

e) GHG emissions from IPPU

GHG emissions from the IPPU activities contributed between 25% and 35% of the overall industrial emissions for the assessment period. Relative to the energy-use emissions, IPPU emissions grew at a lower annual growth rate of 6% increasing from ~ 102 MT in 2005, to ~156 MT in 2013. Figure 31 illustrates the emission trend from various IPPU activities. Cement production, ammonia production and iron & steel manufacturing account for more than 80% of the emissions during the assessment period. Cement sector alone contributes to more than 50% of total IPPU related emissions, as it consumes more than 90% of total limestone/dolomite produced in the country (IBM, 2015).

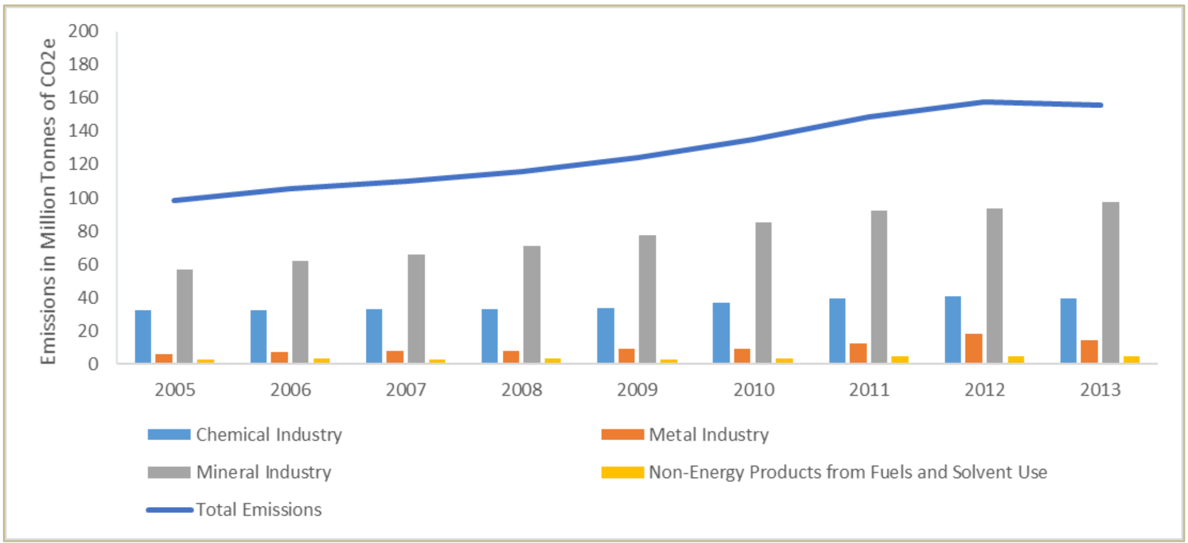


Figure 31: Sectoral emissions from industrial product and process use for the period 2005 to 2013

India is the world's second largest consumer of nitrogenous fertilizers (United Nations Food and Agriculture Organization, 2009). Ammonia is a key intermediary in fertilizer production, which amounts to this sector's major contribution in the IPPU emissions. During 2005 to 2013, ammonia production contributed nearly 17% of total IPPU emissions. As for Iron and Steel, in comparison to energy requirement (and hence energy derived emissions), effect of carbonaceous material consumption on emissions is relatively low. Further specific requirement of carbonaceous material is far lesser compared to cement sector. A steadily growing steel demand, and the resultant increase in has resulted in the sector having the third largest share of ~6%.

f) Trends observed in the state-wise IPPU related emissions

State wise IPPU emission trend is observed to be constant, which partially indicates that the relative change in activity and process and technology use across the relevant sectors has not changed. State-wise IPPU emission profile can be observed from Figure 32 and Figure 33 each depicting base year (2005), and current year (2013) respectively. A quick view suggests Gujarat (16%) to be highest emitter, followed by Maharashtra (14%), Rajasthan (11%) and Andhra Pradesh (9%). These five states represent almost 50% of the overall IPPU emissions.

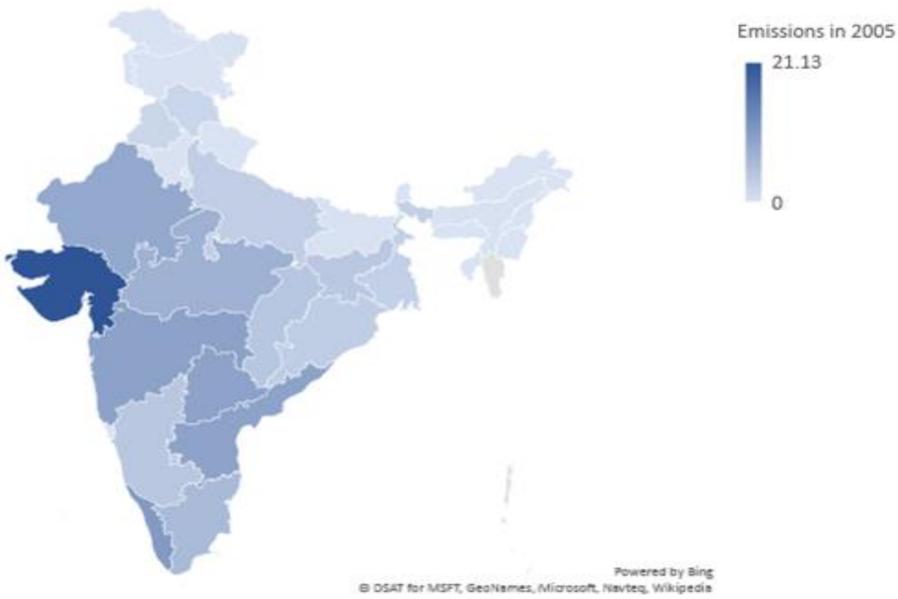


Figure 32: State-wise IPPU emissions for the year 2005 (in Million tonnes CO_2eq)

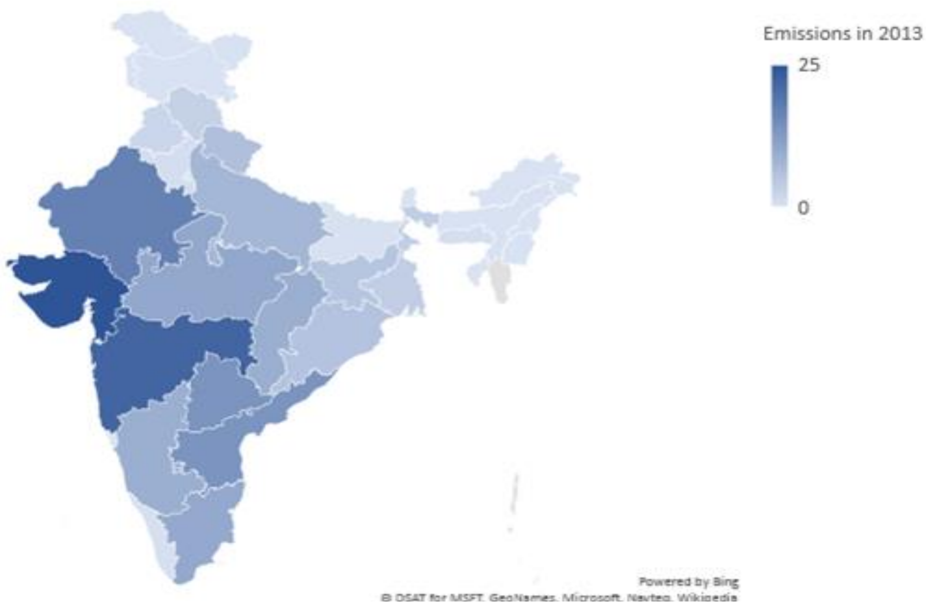


Figure 33: State-wise IPPU emissions for the year 2013 (in Million tonnes CO_2eq)

Figure 34 captures IPPU emission trend for major industrial sectors, coming from top five emitting states. Fertilizer and petrochemical industry (particularly ammonia and urea) has increasingly contributed to the emissions in Gujarat and Maharashtra. Similarly, the presence of non-metallic mineral industry (primarily cement) has majorly contributed to the increasing emissions in Rajasthan, Andhra Pradesh and Madhya Pradesh.

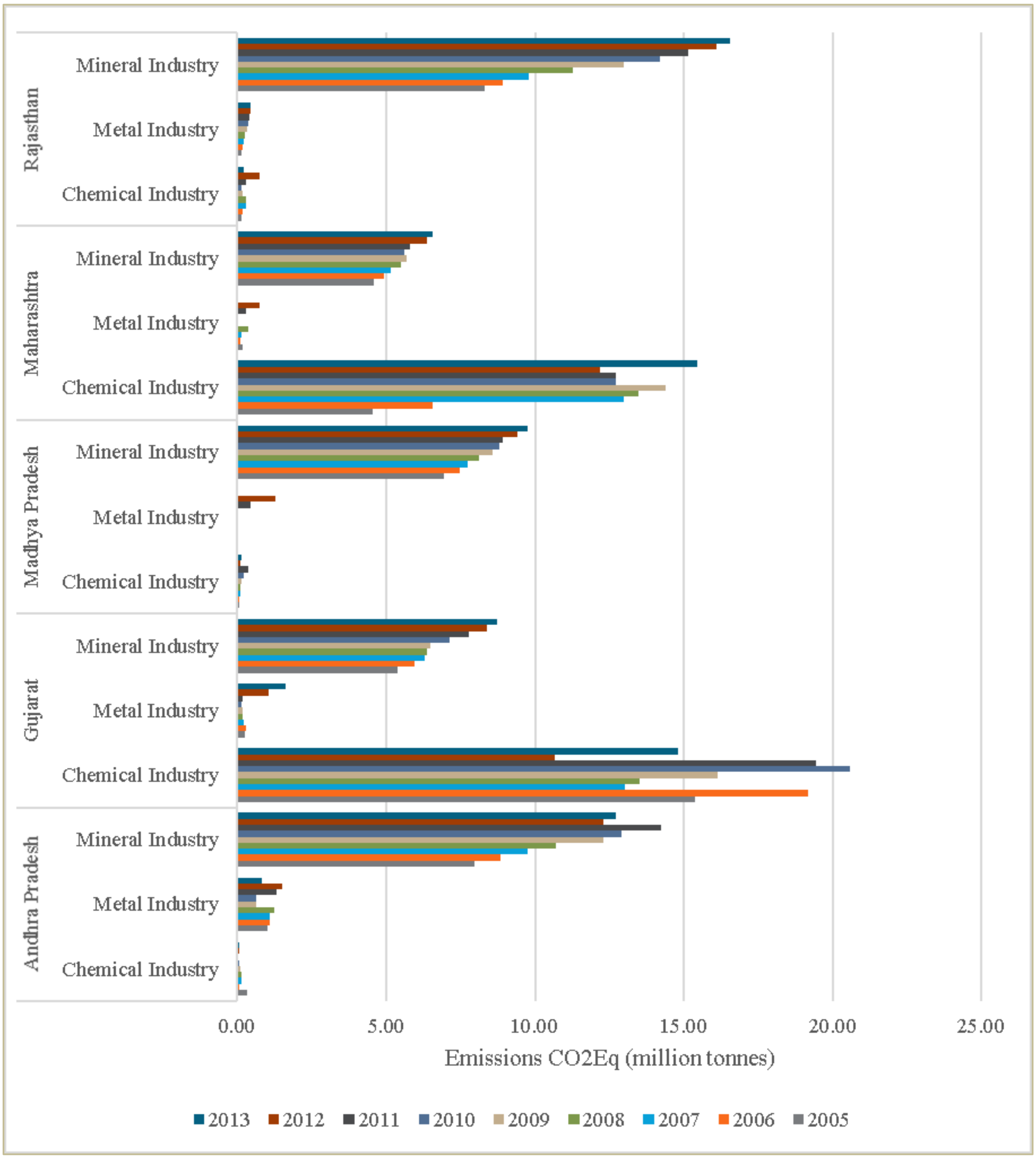


Figure 34: Industry-wise IPPU emissions from the top 5 emitting states

3. Conclusion

India's has committed to a reduction in emission intensity by 33% to 35%, as compared 2005 levels by 2030. Simultaneously, India also has ambitions of increasing its overall manufacturing base. Though the two stated objectives are seemingly at odds, efficiency gains and changes in fuel mix can significantly aid progress in both.

Our trend analysis indicates that there is no significant decoupling of industrial emissions from contribution, across any of the states. Figure 35 highlights that both emissions and industrial GVA were in-step all through the analysis period. Here, the GVA values are normalised by using running average of preceding and succeeding years to avoid stock-balance factors, and other outlier variables.

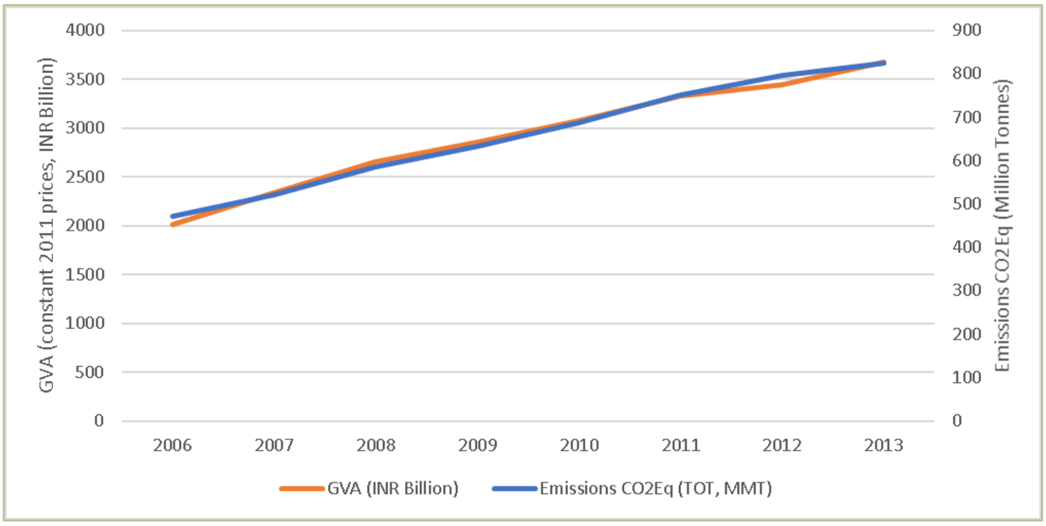


Figure 35: Trends of total industrial emissions and GVA for the period 2006 to 2013

From our analysis, we have found that certain states, such as Chhattisgarh and Odisha offer immense potential for further energy intensity reduction. Industries like Iron and Steel, and Cement in these states have relatively high energy intensities when compared to their counterparts in other states (e.g. Jharkhand).

Relative changes in fuel prices were also found to be significant driver towards the cleaner fuel shifts observed within some states. However, it is also evident that such transitions were not strong enough to make a significant cut in the share of coal use by industries. The uptake in natural gas as fuel by the industries was seen much more prominent in the period 2011 to 2014 as compared to 2004 to 2011. However, the majority of uptake was in states like Gujarat, Uttar Pradesh and Maharashtra because of increasing expanding infrastructure (primarily pipelines) that enables gas consumption. Enabling conditions, such as infrastructure creation or alternative fuels to thrive could prove to be strong drivers of emissions intensity reduction. Gujarat and few states in North-east have benefited immensely from such interventions. Another big driver is technology upgradation, a shift towards efficient processes coupled with expansion of value add chain to curtail emission intensity at economy level.

AFOLU Sector

Vasudha Foundation Analysis

1. Introduction

Emissions from the AFOLU sector can broadly be divided into three parts:

1. Emissions from Livestock
2. Emissions from Land
3. Emissions from Aggregate Sources and Non-CO_2 emissions from Land (primarily due to farming and other management practices such as biomass burning on land)

The graph below explains the emission estimates from these three sub-sectors.

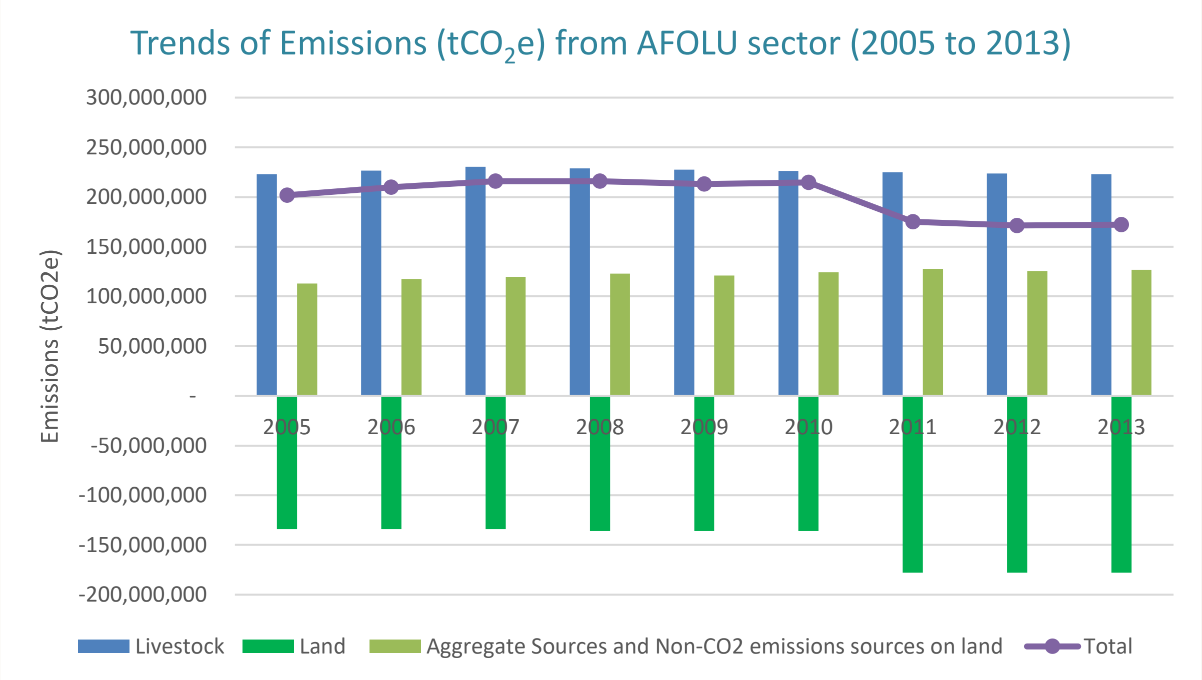


Figure 36. Trends of emissions from AFOLU sector (2005 to 2013)

In general, there is a marginal decline of GHG emissions from AFOLU, primarily due to increased removal of CO_2 by land, primarily forests which are sinks and not sources of GHGs. Emissions from livestock and aggregate sources do not show any pronounced trends and are more or less flat.

Between 2005 and 2013, forests were removing around 40% of the emissions arising out of AFOLU sector, which increased to around 50% from 2011 onwards, as shown in the graph below (figure 37).

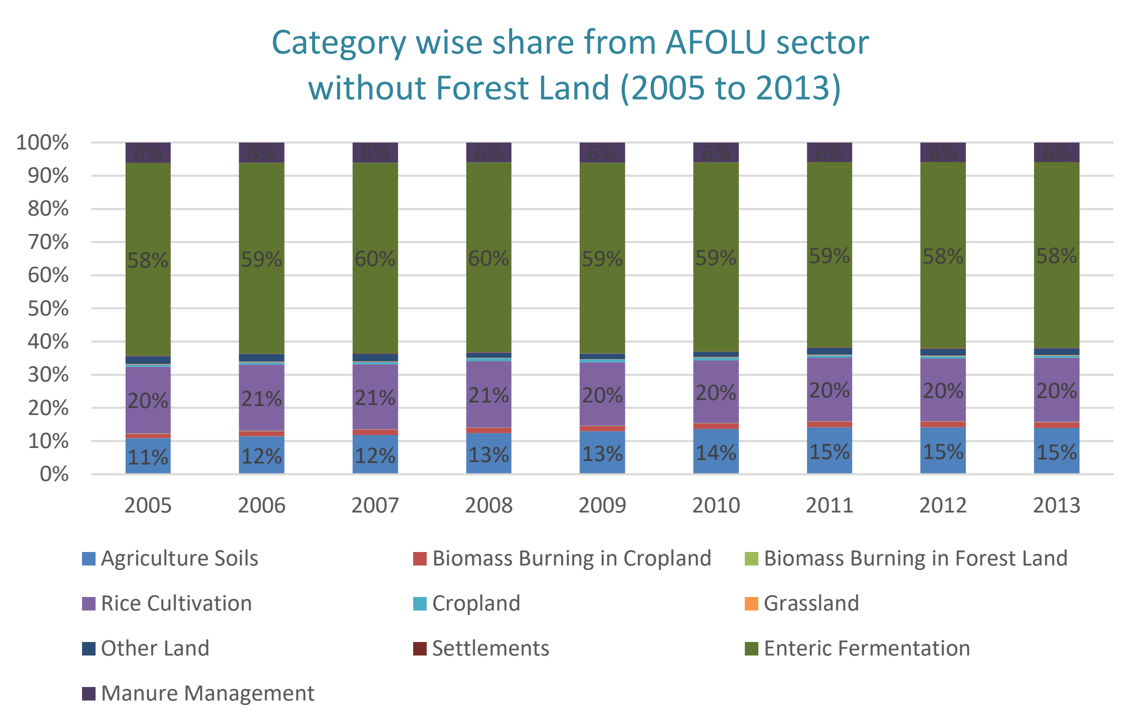


Figure 37. Category wise share from AFOLU sector without Forest Land (2005 to 2013)

The relative contribution of these three sectors viz. livestock, land and aggregate sources and non-CO_2 emissions from land (without adjusting for CO_2 removals from the forests) to the overall emissions from AFOLU sector is shown in the graph below:

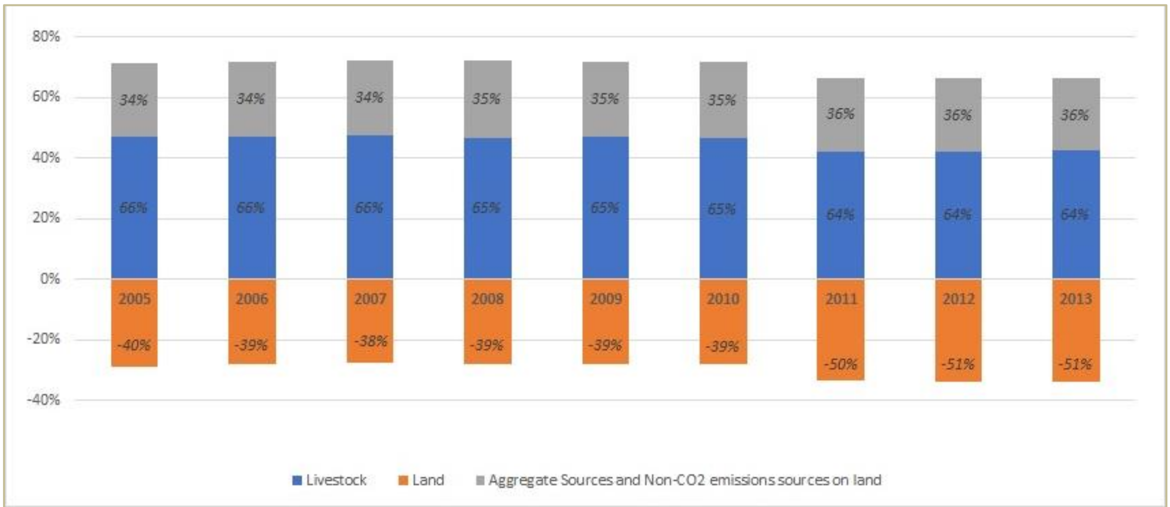


Figure 38. Sectorwise emission share from AFOLU sector (2005 to 2013)

Clearly, emissions from this sector are dominated by mainly two sources viz. livestock and rice cultivation which together account for close to 80% of the emissions from this sector. The emissions emanating from these two sources, however, have been fairly stable over the estimating period. Apart from these two, the other significant category of emissions is agriculture soils that show a creeping upward trend primarily due to use of fertilisers.

Among the states, Uttar Pradesh is the top emitter from the AFOLU sector in the country in years 2005 and 2013. The other large emitters from the AFOLU sector in year 2005 are Rajasthan, Andhra Pradesh[12], Bihar and Maharashtra. However, in year 2013, states with maximum emissions from AFOLU sector are Uttar Pradesh, Andhra Pradesh, Rajasthan, Bihar and West Bengal, which replaces Maharashtra in the top 5 emitters in 2013. There are, however, many states that have negative emissions from the AFOLU sector, primarily since they still contain a good amount of forests within their territories. The top 5 states/UT that have negative emissions from are AFOLU sector in India in 2013 are Kerala, Tamil Nadu, Arunachal Pradesh, Jammu & Kashmir, and Andaman & Nicobar Islands. The overall pattern of emissions from the AFOLU sector is shown in the two charts shown below:

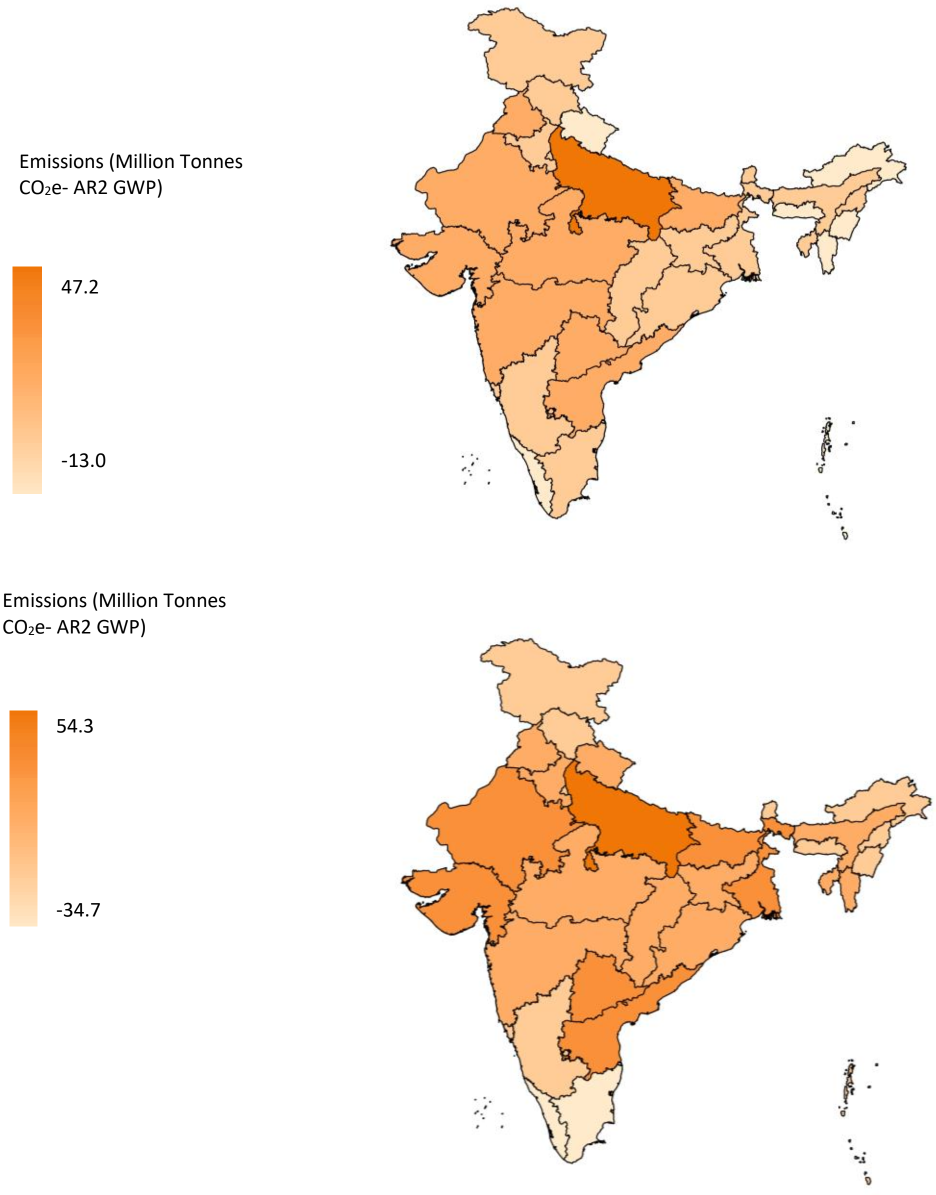


Figure 39. Overall pattern of emissions from the AFOLU sector in 2005 and 2013

[12] All references to Andhra Pradesh are for the undivided legal and geographical entity before it was bifurcated into Telangana and Seemandhra. This is because all data that was collected and analysed is for the period before the state was bifurcated in 2014.

It is also significant to note that the top 5 contributors among states to emissions from the AFOLU sector account for 88% of India's emissions, as is shown in the graph below:

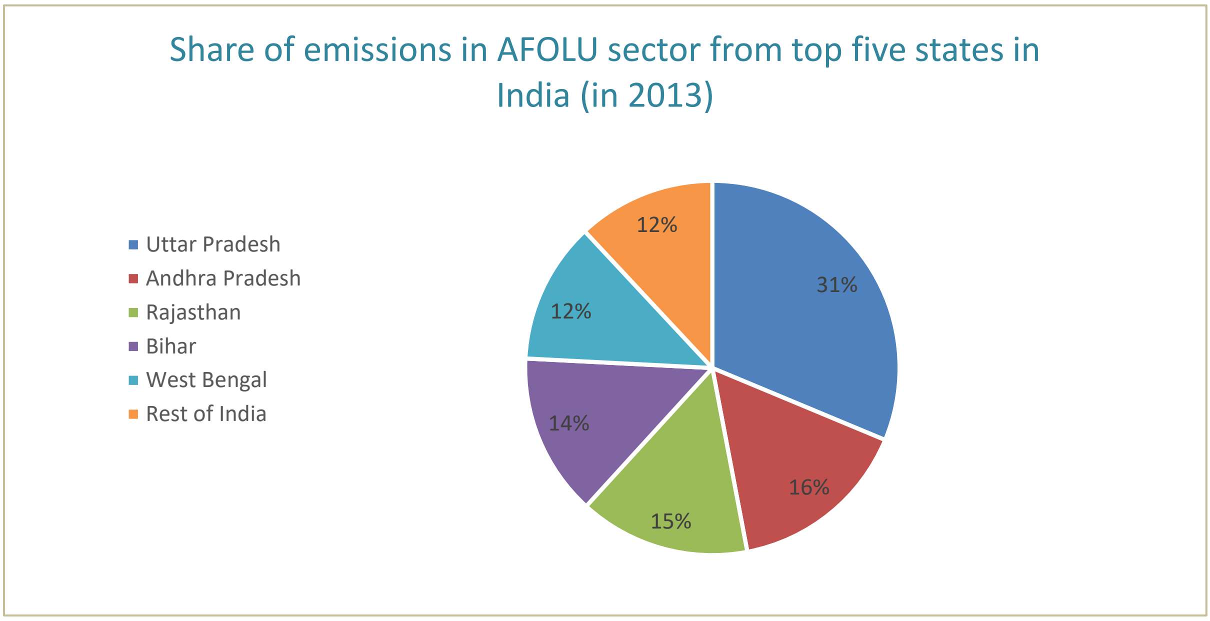


Figure 40. Share of emissions in AFOLU sector from top five states in India (in 2013)

2. Analysis of the Trends of GHG Emissions of the AFOLU Sector

A snapshot of the sub-sectoral trends within the AFOLU sector is being provided below:

a) Emissions from Livestock

The overwhelming proportion of the emissions from this sub-sector emanate from the process of enteric fermentation *(a digestive process of breaking down the food ingested by cattle leading to emissions of methane gas)*, as shown in the graph below.

Another aspect of this is the relative share of bovines, both dairy and non-dairy animals to the overall emissions emanating from the livestock sub-sector, which is around 90% of all emissions from this sub-sector, as shown in the graph below.

Thus, the population of indigenous cattle, crossbred cattle and buffaloes mainly drives emissions from the livestock sector. The other aspect of emissions from this sector would be how animal husbandry practices are adapted by modifying feeds to animals in order to reduce or minimize the emissions from enteric fermentation.

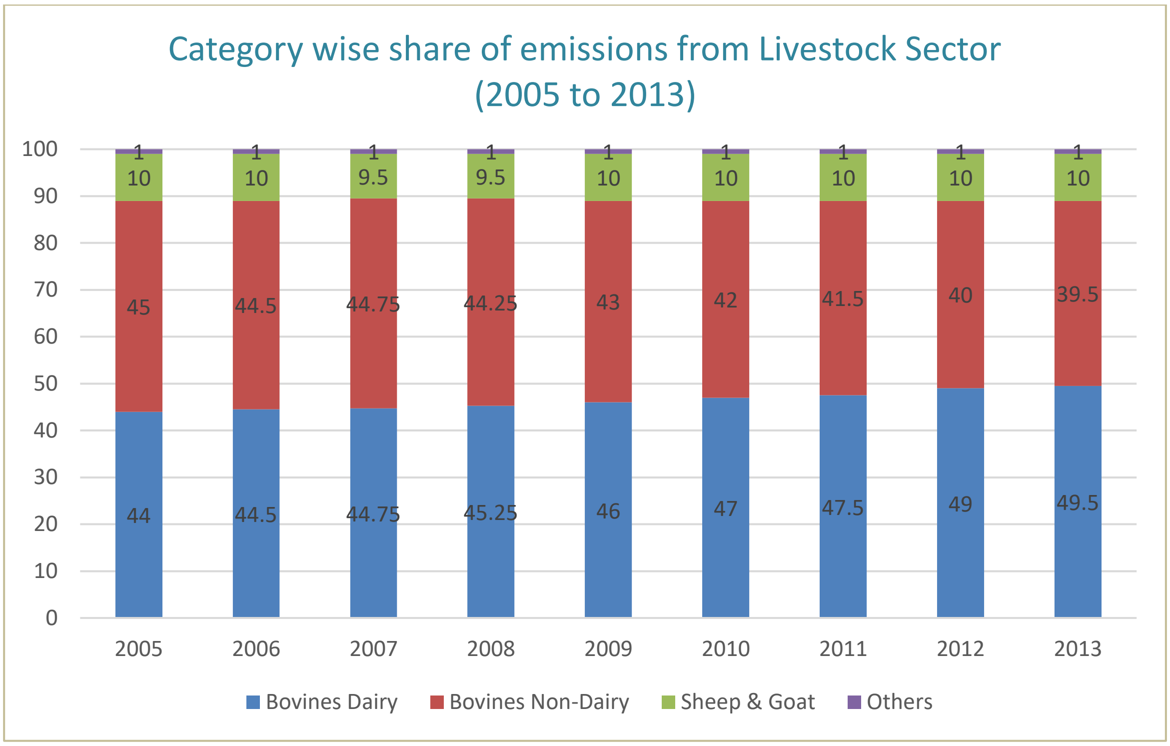


Figure 41. Category wise share of emissions from Livestock Sector (2005 to 2013)

As far as actual emissions are concerned, between 2005 and 2013, despite a slight rise between 2005 and 2007, by 2013, GHG emissions from livestock had settled down at the same level as found in 2005. Thus, the overall trend of emissions due to livestock is one of stability and stagnation.

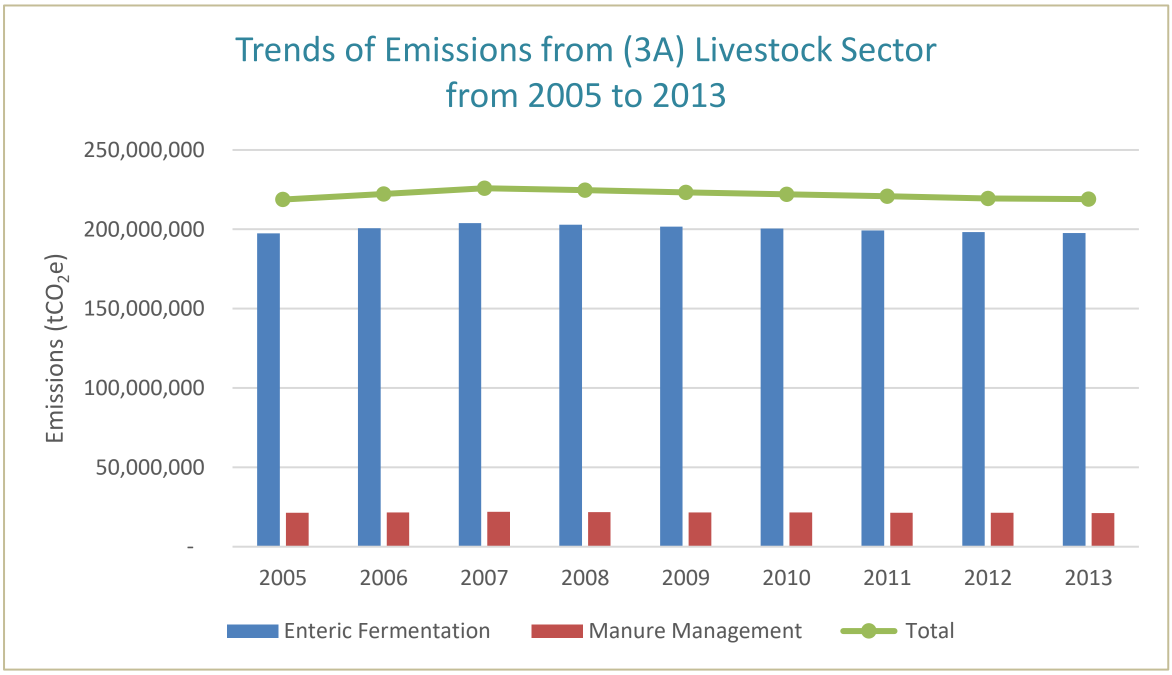


Figure 42. Trends of Emissions from (3A) Livestock Sector from 2005 to 2013

The state that contributes most towards emissions from livestock is Uttar Pradesh, primarily since it has the highest population of cattle in the country. The other states that are big emitters of GHGs in 2013 from the livestock sector are Uttar Pradesh, Rajasthan, Madhya Pradesh, Andhra Pradesh and Maharashtra. The states that contribute least to emissions from livestock sector in year 2013 are Nagaland, Delhi, Sikkim, Goa and Mizoram.

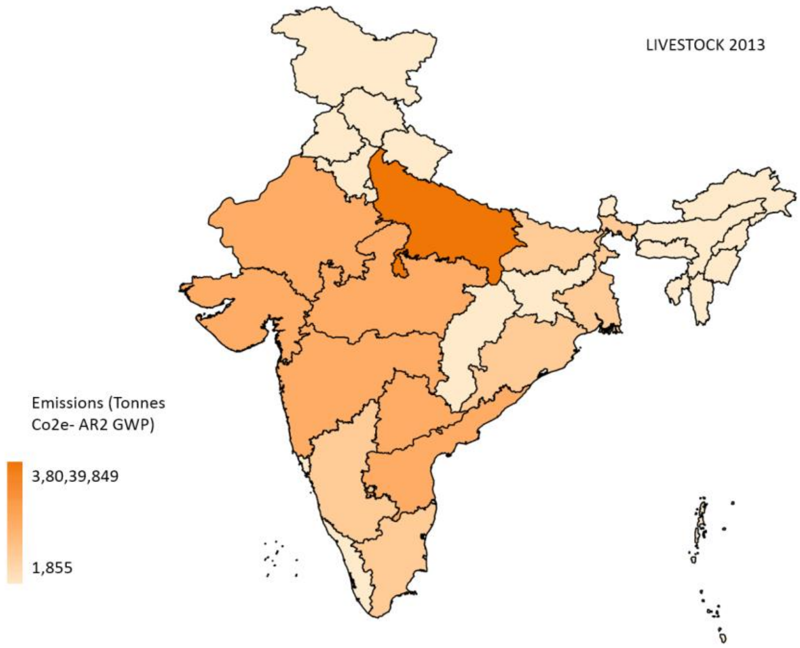


Figure 43. Statewise emissions profile of Livestock sector in 2013

The top 5 contributors among states to emissions from the Livestock sector account for 50% of India's emissions, as is shown in the graph below:

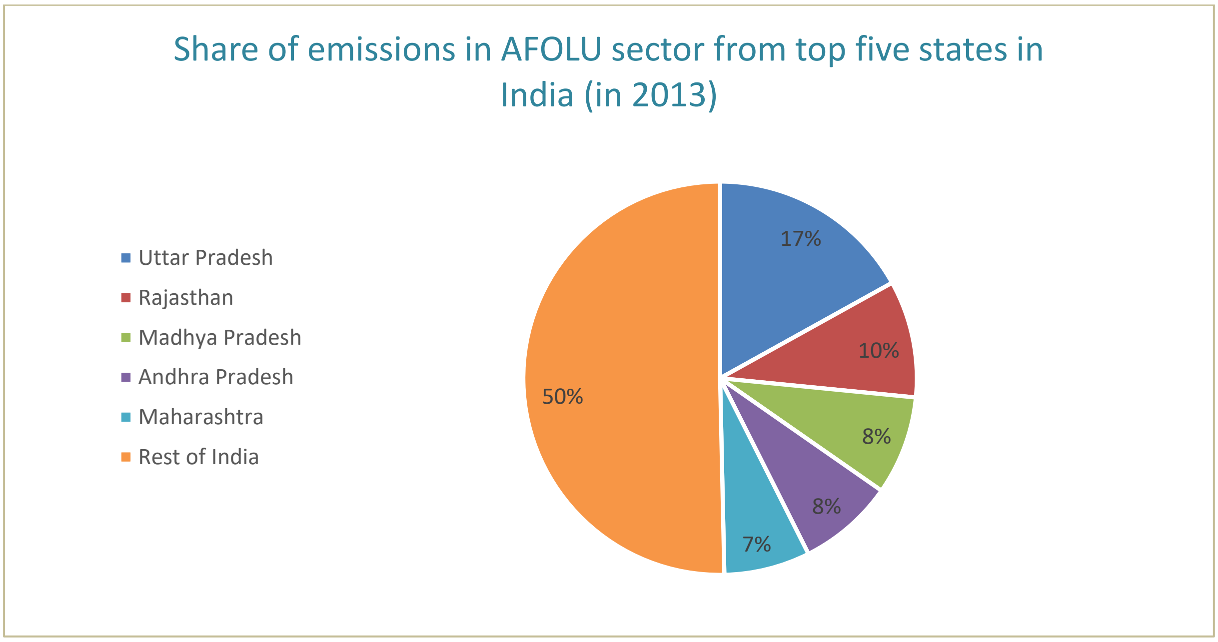


Figure 44. Share of emissions in AFOLU sector from top five states in India (in 2013)

b) Emissions from Land

Positive emissions from land are almost negligible. Negative emissions from this sector, primarily from forests, overwhelm the positive emissions from croplands, grasslands, settlements and other lands, and thus result in this category being an overall sink rather than a source. The graph placed below illustrates this.

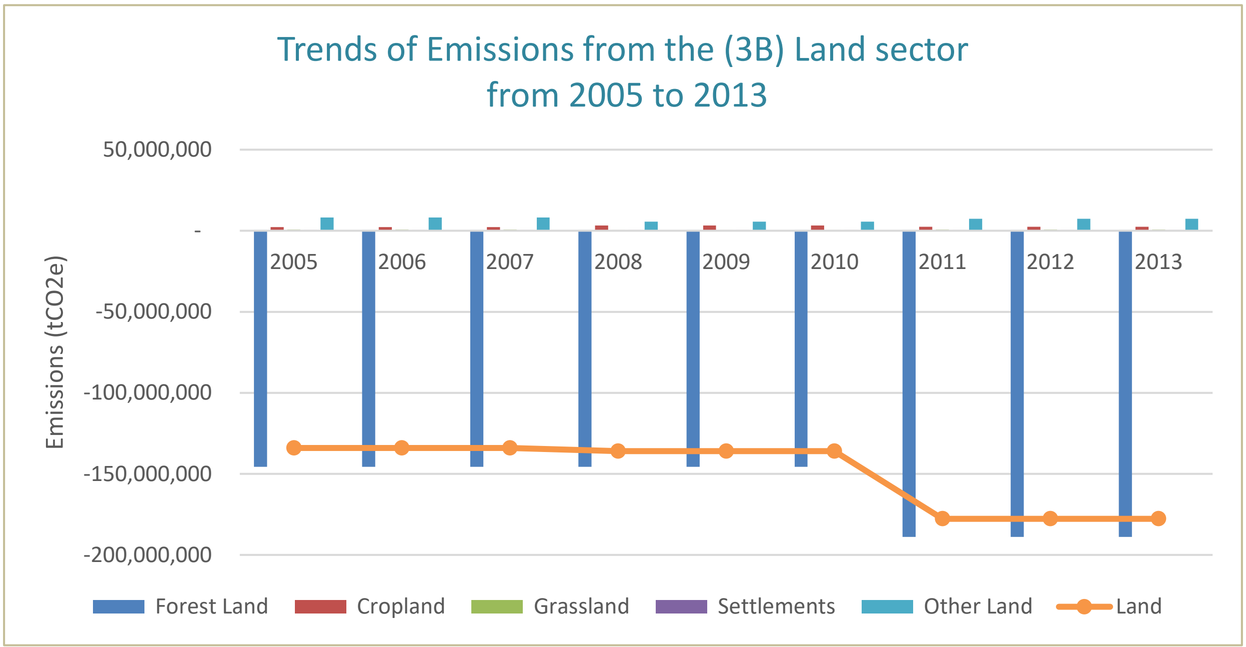


Figure 45. Trends of Emissions from the (3B) Land sector from 2005 to 2013

Between 2005 and 2013, the overall trend of emissions is negative, primarily due to greater CO_2 removals by forest lands after 2011.

This is primarily due to India's success in avoiding deforestation during the period under consideration. Between 2005 and 2015, India's forest cover[13] remained at a level of around 21% of the total land available in the country.

The state accounting for maximum CO_2 removals in 2005 was West Bengal, followed by Arunachal Pradesh, Odisha, Andhra Pradesh and Kerala. In 2013, however, the state showing maximum CO_2 removals was Tamil Nadu, followed by Jammu and Kashmir, Arunachal Pradesh, Karnataka and Kerala. Only six Indian states contribute to emissions (net positive) from the Land sector and are shown in the graph below:

[13]. *Forest Survey of India: State of Forest Report from 2001 to 2015.*

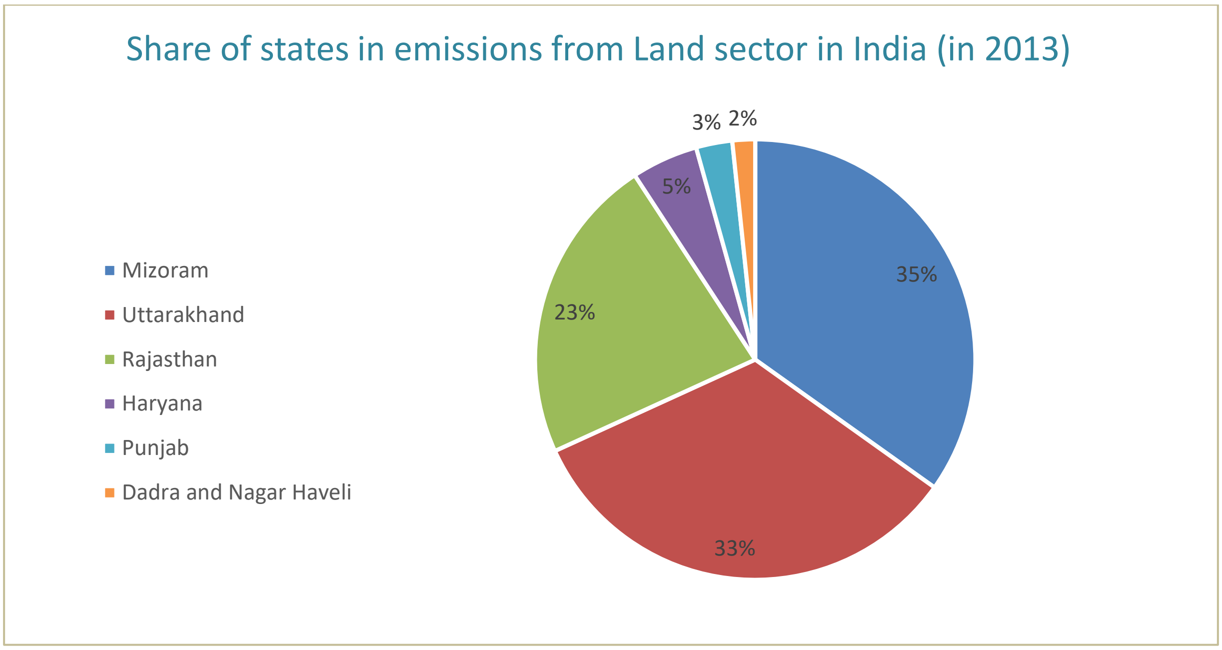


Figure 46. Share of states in emissions from Land sector in India (in 2013)

The top 5 contributors among states to net removals from the Land sector account for 69% of India's removals, as is shown in the graph below:

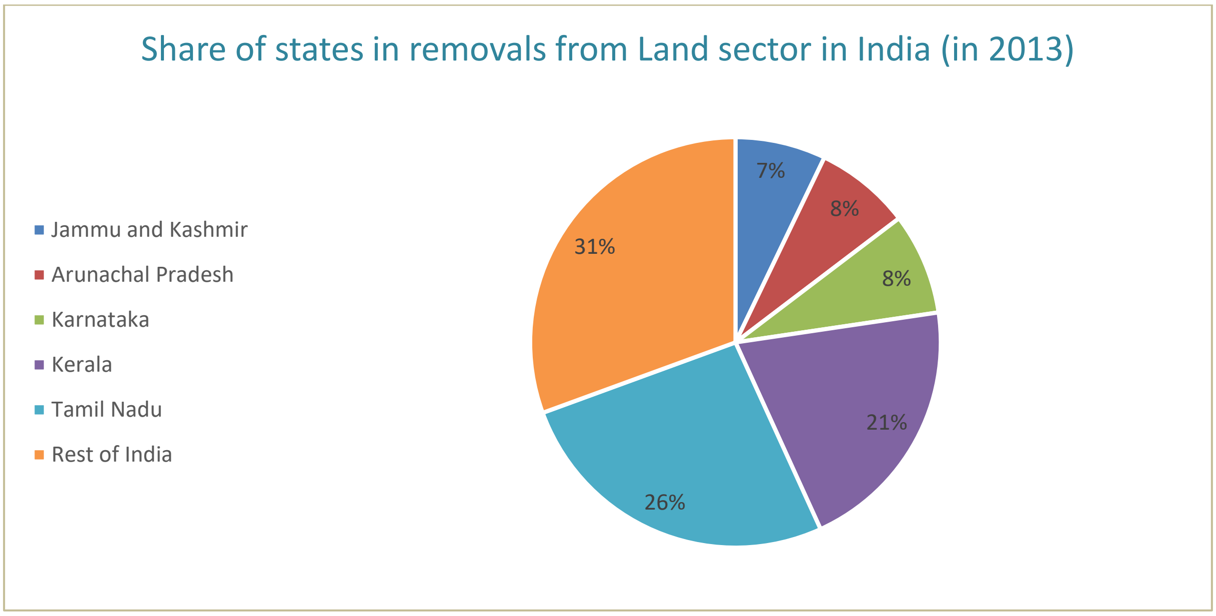


Figure 47. Share of states in removals from Land sector in India (in 2013)

c) Emissions from Aggregate Sources and Non-CO_2 emissions from Land (primarily due to farming and other management practices such as biomass burning on land)

Emissions from this sector are primarily of methane and nitrous oxide. Their relative shares, in carbon dioxide equivalent emissions are shown in the graph below:

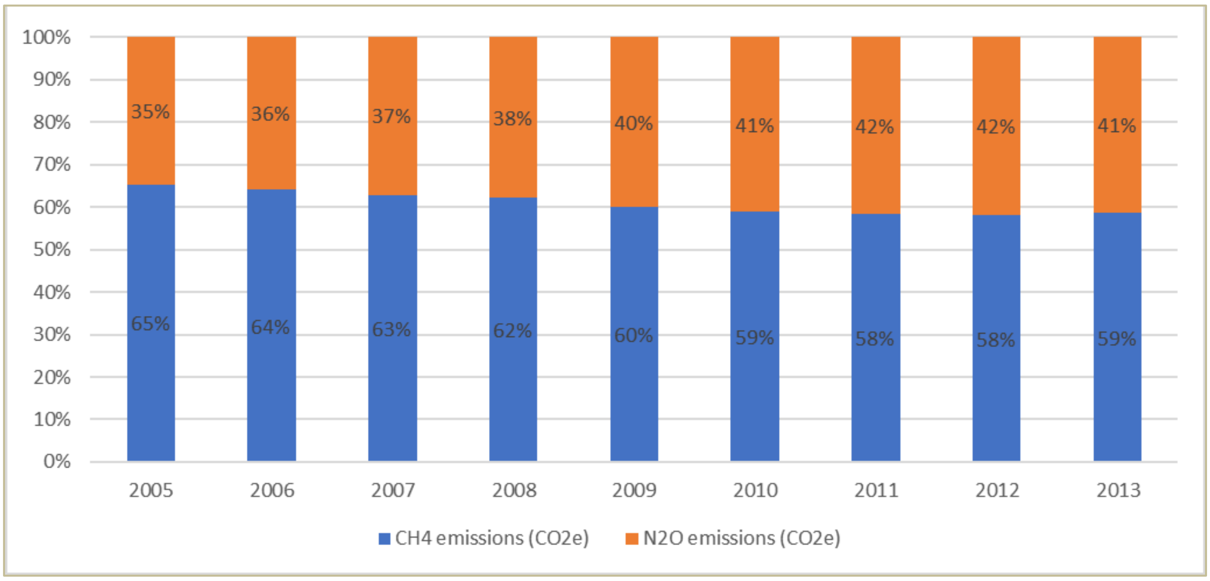


Figure 48. Trends in methane and nitrous oxide emissions (in tCO_2e) from aggregate sources and non-CO_2 emissions sources on land

Methane emissions are a major constituent of emissions from this sector, primarily due to rice cultivation. However, the relative contribution of nitrous oxide emissions has been gradually increasing because of growing fertilizer use.

The major sources of GHG emissions in this sector are shown below.

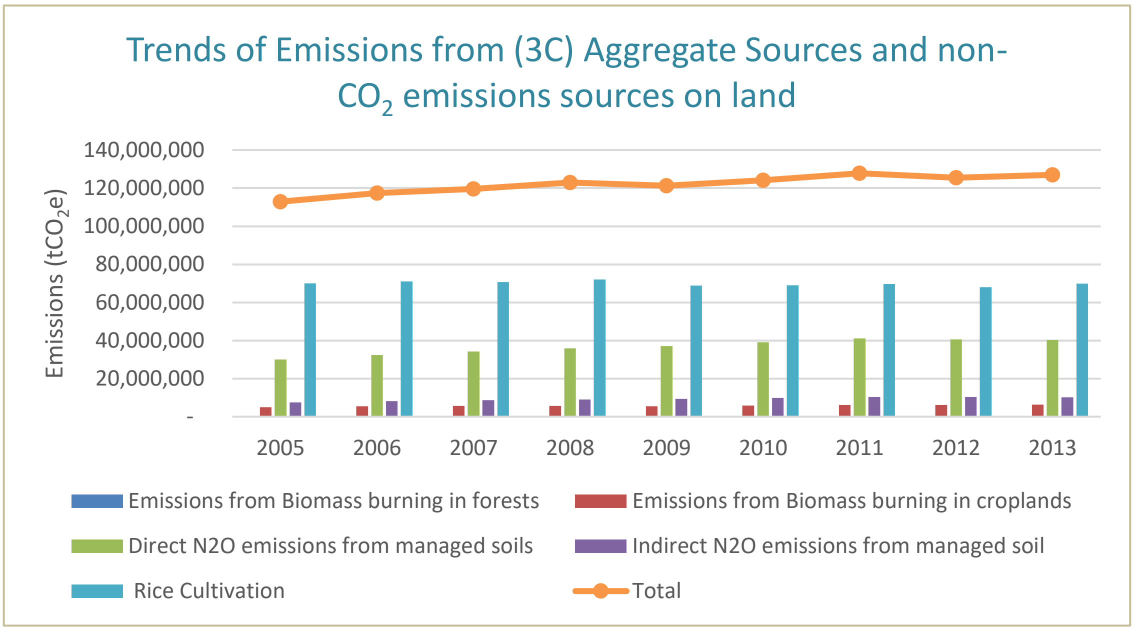


Figure 49. Trends of Emissions from (3C) Aggregate Sources and non-CO_2 emissions sources on land

The dominant activity contributing to emissions from this sector is rice cultivation.

The states that have a major contribution to emissions from this sector in 2013, primarily due to widespread cultivation of rice are Uttar Pradesh, Andhra Pradesh, West Bengal, Bihar and Odisha as shown in graph given below. Together these states combine to net emissions of 52%.

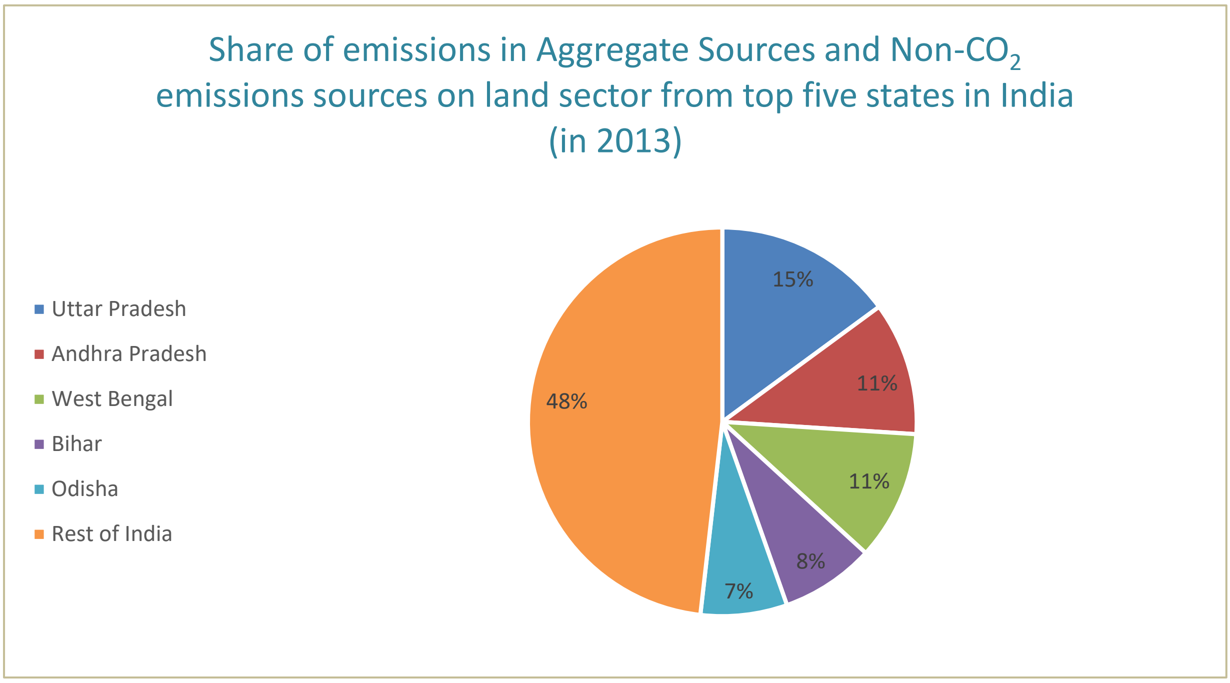


Figure 50. Share of emissions in Aggregate Sources and Non-CO_2 emissions sources on land sector from top five states in India (in 2013)

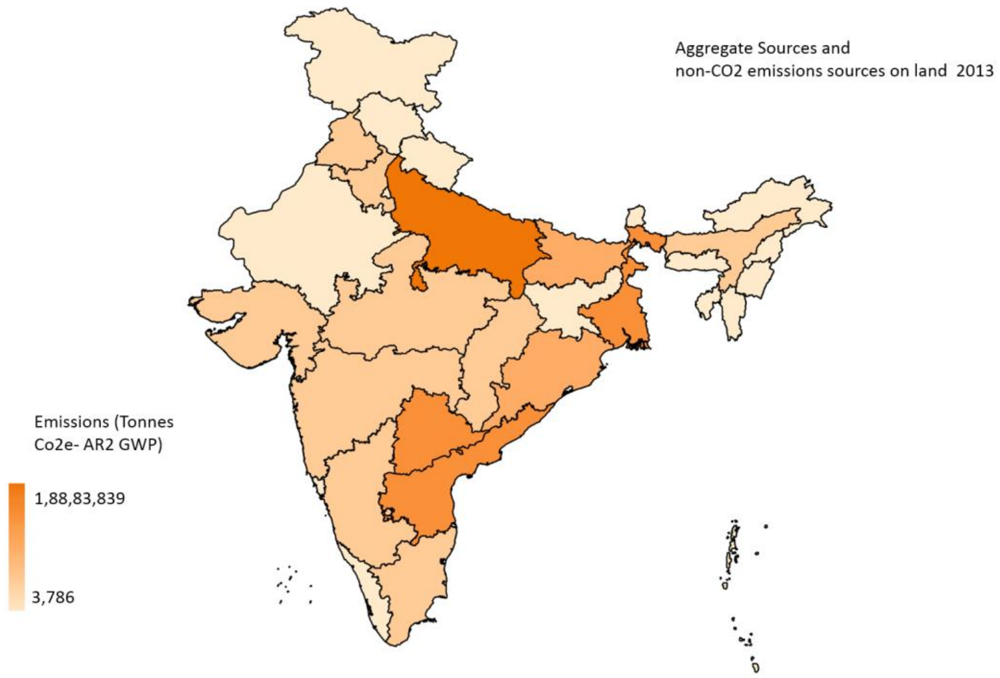


Figure 51. Emissions profile from aggregate sources and non-CO_2 emission sources on land in India (2013)

3. Conclusion

While emissions from the AFOLU sector remain significant in India, their importance is gradually declining, as is evident from the graph below showing a declining trend in both per capita emissions from AFOLU sector as well as a decline in intensity of emissions from this sector.

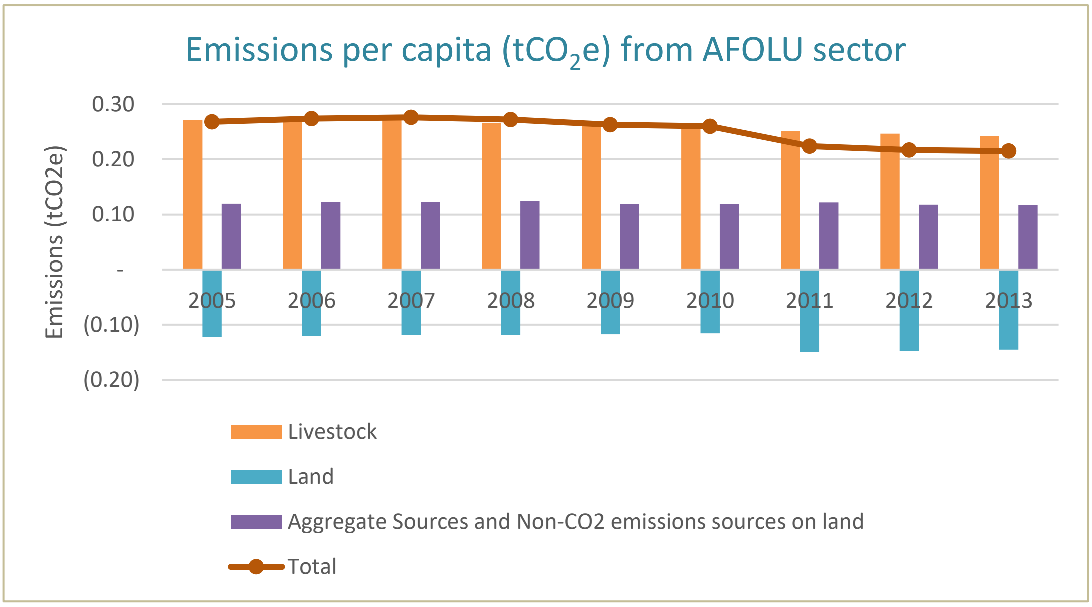


Figure 52. Emissions per capita (tCO_2e) from AFOLU sector

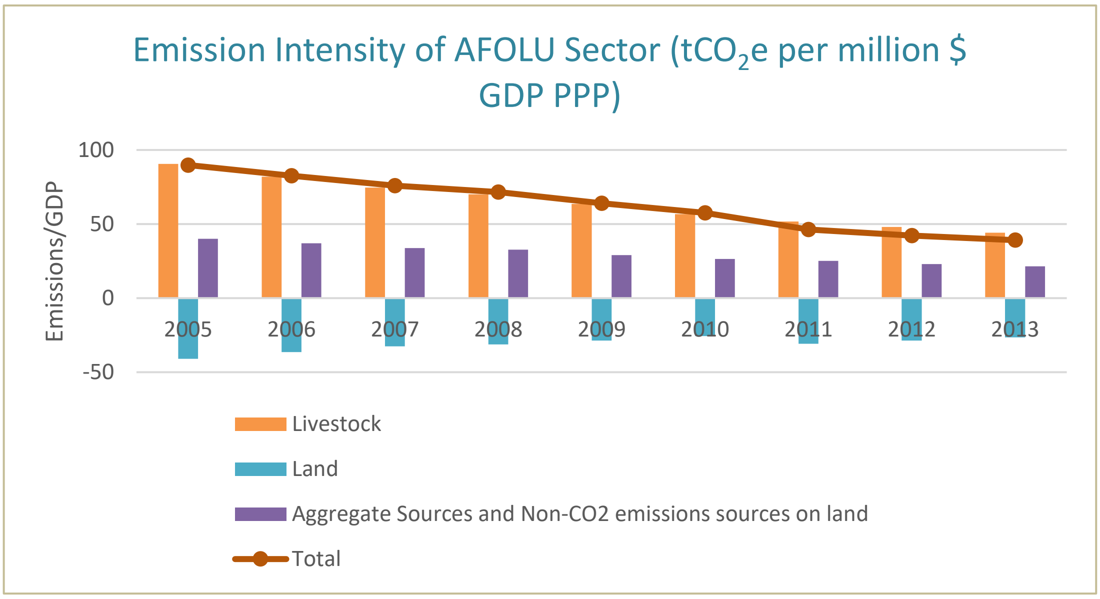


Figure 53. Emission Intensity of AFOLU Sector (tCO_2e per million $ GDP PPP)

However, these trends also allude to the pervasive agrarian distress that prevails in India. An improvement in the economic health of this sector could well mean an increase in its emissions, unless there are substantive changes in the technologies and production processes being deployed in the sector.

Waste Sector

ICLEI Local Governments for Surtainability (South Asia) Analysis

GHG Emission and Trend Analysis for Waste Sector

1. Key Trends for the Waste Sector

Municipal solid waste, domestic wastewater and industrial wastewater are the key sources of GHG emission in the country's Waste sector. Methane (CH_4), a potent GHG having a global warming potential (GWP) that is 25 times greater than that of carbon dioxide (CO_2), is produced and released into the atmosphere as a by-product of the anaerobic decomposition of solid waste and when domestic and industrial wastewater is treated or disposed anaerobically. A smaller amount of Nitrous oxide (N_2O) emissions occur from the disposal of domestic wastewater into waterways, lakes or seas due to the protein content present in domestic wastewater.

National emission estimates prepared for the years 2005 to 2013 by the GHG Platform – India indicate that India's Waste Sector contributed to GHG emission of 89.14 Million tonnes (MT) of carbon dioxide equivalent (CO_2e) in the year 2013 (see Table 1). Over the years, GHG emissions resulting from the treatment and discharge of domestic wastewater account for a major share of all GHG emissions from the Waste sector; contributing to nearly 60% of the total GHG emissions from the country's Waste sector in 2013. Treatment and discharge of industrial wastewater was the 2nd largest contributor to GHG emissions in the Waste sector, with a share of 23.5% in 2013, followed by solid waste disposal which contributed to 16.7% of emissions.

GHG emissions from Waste have increased by 36% in the year 2013 from that in 2005, rising at a compound annual growth rate (CAGR) of 3.9% over this period. The trend of the overall emission is observed to be quite steady with a relatively higher rise between for the year 2010 and 2011. This can be attributed to the corresponding increase in the estimated domestic wastewater emissions which results from use of different input datasets considered for these two years. Census 2001 data on the use of different wastewater discharge/treatment systems by rural and urban households has been used in the estimation from year 2005 to 2010 while Census 2011 data have been used from the year 2011 onwards.

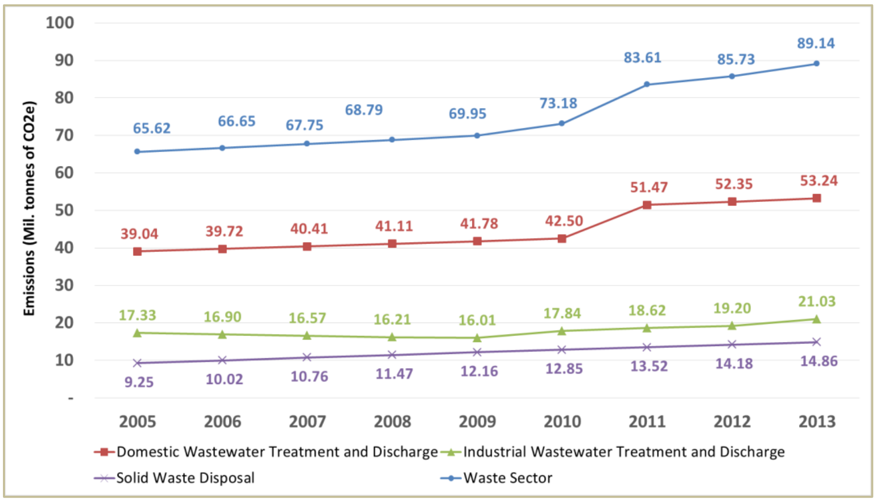


Figure 54: GHG emission estimates for Waste Sector in India (2005 to 2013)
(Source: GHG platform India-2005 to 2013 National Estimates – 2017 Series)

The state of Uttar Pradesh has the highest contribution to the estimated total Waste sector emissions, with a share of 15.8% while Maharashtra contributes to 10% of the aggregate emissions[14]. The five states of Uttar Pradesh, Maharashtra, Gujarat, Andhra Pradesh[15] and Tamil Nadu together contribute to half of the total estimated Waste sector emissions across the years (see Figure 55). The union territories and states of Dadra & Nagar Haveli, Daman & Diu, Andaman & Nicobar, Sikkim, Arunachal Pradesh, and Mizoram cumulatively contribute to less than 0.5% of the total emissions, which mirrors the low share of the country's population residing in these states.

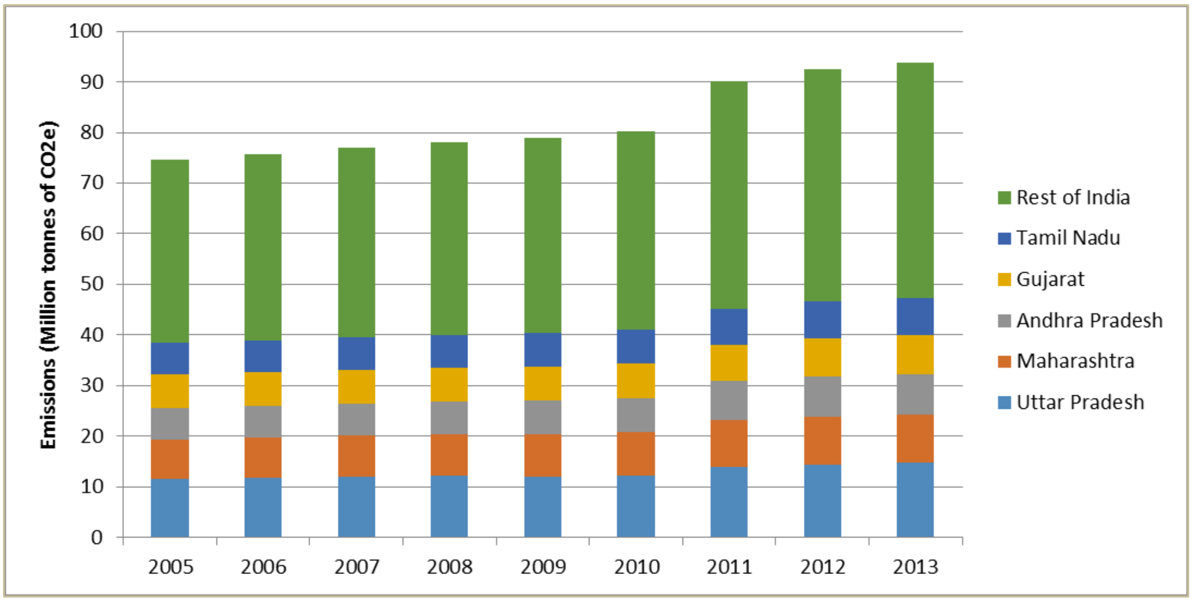


Figure 55: GHG emission estimates for Waste Sector in India (2005 to 2013)
(Source: GHG platform India-2005 to 2013 State Estimates – 2017 Series)

At the national-level, emission intensity of the Waste sector emissions, in terms of GHG emission per unit GDP, is observed to have decreased by 23% in 2013 as compared to the base year of 2005, falling at a CAGR of -3.2% from 2005 to 2013. Emission intensity is also seen to decrease in the key states that have high contribution to emissions in the sector (see Table 8). Per capita emissions from the Waste sector for the country increased from 0.06 tonnes of CO_2e in year to 0.071 tonnes of CO_2e in the year 2013, growing at a CAGR of 2.1% per annum from 2005 to 2013. Per capita emissions are observed to increase over the years in the key states as well.

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[14] Emissions have been estimated for the Waste sector at the two levels - national-level and the state-level - under the GHG Platform-India. While this assessment largely follows a common methodological approach in the emission estimation at these two levels, given the diversity that exists in the Waste sector and its associated input parameters across the states in the country (in terms of the waste and wastewater generation, solid waste composition, treatment, food intake, lifestyles etc.) and given the lack of state-level data availability from single source datasets, the cumulative total of the state-level emission estimates does not match the total national-level emission estimates for the 3 sub-sectors and for the overall Waste sector. The total state-aggregate emission estimates for the Waste sector amount to 93.78 Mil. tonnes of CO_2e. However, given that nationally reliable data sources have been used for both national and state level estimation, the analysis and insights provided for the states is deemed to be reasonably applicable.

[15] All references to Andhra Pradesh are for the former undivided state before it was bifurcated into Telangana and Andhra Pradesh, since all data reported and analysed is for the period before the state was bifurcated in 2014.

Table 8: Indicators and emission related trends for key states

Year	Uttar Pradesh	Maharashtra	Andhra Pradesh	Gujarat	Tamil Nadu	West Bengal	Bihar
Population (Million)							
2005	179.6	103.1	79.6	54.6	66.3	84.6	91.4
2013	208.0	116.1	86.8	62.9	74.5	94.0	109.4
Gross State Domestic Product (Trillion INR)[16]							
2005	2.78	4.71	1.42	2.34	2.50	2.22	0.76
2013	4.65	8.97	2.47	4.53	4.81	3.72	1.73
Waste sector Emissions (Mil. tonnes of CO_2e)							
2005	11.61	7.78	6.27	6.63	6.25	5.22	3.04
2013	14.79	9.40	8.02	7.71	7.46	6.31	4.18
Solid waste disposal Emissions (Mil. tonnes of CO_2e)							
2005	0.89	0.82	0.68	0.33	0.80	0.69	0.21
2013	1.21	1.27	1.14	0.45	1.18	0.98	0.25
Domestic wastewater treatment and discharge (Mil. tonnes of CO_2e)							
2005	6.83	4.73	3.24	2.19	2.85	3.48	2.79
2013	9.49	5.88	4.45	3.24	3.62	4.25	3.87
Industrial wastewater treatment and discharge (Mil. tonnes of CO_2e)							
2005	3.89	2.24	2.36	4.10	2.60	1.05	0.04
2013	4.09	2.25	2.43	4.02	2.66	1.08	0.07
Per capita Emissions for Waste sector (tonnes of CO_2e)							
2005	0.065	0.076	0.079	0.122	0.094	0.062	0.033
2013	0.071	0.081	0.092	0.123	0.100	0.067	0.038
Emission Intensity for Waste sector (tonnes per Mil. INR)							
2005	4.2	1.7	4.4	2.8	2.5	2.4	4.0
2013	3.2	1.0	3.3	1.7	1.6	1.7	2.4

(Source: Analysis based on GHG platform India-2005 to 2013 State Estimates –2017 Series)

2. Analysis of GHG Emission Trends for the sub-sectors in Waste

a) Solid Waste Disposal

Municipal solid waste (MSW) is generally defined as waste collected by local municipal governments or other local authorities, typically including residential, commercial and institutional waste, street sweepings, and garden and park waste in either solid or semi-solid form (excluding industrial, hazardous, bio-medical and e-waste). When MSW is disposed in landfills or in dumpsites and in the presence of anaerobic conditions, the methanogenic bacteria break-down the degradable organic component in the waste, releasing CH_4 emissions. Decomposition of waste does not begin immediately after the disposal but typically with a time delay and occurs gradually. Thus, CH_4 emissions from decomposition of a given mass of waste continue to be released over a prolonged time period (around 50 years) after the waste is disposed (IPCC, 2006). Waste disposal in the rural areas of India predominantly occurs in a dispersed manner and does not generate significant CH_4 emissions

[16] Based on reported GSDP at constant 2004-05 prices. Since GSDP is reported on financial year basis, the GSDP for 2005-06 has been considered for year 2005 and GSDP for 2013-14 has been considered for year 2013.

because negligible rural solid waste is piled up in the disposal sites in a way that forms anaerobic environments enabling CH_4 generation (Michealowa, 2015).

GHG emission from solid waste disposal depends mainly on the quantity and composition of solid waste undergoing disposal, the method of disposal and characteristics related to the disposal site. The composition of degradable organic fractions in solid waste (food waste, garden/park waste, paper, textiles, etc.) and the compostable matter content are important parameters to calculate degradable organic carbon (DOC) content, which is a critical factor for CH_4 emission calculation (IPCC, 2006).

Waste composition in Indian cities has undergone a change over the years with urbanization– leading to an increase not only in the consumption of paper, paper packaging, plastics and consumer products, but also an increase in the biodegradable waste (reflected by the total compostable matter) (see Table 9). Consequently, the estimated DOC content in MSW has increased from 0.088 in 1971 to 0.114 in 2005. Driven by changing consumption patterns, the per capita solid waste generation has been growing by 1.3% annually in recent years (Joshi, 2016). Emissions from solid waste disposal are observed to have the highest year-on-year growth on average in the Waste sector, with a CAGR of 6.1% from 2005 to 2013.

Table 9: Changing Physical Composition of MSW in India

Waste Component	1971	1995	2005
Paper	4.14%	5.78%	8.13%
Plastics	0.69%	3.90%	9.22%
Metals & Others	0.50%	1.90%	4.50%
Glass	0.40%	2.10%	1.01%
Rags	3.83%	3.50%	4.40%
Ash and Fine Earth	49.20%	40.30%	25.16%
Total compostable matter	41.24%	41.80%	47.40%

(Source: GHG platform India-2005 to 2013 National Estimates – 2017 Series)

Changing waste composition in Indian cities has impacted the quantum of emissions generated due to MSW disposal over the decades – disposal of a tonne of MSW led to GHG emission of 86 kg of CO_2e during 1954-1960, which has now increased by 2.7 times to 233 kg of CO_2e for every tonne of MSW disposed during 2005 to 2013 (see Figure 56).

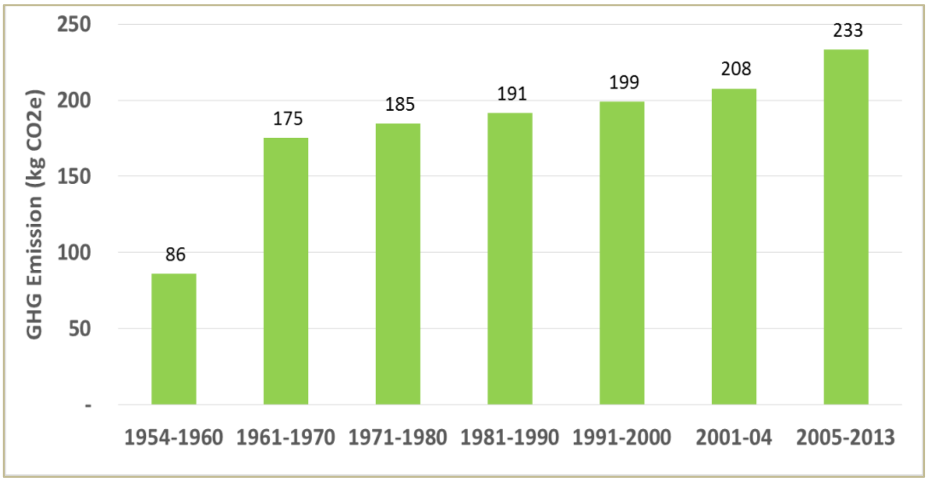


Figure 56: Increase in GHG emission per tonne of MSW disposed in India over the Years
(Source: Analysis based on GHG platform India-2005 to 2013 National Estimates –2017 Series)

The states of Maharashtra, Uttar Pradesh, Tamil Nadu, Andhra Pradesh and West Bengal contribute to 53% of the total emissions from solid waste disposal in 2013. The state of Maharashtra is the largest contributor to the aggregate state level emissions from solid waste, with a share of 11.7%, followed by Uttar Pradesh which contributes to 11.2% of total emissions from solid waste disposal. With the quantum of solid waste that is generated being significantly influenced by the size of the resident population, it is no surprise the five states with the highest contribution to emissions from solid waste disposal also rank high in terms of the size of the resident urban population. Emissions in these states are also influenced by relatively higher per capita waste generation rates and higher proportions of organic constituents in solid waste. The states of Arunachal Pradesh, Nagaland, Sikkim, Dadra & Nagar Haveli, Daman & Diu, and Lakshadweep have the lowest contribution to solid waste emissions, primarily due to lower population size.

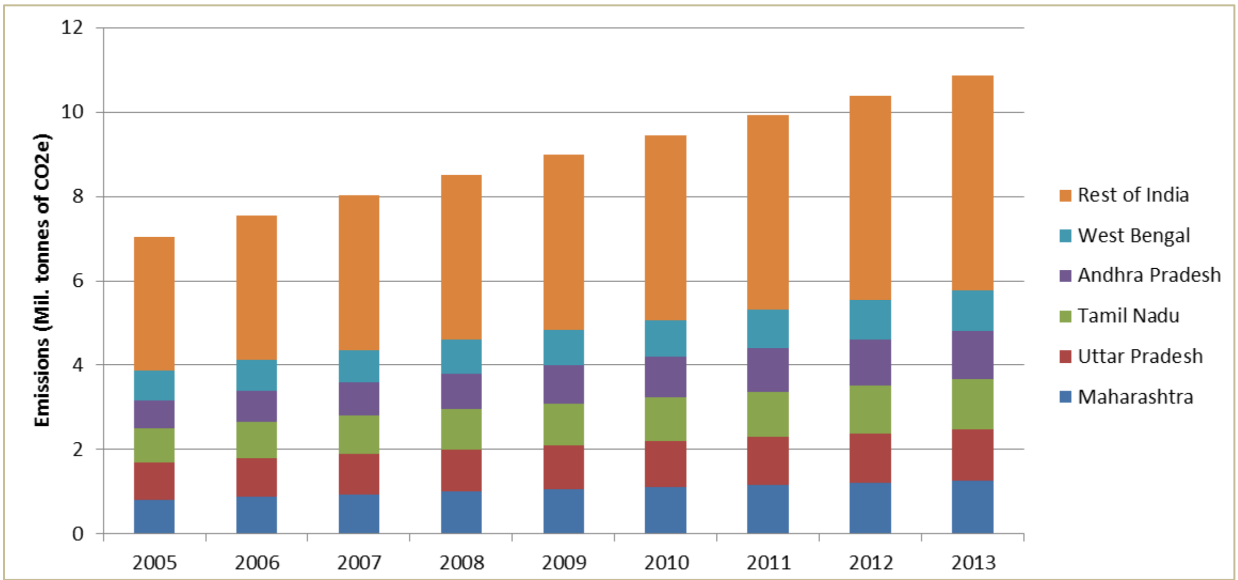


Figure 57: GHG emissions from solid waste disposal for top five states (2005 to 2013)

(Source: Analysis based on GHG platform India-2005 to 2013 State Estimates –2017 Series)

The impact of prevalent waste composition on emission generation is evident when comparing the GHG emission for every tonne of waste disposed across the states. The state-wise GHG emission per tonne of waste disposed ranges from 131 kg of CO_2e to 329 kg of CO_2e in year 2013, which reflects the varying waste composition due to food habits, lifestyles, socio-economic factors, climatic conditions across the country. Himachal Pradesh has the highest GHG emission per tonne of waste disposed at 329 kg of CO_2e in year 2013 followed by Chandigarh (261 kg of CO_2e), Meghalaya (261 kg of CO_2e) and Andhra Pradesh (248 kg of CO_2e). Organic components such food and garden waste, paper, and textile rags account for higher proportions (63% or higher) in the solid waste generated in these states, which results in a higher DOC value and thereby higher emission generation. States wherein organic constituents have a relatively lower share fare better in this regard, as in the case of Gujarat which has 51% of organic components in its solid waste and is seen to generate 200 kg of CO_2e per tonne of waste disposed.

b) Domestic wastewater treatment and discharge

Wastewater from domestic sources generates CH_4 emission on its treatment (on site, sewered to a centralized treatment plant or disposed of untreated in nearby areas or via an outfall) or disposal anaerobically (IPCC, 2006). The extent of CH_4 emission from wastewater depends primarily on the quantity of degradable organic material in the wastewater, the volume of wastewater generated and the type of treatment system (Aswale, 2010). Domestic wastewater includes human sewage mixed with other household wastewater, which can include effluent from shower drains, sink drains, washing machines, etc. and degradation of the nitrogen components (urea, nitrate and protein) present in the domestic wastewater leads to N_2O emission (Gupta, 2012).

The characteristics of domestic waste water and consequently the associated GHG emissions vary from place to place depending on factors such as economic status, community food intake[17], water supply status, treatment systems and climatic conditions of the area. **The CH_4 emissions are also dependent on the type of treatment system or wastewater discharge pathway being used (such as sewers, septic tanks, latrines, centralized treatment plants, and direct discharge to sea, lake or river) and its corresponding methane generation potential, and the proportion of the resident population that uses these different wastewater treatment/discharge pathways or systems** (IPCC, 2006). To factor in these considerations, domestic wastewater emissions are categorized into urban and rural areas.

Emissions from rural domestic wastewater are seen to contribute to about 60% of the total emissions from domestic wastewater in the country from 2005 to 2013. However, given that the rural population accounted for 68.9% of India's population in the year 2011, the corresponding GHG emission generated from urban domestic wastewater is considerably higher. Per capita GHG emissions from domestic wastewater for the urban population were 36.4 kg of CO_2e as compared to 24.2 kg of CO_2e for the rural population in the year 2013, a difference of 50%.CH_4 emissions are higher than the N_2O emissions for both urban and rural areas.

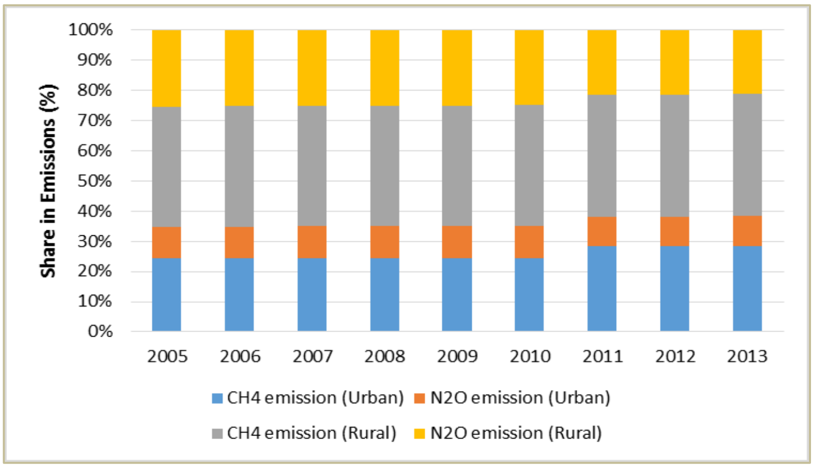


Figure 58: Distribution of GHG Emission from Urban and Rural domestic wastewater treatment and discharge, 2005 to 2013

(Source: Analysis based on GHG platform India-2005 to 2013 National Estimates – 2017 Series)

[17] The principal factor in determining the CH_4 generation potential of domestic wastewater is the amount of degradable organic material in the wastewater i.e. BOD content. Wastewater with higher BOD concentrations will generally yield more CH_4 than wastewater with lower BOD concentrations. Both the type of wastewater and the type of bacteria present in the wastewater influence the BOD concentration of the wastewater.

In terms of state-wise emissions, Uttar Pradesh, Maharashtra, Andhra Pradesh, West Bengal and Bihar are the largest contributors to emissions from domestic wastewater. These five states contribute to nearly 50% of the total domestic wastewater emissions. The states of Tamil Nadu, Rajasthan, Gujarat, Madhya Pradesh, Karnataka and Kerala are the next highest contributors. Put together these 11 states contribute to around 80% of the total emissions from domestic wastewater. Uttar Pradesh has the highest contribution at 16%, followed by Maharashtra which contributes to nearly 10% of the total emissions. The key states rank high in terms of population size as well and given that the volume of wastewater generated is directly dependent on the size of the population, they generate higher emissions. The union territories and states of Sikkim, Andaman & Nicobar, Daman & Diu, Dadra & Nagar Haveli, and Lakshadweep house lower populations and each contribute to less than 0.01% of the total domestic wastewater emissions.

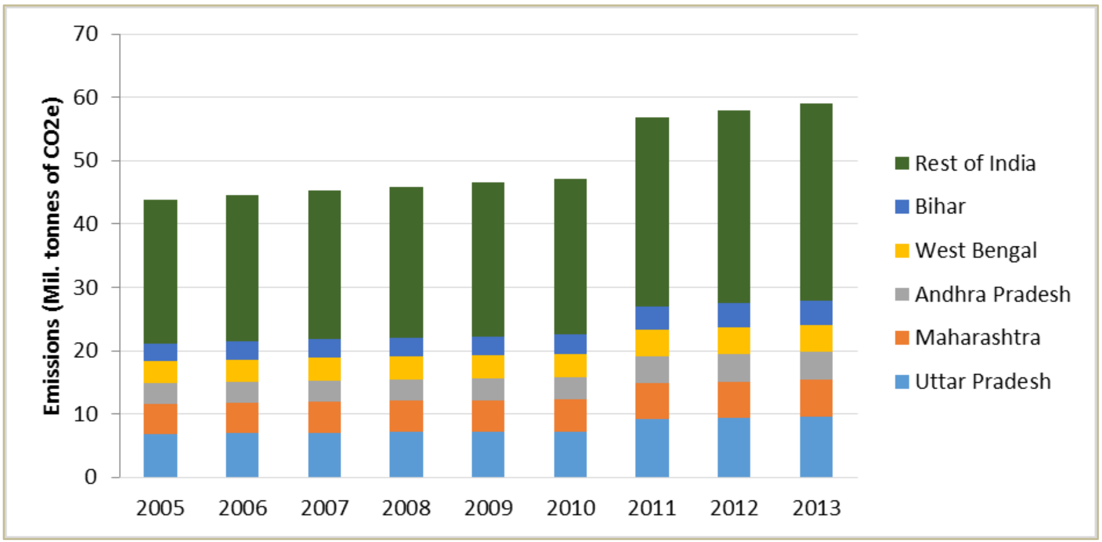


Figure 59: GHG emissions from domestic wastewater treatment and discharge for top five states (2005 to 2013)

(Source: Analysis based on GHG platform India-2005 to 2013 State Estimates –2017 Series)

CH_4 emissions are dependent on how wastewater is handled in urban and rural areas, having a direct correlation with the proportion of waste water that is discharged or treated through different systems or pathways. Over the period from 2005 to 2013, the connectivity of the sewer network has improved across the states along with the volume of wastewater that is collected and treated. The connectivity to septic tank systems has also witnessed an increasing trend in the states. The improved connectivity and increase in treatment facilities has resulted in decrease of untreated wastewater finding its way to the ground or to water bodies.

Emissions from septic tanks have the highest contribution to CH_4 emissions from urban domestic wastewater in the states, ranging from 40.5% to 83.9% for the states that rank in the top emission contributors (see Figure 59). The degree of utilization (i.e. the proportion of population using a certain treatment system) for septic tanks is quite significant in urban areas of these key states as well, ranging from 28.6% to 52.7% (see Figure 59). Septic tanks are on-site treatment systems having a relatively higher CH_4 emission generation potential (methane correction factor value of 0.5) and thereby contribute significantly to CH_4 emissions from urban domestic wastewater. Aerobic treatment systems are the second highest contributor to the total CH_4 emissions from urban domestic wastewater across the states. This is mainly due to the existing aerobic treatment based sewage treatment plants in the country not being well managed. The 'methane correction factor' value for 'not well managed aerobic systems' is 0.3 as against a 'methane correction factor' value of 0 (and therefore no CH_4 emission) for 'well managed aerobic treatment systems'. Therefore, it is important to manage aerobic treatment systems effectively. Further, some portion of urban wastewater that is collected through the sewer network is not treated downstream (i.e. sewer - collected & not treated category) due to insufficient installed capacity and operational inefficiencies of STPs. Such wastewater that is collected through sewer systems but does not flow to a sewage treatment plant usually stagnates and leads to CH_4 emission.

In rural areas, given the minimal closed sewer network (approximately 95% of domestic wastewater is either conveyed through open drains or is not collected at all) and the absence of wastewater treatment facilities, domestic wastewater is not handled or treated downstream and decomposes under aerobic conditions, thereby not leading to CH_4 emissions. Emissions are largely driven by direct discharge of wastewater into 'ground' and 'rivers, lakes, estuaries, sea' without any kind of treatment (i.e. Others/None category) and by septic tank systems. This is evident in the top five states with high wastewater emissions as well, with a large proportion of the rural population estimated to discharge wastewater without treatment in the absence of wastewater collection systems (see Figure 60).

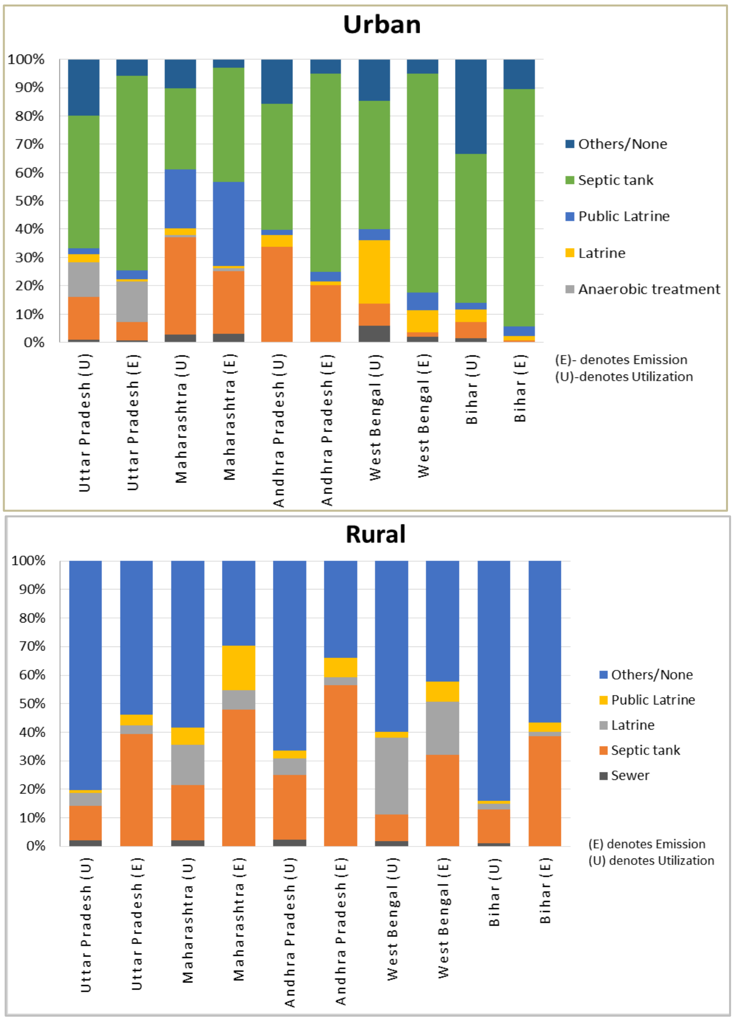
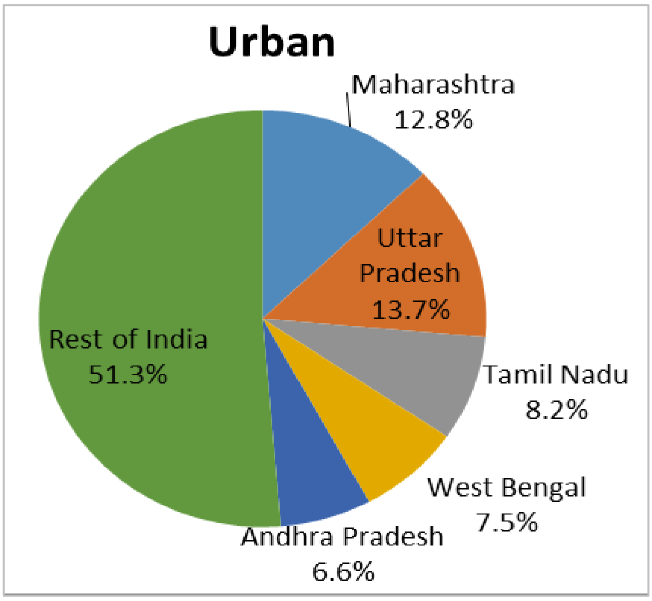


Figure 60: CH_4 Emissions and Utilization of different treatment systems in urban and rural areas for top five states (2013)
(Source: Analysis based on GHG platform India-2005 to 2013 State Estimates –2017 Series)

N_2O emissions from domestic wastewater have a direct correlation with human protein consumption and the size of the population. N_2O emissions from urban and rural domestic wastewater have increased steadily at a CAGR of 3.0% and 1.5% respectively from 2005 to 2013, in line with steadily rising nutritional intake of protein and growing population. As observed in the case of CH_4 emissions, the states having higher urban and rural population are key contributors to the corresponding N_2O emissions from urban and rural wastewater as well. Maharashtra is the largest contributor to N_2O emissions from urban domestic wastewater, with an average share of 13.1% in the total urban N_2O emission from 2005 to 2013, followed by Uttar Pradesh (12.7%), Tamil Nadu (8.4%), West Bengal (7.4%), Andhra Pradesh (7.0%) and Gujarat (6.6%). Uttar Pradesh has the highest contribution (20.3%) to N_2O emissions from rural wastewater, followed by Bihar (10.9%), Rajasthan (7.4%), Maharashtra (7.3%), West Bengal (6.8%), Madhya Pradesh (6.6%) and Andhra Pradesh (6.3%).



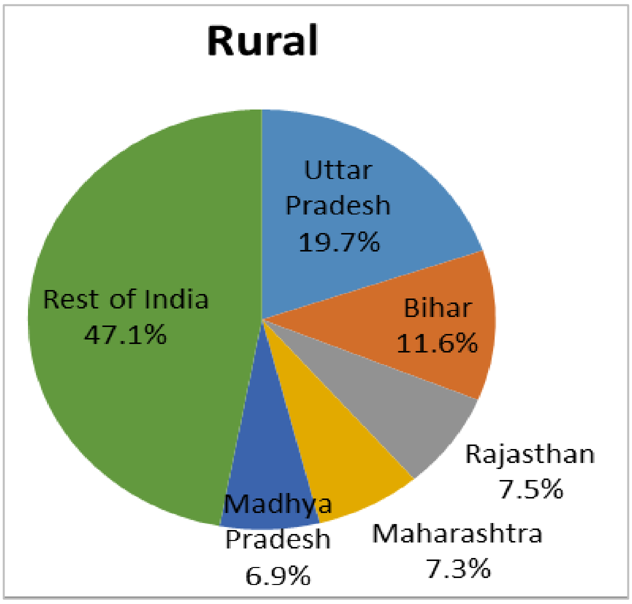


Figure 61: Share of N_2O Emissions of top five states for Urban and Rural areas (2013)
(Source: GHG platform India-2005 to 2013 State Estimates – 2017 Series)

c) Industrial wastewater treatment and discharge:

The national-level emission estimates for industrial wastewater include 12 industrial sectors - Fertilizers, Meat, Sugar, Coffee, Pulp and Paper, Petroleum, Beer, Soft Drinks, Rubber, Dairy and Tannery, Iron and Steel. Production in all 12 sectors results in generation of waste water with significant organic load with potential to release CH_4 emissions, which is dependent on the type of wastewater treatment. **The analysis reveals that the Pulp & paper, Coffee, Soft drink, Meat and Tannery sectors are critical sectors with the highest GHG emission per tonne of product or per unit volume of treated wastewater** (see Table 10)**.**

Table 10: Average GHG emission per tonne of industrial product and per m^3 of industrial wastewater generated in India (2005 to 2013)

Industry Sector[18]	GHG emission per tonne of product (kg of CO_2e)	GHG emission per m^3 of wastewater generated (kg of CO_2e)
Coffee	189.0	37.8
Soft drink	139.9	37.8
Pulp & Paper	1,749.5	24.8
Meat	201.5	17.2
Tannery	104.2	3.3
Fertilizers	25.2	3.1
Sugar	3.1	3.1
Beer	27.4	3.0
Dairy	7.1	2.4

(Source: Analysis based on GHG platform India-2005 to 2013 National Estimates – 2017 Series)

Unavailability and low reliability of industry related data has been a key challenge in both the national-level and state-level emission estimation for the industrial wastewater sub-sector. In the absence of recorded information on sector-wise volume of wastewater generated by industries across the country, industrial production is a key parameter required to estimate the total wastewater generation[19] by industry sector and the CH_4 emission resulting from its degradable organic concentration (COD) and the treatment technology used. However, during the assessment it was observed that the requisite industrial production data for the 12 industrial sectors under consideration is not available in a single source dataset, thereby necessitating the use of multiple data sources for each of the industrial sectors. Notable variation is observed year on year in the national-level industrial wastewater emission estimates (see Figure 62). While nationally acceptable data sources such as the Indian Bureau of Mines, National Dairy Development Board, Rubber Board, Fertilizers Association of India, and the Department of Industrial Policy & Promotion were used to obtain industrial production data, the use of multiple data sources for this key parameter and inherent inconsistencies in these datasets has impacted the reliability of information and the emission estimates.

The data challenges are formidable for state-level estimates. A number of issues have been observed with regard to the availability, reliability and quality of reported activity data on state-level industrial production in particular. While emissions from Beer and Soft drinks sector have been included in the national-level emission estimates, these sectors have not been considered in the state-level emission estimates due to unavailability of relevant activity data at the state-level to enable emission estimation. Given these challenges in the availability of state-level data, apportionment has been used as an approach to address data gaps (to varying degrees) in 8 out of the 10 industry sectors considered in the state emission estimation - based on relevant proxy data such as installed production capacity

[18] In the assessment, the condition of the prevalent aerobic type wastewater treatment systems for Iron & Steel, Petroleum and Rubber industries is assumed to be well managed, and thereby these systems have Methane Correction Factor value of zero and thereby an emission factor value of zero (based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories), thereby leading to no CH_4 emissions from wastewater treatment. Thus, the Iron & Steel, Petroleum and Rubber sectors are not included in the Table.

[19] Total annual volume of wastewater generated (in cubic meters) is estimated based on the industrial production (in tonnes) and the unit wastewater generation per tonne of product (cubic meters/tonne) based on the methodology outlined in the 2006 IPCC Guidelines for National GHG Inventories

by state, no. of manufacturers or manufacturing facilities by state, gross economic value added by state, etc. Access to better quality and reliable industry related data that is representative of the industrial activity in each state will contribute to improving reliability of the estimates and strengthen inferences that can be drawn.

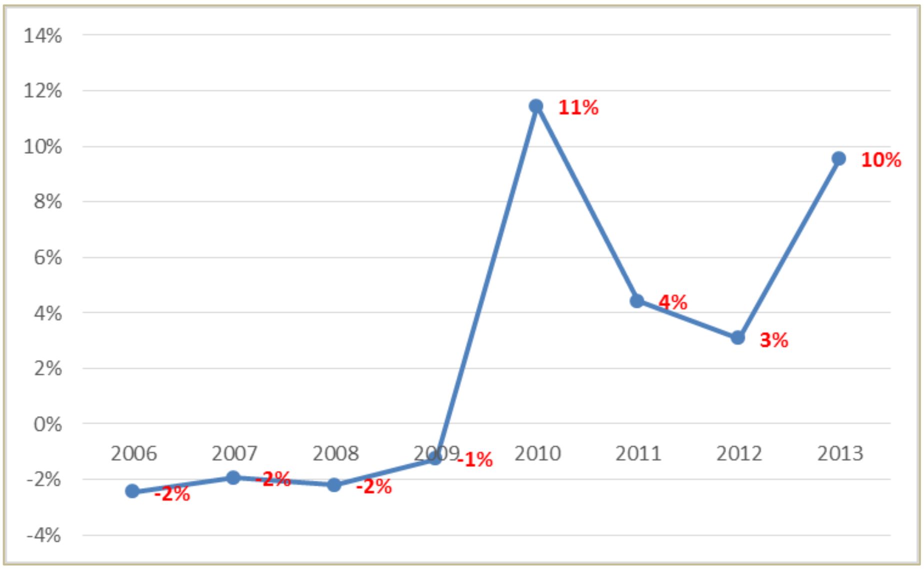


Figure 62: Year-on-Year Variation Observed in National-level Industrial Wastewater GHG emissions, 2005 to 2013

(Source: Analysis based on GHG platform India-2005 to 2013 National Estimates – 2017 Series)

Based on the estimated emissions, it is seen that the five states of Gujarat, Uttar Pradesh, Andhra Pradesh, Tamil Nadu, and Maharashtra contribute to nearly 70% of the total industrial wastewater emissions, with Uttar Pradesh and Gujarat contributing nearly 17% each. This stems from the higher level of industrial activity reported for these states; primarily for the Pulp and paper industry along with the Meat and Dairy sectors. However, given that the reliability of state-level data used in this assessment varies across the sectors and years, it is advisable to exercise caution while drawing conclusions from the state-wise trend.

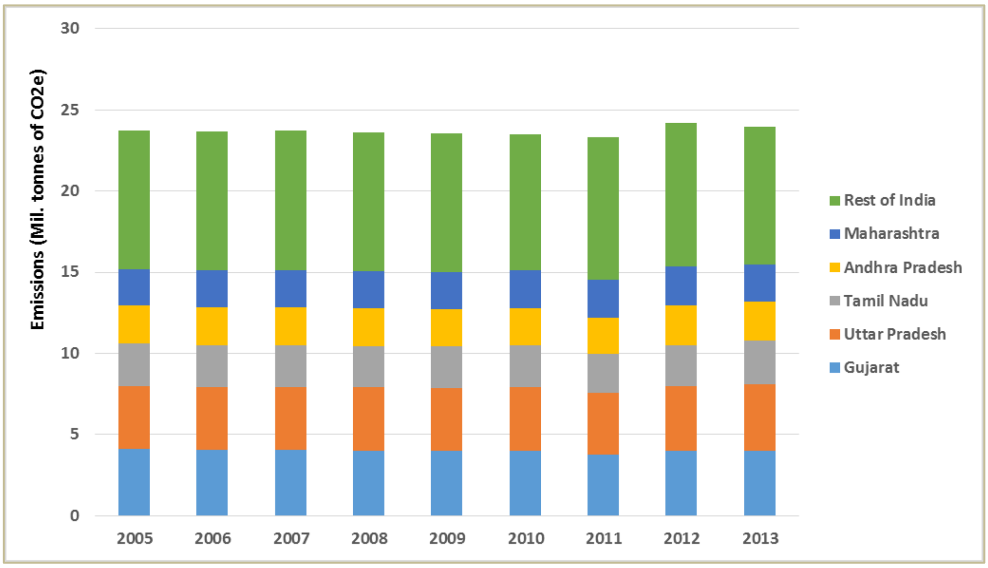


Figure 63: GHG emission from industrial waste water in top five states (2005 to 2013)

(Source: Analysis based on GHG platform India-2005 to 2013 State Estimates – 2017 Series)

3. Policy Initiatives and Mitigation Measures for the Waste Sector

Solid waste and wastewater management remains poorly addressed across India, with increasing waste and wastewater generation resulting from an ever-rising population and industrial growth contributing to rising GHG emissions and leading to considerable impacts on the local environment and health. The Government of India (GoI) has taken several measures to address infrastructure development, improvements in service delivery and coverage in the Waste Sector, subsequently contributing to GHG emission reduction.

During the considered GHG emission assessment period (2005 to 2013), solid waste and waste water management were key components of GoI's big-ticket programmes such as the **Jawaharlal Nehru Urban Renewal Mission (JnNURM), the Urban Infrastructure Governance (UIG)** and the **Urban Infrastructure Development Scheme for Small and Medium Towns (UIDSSMT)[20].** These programmes led to the creation of significant amount of infrastructure for efficient waste collection and treatment, with about 300 projects addressing solid waste and wastewater sanctioned under the schemes (GoI, 2015). Further, to enhance the performance and delivery of existing services in cities, the Ministry of Urban Development (MoUD) developed the **Service Level Benchmarks (SLB)** in 2008, for various sectors including solid waste, sewerage and sanitation. The Waste Sector benchmarks prescribed provided a platform for cities and states to self-assess their performance with regard to the level of their waste collection, treatment, and disposal along with areas of improvement. To encourage and facilitate the adoption of the SLBs, the MoUD launched a pilot initiative in 2009, which involved provision of technical support for implementing the benchmarks in 28 cities from 14 states (MoUD, 2015).

The GoI's **National Action Plan on Climate Change (NAPCC)**, launched in 2008, gives significant priority to management of waste under one of its eight missions, the **National Mission on Sustainable Habitat (NMSH)**. Specific sector-level recommendations have been formulated under the NMSH, for integration into relevant city's and/or state's regulations and bye-laws to enable improvements in service delivery and address climate change concerns (MoUD, 2015). Realizing the need of improving the sanitation situation in urban areas, the **National Urban Sanitation Policy (NUSP),** was launched in 2008, which aims to address the sanitation challenges through preparation of state level sanitation strategy and city sanitation plans in overall conformity to the policy guidelines (MoUD, 2015).

a) Municipal Solid Waste Management

Despite substantial investments and existing policies and regulations by the GoI, improvement in solid waste management is lagging across the country._Nearly 68 percent of rural households and 24 percent of urban households reported no garbage collection arrangements in 2012 compared to 75 percent of rural households and 21 percent of urban households during 2008-09 (National Sample Survey Office, 2016). A pilot study conducted by the MoUD on assessment of the service levels on implementation of **SLBs** reveals that significant improvement is required solid waste management with regards to coverage, waste segregation, recovery and scientific disposal of MSW (MoUD, 2015)

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[20] The JnNURM, launched in 2005, focused on integrated development of urban infrastructure and services in selected 63 Indian cities with emphasis on provision of basic services to the urban poor (Planning Commission, 2008). Two parallel programmes, the UIG and UIDSSMT, were also launched under the JnNURM to develop infrastructure in the cities not covered under the JnNURM.

(see Table 11). Scope for improvement across these aspects of solid waste management is also evident across key states (see Table 12).

Table 11: SLB's Pilot Initiative Results for Solid Waste Management

Indicator	Benchmark (%)	Lowest (%)	Highest (%)
Household Level Coverage	100	2.6	100
Collection Efficiency of MSW	100	43.2	100
Segregation of MSW	100	2.7	64.9
MSW Recovery	80	3.8	100
Scientific Disposal of MSW	100	0.8	57.6
Collection efficiency	90	30.2	100

(Source: Report of the committee set up to frame National Sustainable Habitat Standards for the Municipal Solid Waste Management, Ministry of Urban Development, 2015)

Table 12: Service Levels for Solid Waste Management in Select States

Indicator	State performance values
Household level coverage	Gujarat (86%), Maharashtra (75.7%), Tripura (71.4%), Karnataka (71.3%), West Bengal (65.7%), Haryana (54.5%)
Efficiency of collection of MSW	Uttar Pradesh (97.1%), Gujarat (91.7%), Maharashtra (90.7%), Odisha (85.3%), Chhattisgarh (84.9%), Tripura (84.6%)
Extent of segregation	Kerala (35.7%), Jharkhand (22.4%), Maharashtra (21.2%), Karnataka (19%), Meghalaya (18.3%), Uttar Pradesh (17.7%)
Extent of MSW recovered	Gujarat (50.1%), Himachal Pradesh (43.5%), Kerala (35.8%), Karnataka (34.5%), Maharashtra (24.2%), Haryana (20.7%)
Extent of scientific disposal	Karnataka (45.5%), Kerala (34.3%), Uttar Pradesh (20.2%), Maharashtra (19.3%), Gujarat (19.3%),

(Source: Water and Sanitation Service Levels in Cities of India (2011-12 and 2012-13), Performance Assessment System (PAS) Project, 2014)

There are about 645 compost/vermin-compost plants and 71 waste-to-energy plants (RDF/pellet - 18, Biogas plants - 41 and power plants - 13) set up by urban local bodies (ULBs) in India for treatment of MSW (Michealowa, 2015). However, most of the treatment facilities have encountered significant problems during operation or operate at throughputs far below their capacity. This has led to inadequate processing/treatment/disposal systems for MSW, resulting in larger quantum of waste being sent to dumping/disposal sites. More than 80% of waste generated is dumped at dumping/disposal sites without any treatment or processing. India had only 69 sanitary landfill sites constructed and operational in 2013-14, hence most of the MSW waste is dumped on open land or in unsanitary landfills (open dump sites) (Michealowa, 2015).

The **NMSH** addresses GHG emission from solid waste management and has laid out recommendations for improving the solid waste management system, to be taken up for inclusion in the legal provisions/bye-laws of state and/or city (MoUD, 2015). For improving solid waste management practices in urban areas, the GoI launched **the Municipal Solid Waste (Management and Handling) Rules** in 2000. These rules have specific guidelines for local, district and state level departments for proper and scientific management of MSW. Under these rules, it is mandatory for all the urban local bodies to provide facilities for collection, transportation, treatment and disposal of MSW in a scientific and hygienic manner[21] (MoEFCC, 2000). The **National Environment Policy, 2006,** encourages the development of viable public private partnership (PPP) models for setting up and operating secure landfills, incinerators, and other waste processing technologies (MoEFCC, 2006). The **Hazardous Wastes (Management and Transboundary Movement) Rules, 2008** were released by the GoI to ensure proper management of different types of hazardous waste. The GoI launched the **Plastic Waste (Management and Handling) Rules in 2011** to reduce the generation of plastic waste and ensuring its proper disposal. The **E-waste (Management and Handling) Rules, 2011** are based on the extended producer responsibility concept[22] and promote GHG emission reduction through proper handling and recycling of electronic waste.

To address the lack of funding to set up and operate modern waste treatment facilities, notable investments for solid waste management were earmarked under the 12th and 13th Finance Commission[23] through programmes such as the **JnNURM.** Moreover, performance grants earmarked under the 13th Finance Commission have been linked to improvements in service standards for four service sectors including solid waste management, (GoI, 2009). About 45 projects worth INR 20.9 billion (USD 313 million) have been sanctioned under the **UIG** scheme and 56 projects worth INR 3.4 billion (USD 50.8 million) under the **UIDSSMT** (GoI, 2015).

The high organic content of MSW in India drives emissions, as seen in section 2.1 for key states such as Uttar Pradesh, Maharashtra, Andhra Pradesh, Himachal Pradesh, Meghalaya, Chandigarh, and Tamil Nadu among others**. The increased focus on waste segregation makes composting a key opportunity to process organic waste and mitigate GHG emissions which would otherwise result from its unscientific disposal. The quantum of recyclables such as plastic, metal, glass, construction and demolition waste is also growing across states in the country. Ensuring the availability of the right type and quality of waste through improved waste segregation will help realize the mitigation potential from reuse and recycling of such waste** (Michealowa, 2015)**. Bio-methanation technology can help generate methane-rich biogas from organic waste, which can be used for heating, upgrading to natural gas quality or co-generation of electricity and heat, thereby substituting fossil energy. Other waste to energy technologies such as incineration can be adopted to convert inorganic combustible waste into energy. Scientific treatment and disposal of MSW and scientific closure of already existing landfill/dump sites will drastically reduce the release of CH_4.**

Along with infrastructure development and service delivery enhancement, ensuring sustainable operation of technologies, particularly waste-to-energy, has become important to improve the overall solid waste management system and reduce emissions. Developing a National level framework for guiding the construction and operation of such technologies will be beneficial and improve their performance. Policies and regulations should encourage minimization of waste generation; policies based on polluter pays principle and encouraging extended producer responsibility initiatives are a right step in this direction. It is important that cities in the states

[21] The Solid Waste Management Rules have been amended recently in 2016.

[22] Extended Producer Responsibility (EPR) is an environmental policy approach in which a producer's responsibility for a product is extended to the post-consumer stage of a product's life cycle. In practice, EPR implies that producers take over the responsibility for collecting or taking back used goods and for sorting and treating for their eventual recycling.

[23] The Finance Commission has been established by the President of India under Article 280 of the Indian Constitution to primarily recommend measures and methods on distribution of revenues between the Centre and the States. The 12th finance commission was appointed for the duration 2010-2015 and the 13th finance commission was appointed for the duration 2010-2015.

develop long-term action plans and monitoring frameworks to improve and manage the overall system and reduce open dumping of waste, in line with the National level solid waste management policies and guidelines.

b) Domestic Waste Water Management

Access to sanitation has been a major challenge in India although initiatives have been undertaken to improve sanitation and domestic wastewater management. A comparison of the percentage of households without access to wastewater handling system during 2012 and 2008-09 based on the National Sample Survey of India, shows that during 2012 nearly 50 percent of rural households and 12.5 percent of urban households had no wastewater collection facility compared to 56 percent of rural households and 15 percent of urban households during 2008-09. During 2012, waste water was directly discharged without treatment to open low lands, ponds and nearby rivers by nearly 67 percent households in rural areas and 18.5 percent of the households in urban areas while safe re-use after treatment was hardly done by any household in either rural or urban areas (National Sample Survey Office, 2016).

Wastewater treatment capacity exists for only about 30% (11,787 MLD) of about 38,254 MLD of the domestic wastewater generated from class I and class II cities in the country (CPCB, 2009). Moreover, the existing wastewater treatment capacity is lying underutilized because of high operation and maintenance costs of the STPs and their non-conformance to environmental standards for discharge into streams (CPCB, 2007). Hence, a sizeable proportion of domestic sewage and industrial effluent remains untreated, and its discharge contaminates locally available water courses (surface as well as ground water). Such untreated discharge also contributes to significant amount of methane emissions across both urban and rural areas in the states, as seen in section 2.2. The MoUD's pilot study on assessment of service levels for sewerage and sanitation services on implementation of the SLBs indicates that significant gaps remain with regards to coverage of sewerage network, the treatment facilities and quality of treatment, and the extent of reuse and recycling of wastewater (MoUD, 2015) (see Table 6). Assessing service levels across the states further reiterates the need to improve wastewater management (see Table 7).

Table 13: SLB's Pilot Initiative Results for Sewerage and Sanitation

Indicator	Benchmark (%)	Gap in Service/ Points (%)	National Average (%)
Toilet Coverage	100	14.2	85.8
Sewerage Network Coverage	100	51.5	48.5
Waste Water Collection Efficiency	100	58.1	41.9
Waste Water Treatment Adequacy	100	51.2	48.8
Quality of Waste Water Treatment	100	41.2	58.8
Extent of Reuse & Recycling of treated Waste Water	20	13.2	6.8
Collection Efficiency	90	47.5	42.5

(Source: Report of the Committee set up to frame National Sustainable Habitat Standards for the Urban Water Supply and Sewerage Sector, Ministry of Urban Development, 2015)

Table 14: Service Levels for Sewerage and Sanitation in Select States

Indicator	State performance values
Toilet Coverage	Haryana (93.2%), Kerala (91.1%), West Bengal (90.6%, Maharashtra (86.2%) and Uttar Pradesh (83.8%)
Sewerage Network Coverage	Haryana (82.9%), Punjab (71.4%), Gujarat (67.7%), Maharashtra (34.7%) and West Bengal (31.1%).
Waste Water Collection Efficiency	Gujarat (93.3%), Punjab (43.3%), Haryana (40.8%), Uttar Pradesh (32.3%) and Maharashtra (30.0%)
Waste Water Treatment Adequacy	Gujarat (97.5%), Haryana (49.1%), Maharashtra (38.7%), Uttar Pradesh (35.2%) and Punjab (25.8%),
Quality of Waste Water Treatment	Gujarat (97%), Maharashtra (44.8%), West Bengal (42.3%), Haryana (30.1%) and Uttar Pradesh (18.1%)

(Source: Water and Sanitation Service Levels in Cities of India (2011-12 and 2012-13), Performance Assessment System (PAS) Project, 2014)

The GoI has also undertaken several initiatives to improve urban sewage treatment through different policies such as the **NSUP** and **NMSH**. The NMSH guidelines provides specific directives for the sewerage department to ensure complete access to sanitation by providing 100% toilet coverage and 100% treatment of sewage, and recycling and reusing of waste water. The guidelines also stress on the need for a focused policy on sewage management issues and suggest the development of Sewage Management Rules similar to MSW (Management & Handling) Rules under the Environment Protection Act and Water Pollution Act (MoUD, 2015).

Significant investments have been made under the **JnNURM** project to reduce the infrastructure gap for wastewater collection and treatment. About 112 projects worth INR 149.92 billion (USD 2,243 million) through the **UIG** and 89 projects worth INR 28.33 billion (USD 423.9 million) under **UIDSSMT** have been sanctioned (GoI, 2015). **There is a need for preventing stagnation of untreated wastewater and increasing the quantity of wastewater that is treated by augmenting treatment infrastructure and improving performance efficiency of STPs. Significant opportunities exist for emission mitigation in STPs across the states, particularly the ones using anaerobic process for domestic wastewater treatment, with around 30 percent of CH_4 generated in such systems being lost as dissolved gas in the treated effluent** (Global Methane Initiative, 2013)**. Anaerobic wastewater treatment systems are more beneficial than aerobic processes because of the potential for CH_4 capture and recovery which may be used beneficially or directed to a flare, leading to decreased GHG emissions while using lower energy in comparison to aerobic processes. Anaerobic systems also result in lower sludge disposal costs. Biogas generated from anaerobic digesters can also be used on-site to offset the use of conventional fuel that would otherwise be used to produce electricity and thermal energy. Aerobic treatment systems are a key contributor to CH_4 emissions from urban domestic wastewater in the states as seen in section 2.2. Improved management of existing aerobic treatment based plants can contribute to lowering their emission generation potential. Opting for improved decentralized wastewater treatment systems (DeWATS) over conventional on-site septic tank systems offers opportunities to reduce emissions in both urban and rural areas.**

c) Industrial Waste Water Management

As per the Water (Prevention and Control of Pollution) Act, 1974, it is mandatory for all industries to provide adequate treatment of their industrial effluents before disposal. Large and medium-scale industries in India have installed individual effluent treatment plants for treating wastewater to meet the regulatory norms. However, with only about 60% of wastewater generated by industries being treated, a substantial portion of the wastewater discharged from industrial units remains untreated before disposal (CPCB, 2005).

88 Common Effluent Treatment Plant (CETPs) with a cumulative capacity of 560 million liters MLD existed in India in 2005. A CPCB survey in 2005 indicated that the performance of CETPs has been largely unsatisfactory because of poor operation and maintenance. As of 2012, there were about 153 CETPs existing in the country, having combined capacity of 1190 MLD and catering to more than 15,000 polluting industries (CPCB, 2012).

Efforts have been taken by the GoI to further promote establishment and technology upgradation of CETPs to address cater to small scale industries and to share the financial burden of expensive wastewater treatment. The erstwhile Ministry of Environment and Forest (MoEF), now known as the Ministry of Environment, Forest and Climate Change (MoEFCC), has been implementing a centrally sponsored scheme since 1991 for enabling small-scale industries to set-up CETPs. The scheme provided guidelines for financial assistance of 50% of the capital cost for establishing new CETPs and/or upgrading the existing ones (MoEFCC, n.d.). The guidelines of this scheme were further revised in the year 2011 and the financial assistance has been increased to 75% of the capital cost of CETPs, with 50% contribution from the central government and 25% of the financial assistance coming from the state governments. Under the revised guidelines of the scheme for CETPs, financial assistance is also provided to promote technologies such as the Zero Liquid Discharge (ZLD), which enables recycling, recovery and re-use of the treated wastewater and thereby ensures there is no discharge of wastewater to the environment.

Promoting process and technology improvements to reduce wastewater generation can play a crucial role in emission mitigation as well, as seen in the Pulp & Paper industries wherein the rate of wastewater generation per unit product has come down by about 7% per year. The industries adopting anaerobic treatment for wastewater include tanneries, integrated pulp and paper mills, dairy, integrated sugar and distilleries, and some food and beverage units. In most of the cases, the CH_4 generated is let out or flared on-site rather than being used. Few industrial sectors in India such as sugar, beer and dairy practice recovery of CH_4 generated from industrial wastewater. Shifting towards anaerobic options for treatment of degradable organic content in industrial wastewater and adopting CH_4 recovery and its utilization to generate electricity or thermal purposes is a key opportunity to bring about quick results towards emission reduction. As of 2011, 11 registered CDM projects on methane avoidance and utilization from industrial wastewater in India contributed to annual average emission reduction of about 300,000 tonnes of CO_2e cumulatively (Telang, 2011). **Policy approaches directly targeting recovery of CH_4 emissions from wastewater are needed to tap this potential mitigation opportunity** (NEERI, 2010)**.**

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