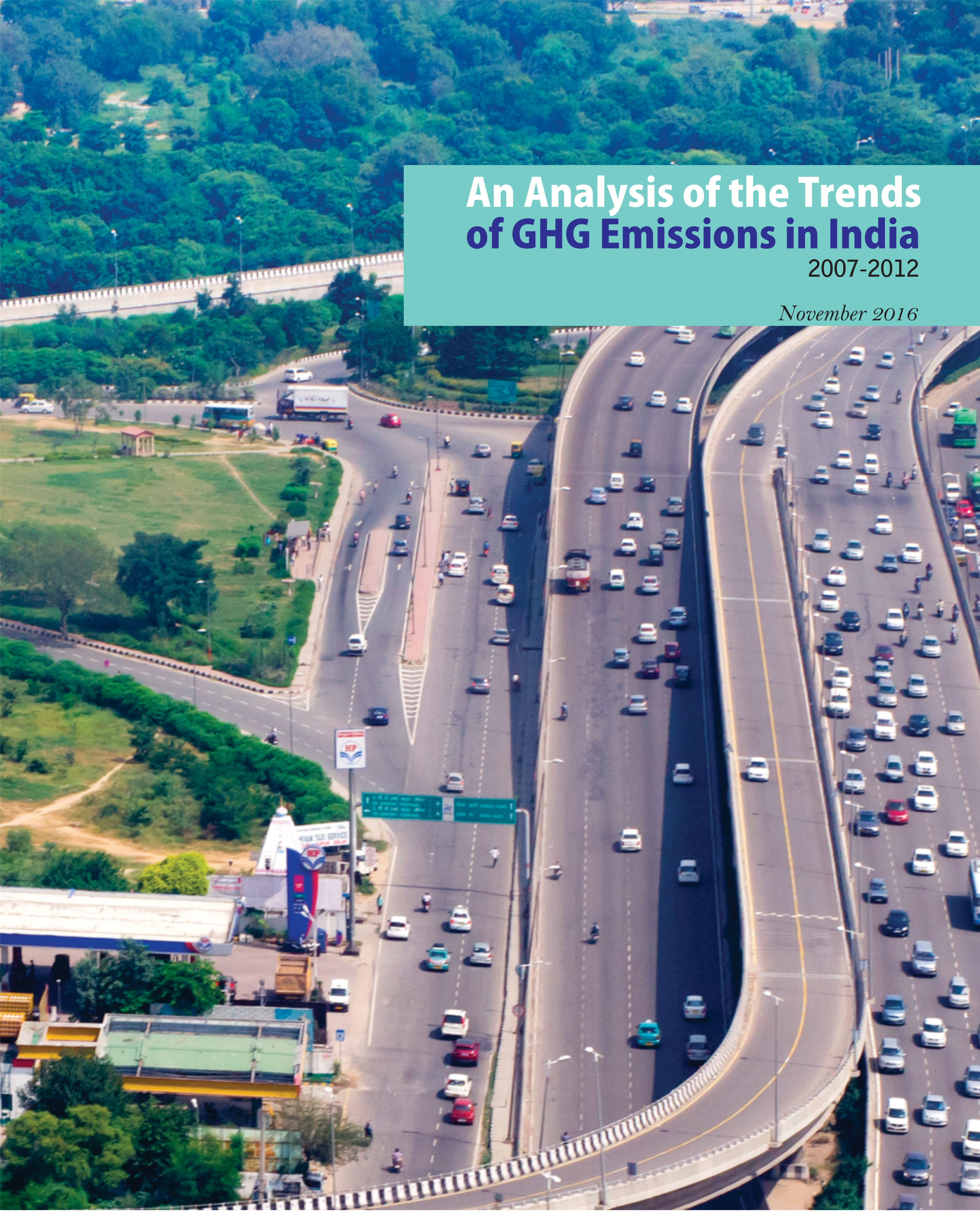

An Analysis of the Trends of GHG Emissions in India

2007-2012

November 2016

GHG
Platform
INDIA

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Foreword

The GHG Platform India is a collective civil society initiative providing an independent estimation and analysis of India's Greenhouse Gas (GHG) emissions across key sectors, namely, **Energy, Industry, Agriculture, Livestock, Forestry, and Land-use and Land-use Change** and **Waste**. The platform comprises notable civil society groups in the climate and energy space in India, who also have a prominent role in the platform and the emissions estimations. These institutions are **Council on Energy, Environment and Water (CEEW) (Industry Sector Lead), Center for Study of Science, Technology and Policy (CSTEP) (Energy Sector Lead) ICLEI Local Governments for Sustainability-South Asia (Waste Sector Lead), Shakti Sustainable Energy Foundation (Funding Partner), Vasudha Foundation (Secretariat and Agriculture, Forest and Land Use Sector lead)** and **World Resources Institute-India (Peer Reviewers and Technical Advisor).** In addition to these organisations, the platform also had sector experts namely, **Dr. T.K. Adhya, Dr. Tek Sapkota, Dr. Mahadeswara Swamy** and **Dr. Sudha Padmanabha** in their individual capacities.

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.

The platform currently hosts annual GHG emissions estimates[1] at the national level from 2007 to 2012 disaggregated by each sector and sub-sector.

- Team, GHG Platform India

1- All the data along with detailed notes on methodology and the sources of data that were used for this exercise are available at www.ghgplatform-india.org

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Introduction

This study analyses the trends of Greenhouse Gas emissions estimated under this Platform from the period 2007-2012. The greenhouse gases covered under this exercise are Carbon Dioxide (CO_2), Methane (CH_4) and Nitrous Oxide (N_2O). The study estimates and assesses greenhouse gas emissions and removals from the following sectors:

I. Energy
II. Industry[2]
III. Agriculture, Forestry, and Other Land Use (AFOLU)
IV. Waste

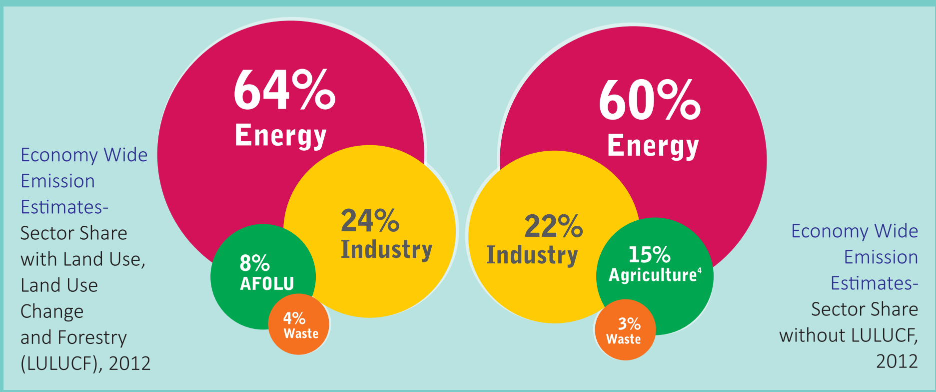

Figure 1: Comparison of Sector wise Emission Estimates

In the year 2012, energy and industry sectors contribute 80-90%[3] of overall emissions (Figure 1).

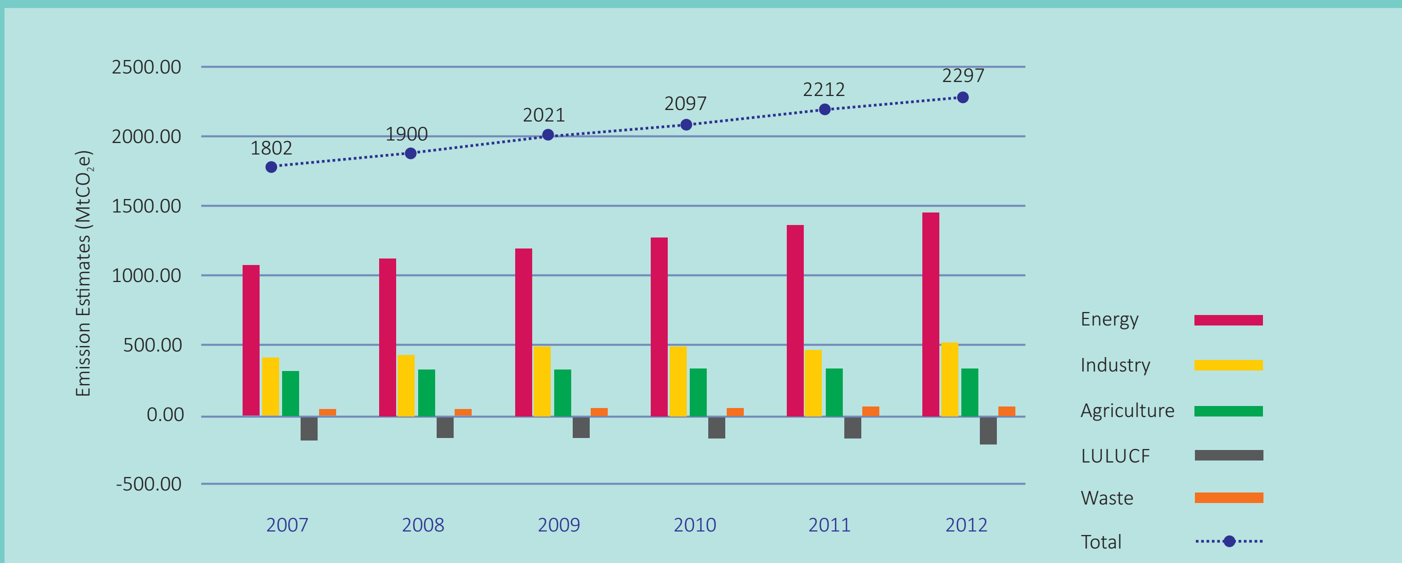

Figure 2: Trend for Economy wide Emissions 2007-2012

From the year 2007-2012, overall emissions increased steadily at an annual growth rate of 4.97%, compounded annually. Emissions had increased from 1802.24 $MtCO_2e$ in 2007 to 2297.32 $MtCO_2e$ in 2012. Figure 2 depicts this increase in the emissions sector by sector. It is notable that while the emissions from the agriculture sector (livestock and farm sector combined) were increasing from 2007 (347.59 $MtCO_2e$) to 2011 (363.64 $MtCO_2e$), there was a decline in the year 2012 (360.19 $MtCO_2e$) mainly due to a decline in the population of cattle. Only the agriculture sector (livestock and farm sector) shows such a decline.

Detailed sector wise trend analysis of GHG emissions of India 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.

Disclaimer: 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 emissions include emissions from Industrial Process and Product Use (IPPU) and fuel combusted for thermal requirements. Emissions from industrial captive generation are recorded in the Energy Sector under Electricity Generation.
3- This percentage is calculated considering removals from LULUCF Sector.
4- Agriculture emissions include emissions from Farming and Livestock.

Chapter 1: Energy

Based on the Inter-Governmental Panel for Climate Change's (IPCC) reporting structure, Electricity Generation (1A1a), Transport (1A3), Other Sectors (1A4) and Fugitive Emissions (1B) fall 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 56% and 54% of total emissions in 2007 and 2010, respectively (Indian Network for Climate Change Assessment, 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 2007 and 2012 from each sub-sector is provided.

Table 1: Sub-sectors under Energy Sector

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

1.1 Trend Analysis

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

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 3 and Figure 4 show how fossil based installed capacity of the utility-based generators and Captive Power Plants (CPP) of 1 MW or above has grown at approximately 9%, to reach nearly 200 Giga Watt (GW) by 2012-13. However, generation from CPP grew by 10%, compared to 6% growth in utilities, making the share of captive generation in total generation increase from 13% to 16% in the reference period. 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.

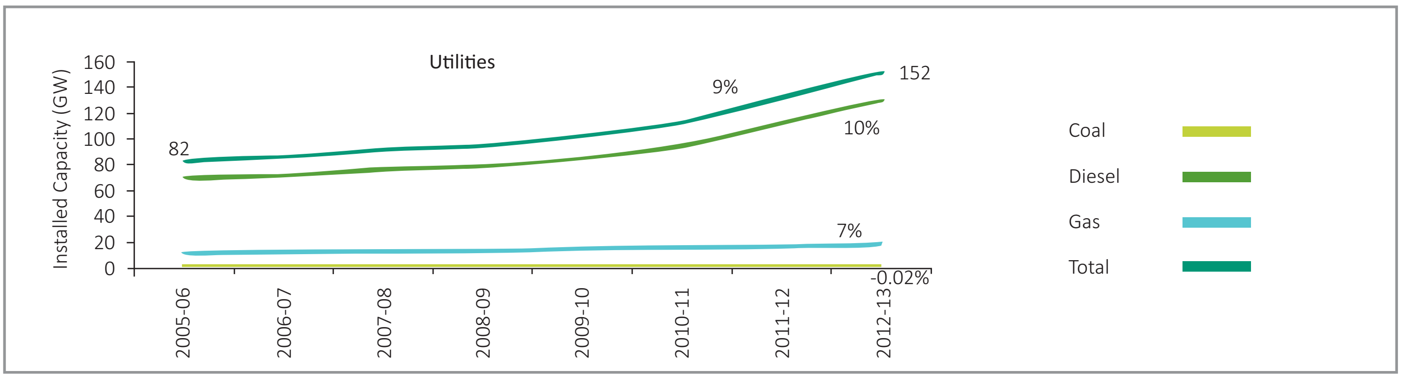

Figure 3: Installed Capacity of Utilities

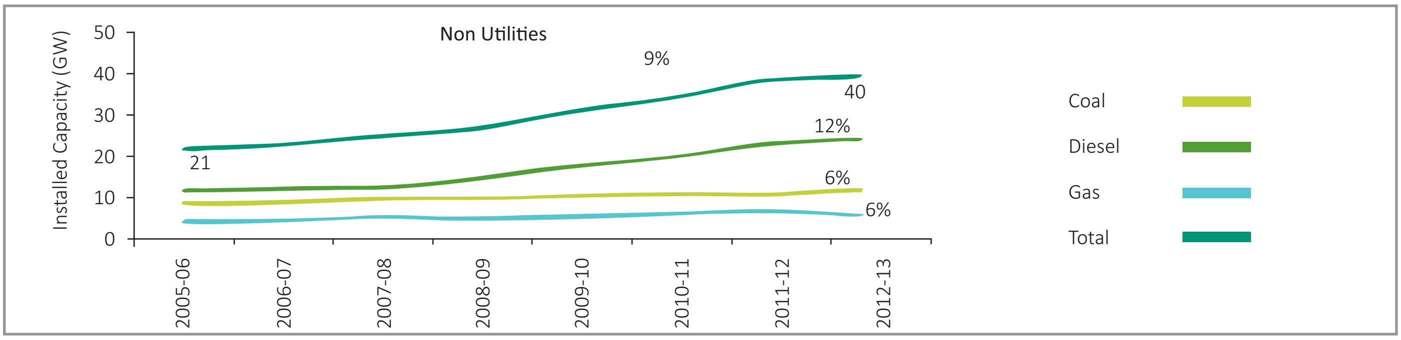

Figure 4: Installed Capacity of Non Utilities

The emissions released while burning fossil fuels for generating electricity have increased at a Compound Annual Growth Rate (CAGR) of 7% from 2007-2012, with CO_2 accounting for almost 99% of the emissions. The annual emission growth rates from utility and captive power plants were 6.35% and 10.37%, respectively. There has been an increasing trend of emissions from coal, gas, lignite and naphtha based power plants. On the contrary, a decreasing trend of emissions was seen in the power plants using furnace oil, diesel and Low Sulphur Heavy Stock (LSHS)/Hot Heavy Stock (HHS). Figure 5 shows the time series emission estimates for the electricity generation from utility and captive power plants.

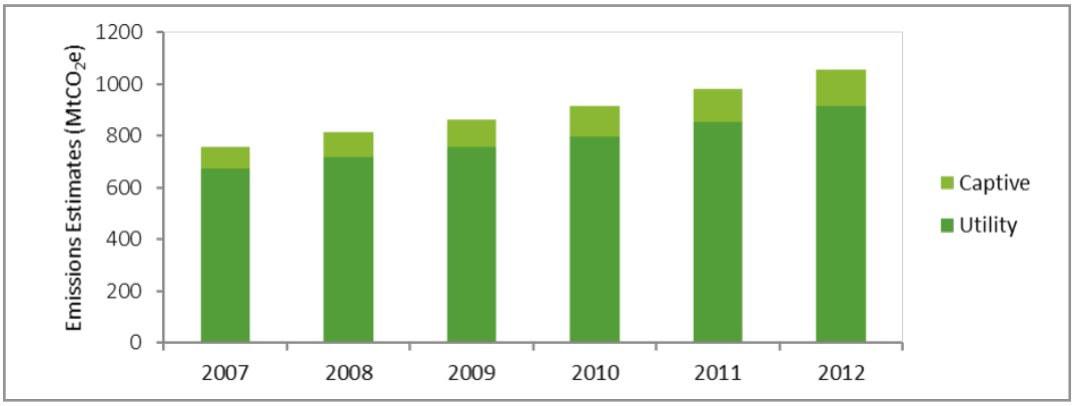

Figure 5: Emission Estimates from Electricity Generation

B. Transport

Between 2007-2012 energy consumption in this sector increased from 2,214 to 3,110 Peta Joules (PJ). Of the total transport energy consumption, road transport consumed about 88% followed by railways at 3%, aviation at 7% and navigation at 1% in 2012. Fuel consumption for the road, railways, aviation and navigation modes are given in the Table 2.

Table 2: Fuel Consumption (PJ) by Transport Sector from 2007-2012

Fuel consumption	2007	2008	2009	2010	2011	2012
Road	1,897	1,929	2,075	2,262	2,540	2,742
Railways	86	92	96	101	104	108
Aviation	194	199	201	210	229	229
Navigation	38	47	51	54	42	31
Total	2,215	2,267	2,423	2,627	2,915	3,110

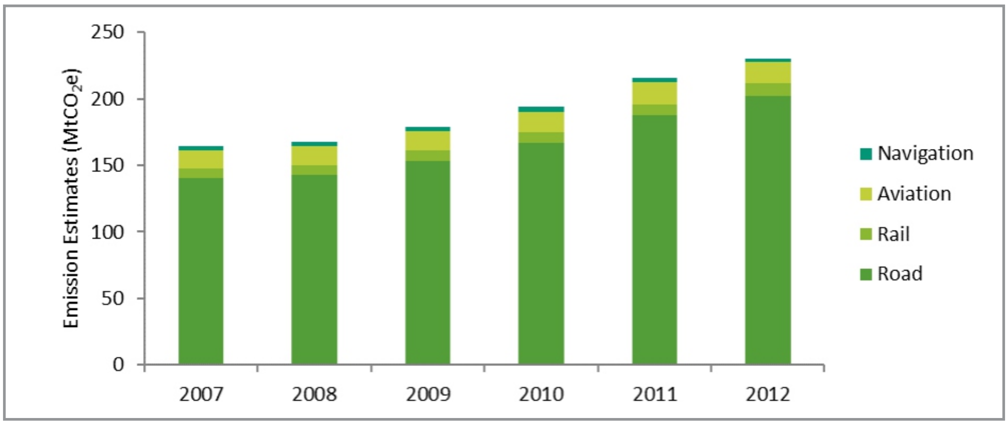

Figure 6: Emission Estimates from Transport Sector

The emission trends from road, railways, aviation and navigation are presented in the Figure 6. The road transport sector GHG emissions dominate the emissions from transport sector and followed an increasing trend for the period 2007-2012. Road transport GHG emissions registered a CAGR of 7.61% during the period 2007 to 2012, whereas the overall transport sector emissions grew at 7.00%.

C. Others (Residential, Commercial and Agriculture/ Fisheries)

With the year on year increase in population and urbanisation, the energy demand for household activities has been steadily increasing. Fuelwood is the the major energy source for household activities. The other sources were Liquified Petroleum Gas (LPG) and Compressed Natural Gas (CNG), coke, coal and charcoal. According to the 68th round of National Sample Survey Organisation (NSSO) database, about 67.3% of the rural households and 14% of urban households used firewood and chips as a source for cooking (NSSO, 2015). There has been an overall 7.7% drop in the usage of non-commercial biomass between 2004-05 and 2011-12. LPG was used dominantly by the urban households (68.4%), with only 15% penetration in the rural households (NSSO, 2015). In case of commercial sector, LPG and kerosene used for cooking and lighting, and diesel used in the DG sets were the main fuels that generate emissions. Use of Diesel Generator (DG) sets in the residential and commercial sectors has increased significantly over the past decade (ICF International, 2014).

The energy usage in agricultural sector is mainly due to the diesel consumption in irrigation pumps, tractors and other implements. Fishing fleets largely use diesel and kerosene as the fuel. Table 3 shows the energy used by residential, commercial, agriculture and fisheries sector from 2007-2012.

Table 3: Fuel Consumption by Other Sectors

Sector	2007	2008	2009	2010	2011	2012
Residential	5,323	5,459	5,100	4,795	4,674	4,575
Commercial	128	154	166	189	208	227
Agriculture	403	385	425	467	496	556
Fisheries	92	84	88	92	96	101
Total	5,946	6,082	5,779	5,543	5,474	5,459

All units in Peta Joules (PJ)

The emissions generated in residential sector by burning LPG, NG and diesel have shown an increasing trend while the emissions from fuelwood and kerosene have been declining during these years. The overall emission from the residential sector has increased by less than 1% annually during 2007-2012.

In case of commercial sector, LPG, kerosene and diesel were the main fuels that generate emissions. The emissions from commercial sector have grown by 12% per annum. The major contributor to emissions in the commercial sector is DG sets, accounting for well over half the total emissions.

In case of agriculture sector, diesel usage accounts for 99% of its emissions. The emission from this sector has increased by 6.6% (per annum) over the years. Emissions from fisheries sector have grown at a CAGR of 1.9% during these years.

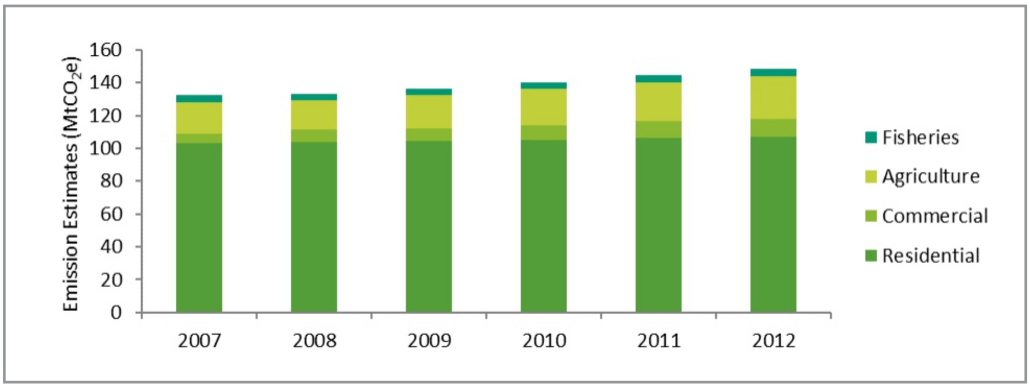

Figure 7: Emission Estimates from Other Sectors

The emissions from kerosene usage have declined by 16% while the emissions from diesel have increased by 14% during this time. Figure 7 shows the time series GHG emission estimates of residential, commercial, agriculture and fisheries sector.

D. Fugitive Emissions

Between 2005 and 2012, coal production in India increased from 382 Million tons to 556 Million tons. This growth was, however, witnessed only in Open Cast (OC) mines, also referred to as surface mines. The share of coal extracted from underground (UG) mines decreased during this period owing to the lack of technological advancement and availability at increased depth. The degree of gassiness (therefore the levels of methane emission) increases with the depth of coal available for extraction.

Around 38 Million Tonnes (Mt) of oil was produced in 2012, compared to 34 Mt in 2004. The natural gas production was accounted to be 40,678 Million Metric Cubic Metres (MMCM) in 2012; an addition of 8,915 MMCM compared to 2005. About 13% of the produced natural gas is utilised in the production facility for internal use. And, after flaring (2%) and leakage (1.65%), the rest is considered as available for consumption. Table 4 shows the activity data for fugitive emissions.

Table 4: Activity Data for Fugitive Emissions

Fuel	Activity	2007	2008	2009	2010	2011	2012
Coal	Total Production (Mt)	451	483	522	533	538	552
	UG	59	59	59	56	53	52
	OC	392	425	464	477	485	500
Oil	Number of Wells	477	503	568	610	614	587
	Production (Mt)	34	34	34	37	38	38
	Refinery Throughput (Million Tons Per Annum, MTPA)	154	160	185	196	202	215
Natural Gas	Production (MMCM)	32,249	32,742	43,846	51,044	48,722	42,398
	Processed (MMCM)	31,307	31,679	42,827	50,066	47,674	41,453
	Distribution (MMCM)	26,932	27,045	37,412	44,744	42,386	36,053
	Leakage (MMCM)	532	540	723	842	804	700
	Flarred (MMCM)	943	1059	1006	970	1050	946

The fugitive emissions grew at a rate of 3% annually from 2007-2012, with similar contributions from coal and oil and gas. Between 2007-2012, the fugitive emission from coal mining grew at 6%, while the emissions from oil and NG production increased at 1% every year. The share of emissions from the mining and post-mining processes of coal production remained at 87% and 13% respectively. Figure 8 shows the time series GHG emission estimates for the Coal, Oil and NG sector.

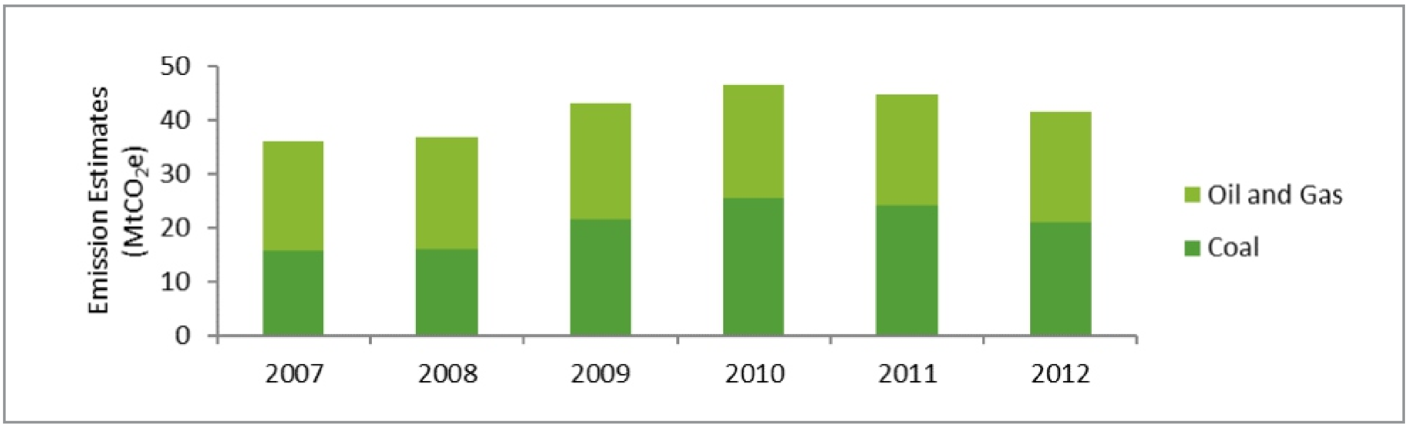

Figure 8: Fugitive Emission Estimates

1.2 Conclusion

The emissions observed in the Energy sector are a result of growing energy needs and government policies that directly or indirectly influence the demand for fossil fuels. This section describes the various policies of the past that had a bearing on the rate of emission from the Energy sector, as well as some policies in future that are likely to influence emissions going forward.

A. Electricity Generation

Consistent growth in electricity driven in particular by commercial and industrial sectors, and push towards rural electrification has ensured rapid capacity expansion in India's electricity sector. Particularly of note has been the growth in fossil-based captive generation, which has somewhat negated the positive effect of renewable energy addition under various government incentives like renewable purchase obligations, accelerated depreciation, generation based incentives, and the National Solar Mission.

In the future, HVAC demands and industrial requirements will continue to propel electricity demand. Due to demand for consistent and quality power, captive and DG capacity are likely to continue expanding. At the same time, RE addition policies like 175 GW RE by 2022 and COP21 target of 40% fossil-free capacity by 2030 can drive down emissions intensity of grid supply. Off-grid RE incentives and rooftop photo-voltaic represent other measures to meet the new demand at zero emissions. Finally, smart grid deployment, segregation of agricultural feeders, improvement in battery technologies and super and ultra-supercritical coal technologies offer great opportunities to make supply consistent and reliable whilst reducing emissions per unit of electricity generated.

B. Transport

The growth in the road transport sector GHG emissions can be attributed to the increase in population, motorization and urbanization rates. With the improvement in the road infrastructure such as National and State Highways, freight transport has also increased significantly. Adoption of higher Bharat Standards (BS) for fuel along the lines of Euro Standards, and phasing out of old vehicles have been the key tactics in reducing the impact of transport sector emissions. 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, National Urban Transport Policy (NUTP) has aimed at improving the mobility of people rather than mobility of vehicles.

Fuel efficiency and alternative fuel policies such as Auto Fuel Policy, National Electric Mobility Mission Plan and Faster Adoption of Manufacturing of Hybrid and Electric Vehicles will have a significant role in reducing the GHG emissions from the transport sector. Policies which focus on modal shift strategies such as NUTP and dedicated freight corridors may contribute to significant reduction in GHG emissions 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.

C. Others

The dependence of the fossil fuels for lighting and cooking has decreased over the years with the implementation of various government programmes to improve the electrification rate. Government schemes like Deendayal Upadhyaya Gram Jyoti Yojana (DDUGJY) (MoP, 2016) and Remote Village Electrification (MNRE, 2016) have helped in providing electricity to rural India and in remote villages. Similarly, Pratyaksh Hanstantarit Labh (PAHAL) Scheme (MoPNG, 2016) and Pradhan Mantri Ujjwala Yojana (PMUY) (MoPNG, 2016) have helped in the penetration of LPG into the domestic kitchens. These schemes have helped the households to reduce the dependence on fuelwood, coke, coal and kerosene for cooking purpose. The GHG emissions from the residential sector are expected to increase at a higher rate as compared to the previous years with the usage of fossil fuels like LPG and Piped Natural Gas (PNG). On the other hand, indoor air pollution, which has been a major cause of mortality and morbidity, particularly in rural India, will significantly reduce due to shift from non-commercial biomass to LPG.

Rural electrification has also benefitted the agriculture sector by helping in electrification of agricultural pumpsets. In 2012, agricultural pumpsets were using 4.04% of the total diesel sold in the country (Nielsen, 2013). With improved rate of rural electrification, the emissions from the pumpsets 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 subsidized kerosene has decreased and the dependence of diesel has increased. These policies have led to the increase in emissions from this sector.

D. Fugitive Emissions

The growth in fugitive emissions from coal production primarily can be attributed to the growing need of electricity. More than 60% of electricity generated is through thermal power plants fuelled by coal. In addition, the energy intensive manufacturing sectors like cement and steel use coal as the primary energy source. Given their role in infrastructure sector, the requirement of coal from metals and minerals industries has also increased significantly during this period. Moving forward, the fugitive emissions from coal sector may increase two to three-fold, owing to the ambitious target of 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 and distribution may increase due to policy impetus that focuses mainly on providing LPG to all households. Urbanisation, rising per capita incomes and growth in mobility needs are likely to continue fuelling private vehicle purchases, which will drive consumption of petroleum products, leading to growth in fugitive emissions from oil.

Chapter 2: Industry

This exercise provides a trend (2007-2012) of greenhouse gas emissions from a highly diverse industry sector of India. Industrial emissions include emissions from Industrial Process and Product Use (IPPU) and Industrial Fuel Combustion (Fuel combusted for captive electricity generation has not been recorded under industry emissions). 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).

2.1 Overall Emissions Trend

India's overall industrial emissions increased at an annual rate (CAGR) of approximately 4% for the period 2007-2012. Table 5 shows the sectoral emissions trend in overall industrial emissions. Iron & steel and non-metallic minerals industries are the major contributors; each contributing to about a third of the overall industrial emissions.

Table 5: Industrial Emissions from Different Sectors for the Period 2007-2012

Consolidated Comparison		2007	2008	2009	2010	2011	2012
Sl no	Sector Descriptions	CO2e (million tonnes)					
1	Iron & Steel	173	166	179	185	191	197
2	Chemicals	50	49	55	58	66	50
3	Ferro Alloys	2	1	1	3	2	1
4	Non-Ferrous Metals	3	6	7	18	27	44
5	Non-metallic minerals	141	165	174	161	159	175
6	Non-Energy products from fuels	4	4	4	5	5	5
7	Refining + manufacture of solid fuels, Other energy Industries	35	37	42	45	45	43
8	Mining	0	0	0	0	0	0
9	Textile and Leather	14	15	14	10	10	11
10	Food & Beverages	4	7	9	2	6	2
11	Pulp, paper and Print	9	10	12	8	8	9
12	Transport Equipment	0	1	1	0	0	1
13	Wood & wood products	0	0	0	0	0	0
14	Construction	0	1	0	0	0	0
15	Machinery	4	4	6	1	1	17
16	Manufacturing n.e.c (jewellery, sports and musical instruments)	2	1	3	2	2	3
Total Emissions		441	465	507	498	521	559

A. Emissions from Fuel Use in industries

Emissions from industry are a combination of emissions from fuel use and emissions from industrial process and product use (IPPU). Over the years, emission from fuel use has contributed between 69% and 74% of the overall industrial emissions.

A1. Emissions from different fuel types

More than 80 different types of fuel inputs reported by industrial units were analysed in the study. Over the years, it is evident that coal has been the most abundant and cheap source of energy that has fuelled industrial growth. Its contribution to the overall energy supply ranges from **62%** to **68%** (Table 6).

Table 6: Energy Consumption by the Industry

	Energy consumption in MTOE			
Year	Coal & Lignite	Natural Gas	Petroleum fuels	Total
2006-07	59.24	12.62	21.21	93.07
2007-08	63.30	14.96	23.57	101.83
2008-09	68.18	16.42	24.03	108.62
2009-10	76.61	16.10	24.38	117.09
2010-11	78.96	16.30	25.04	120.30
2011-12	81.25	14.71	25.46	121.42
2012-13	86.58	14.59	26.70	127.86

Source: MOSPI, 2015

Emissions from coal contribute to more than 80% of the overall emissions from fuel consumption (Figure 9). Hence, the increase in India's industrial emissions is primarily driven by increase in coal consumption. This is also evident from the fact that the fuel mix of Indian industry has remained relatively constant during the period (refer to the next section).

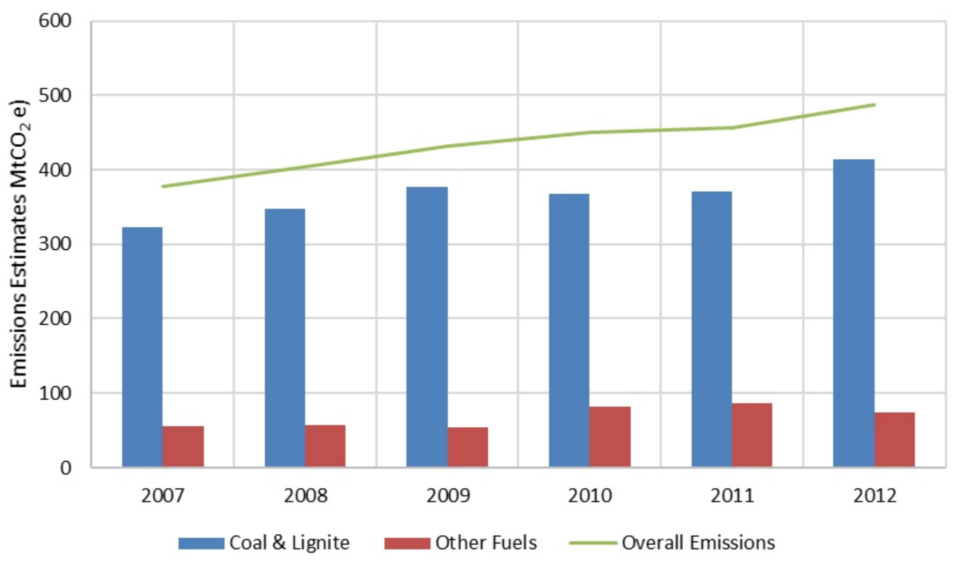

Figure 9: Overall Emission Estimates due to Various Fuel Use within the Industries

A2. Invariant Fuel-mix

India's industrial sector has experienced high growth in terms of industrial value addition during the period 2005-2014 (World Bank, 2015). It is also reflected by the volumetric growth of industrial output by analysing the Index of Industrial Productivity (IIP), registering a CAGR of 8% till 2012 (Figure 10). GHG emissions have grown in a fixed proportion to the increase in energy consumption by industry. This suggests that the average carbon intensity of the basket of fuels used over the years has remained unchanged. Hence, the industrial growth during this period has been principally fuelled by an invariant fuel mix dominated by coal and its products. A shift away from the use of coal would have resulted in lower carbon intensity.

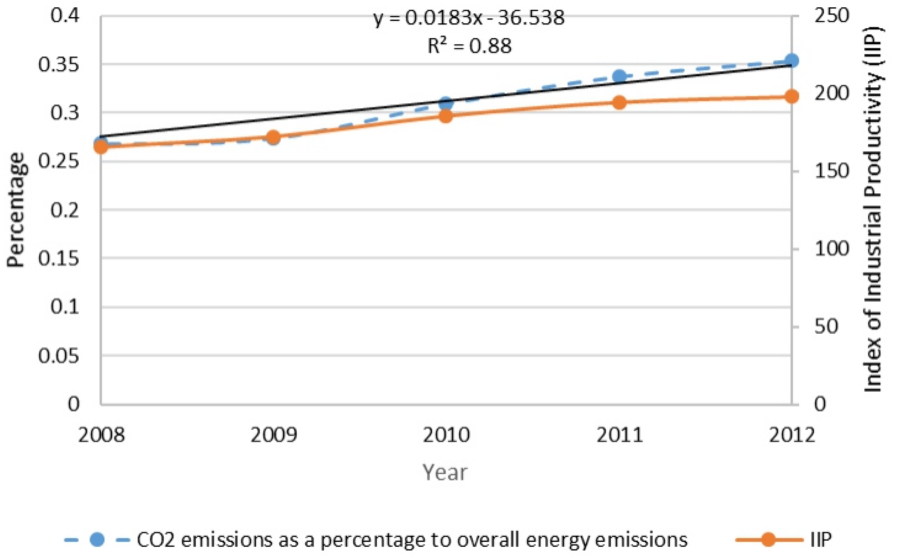

Figure 10: Percentage of CO_2 Emissions of Overall Industrial Energy Consumption

A3. Emissions from industrial sub-sectors

Between 2007 and 2012, emissions from fuel use in industry grew at an annual rate of 3.72%. Figure 11 below shows the trend of emissions from fuel use by various industrial sectors. Over 80% of total fuel use emissions can be attributed to four sectors with, iron and steel and non-metallic minerals sectors being the sources of emissions.

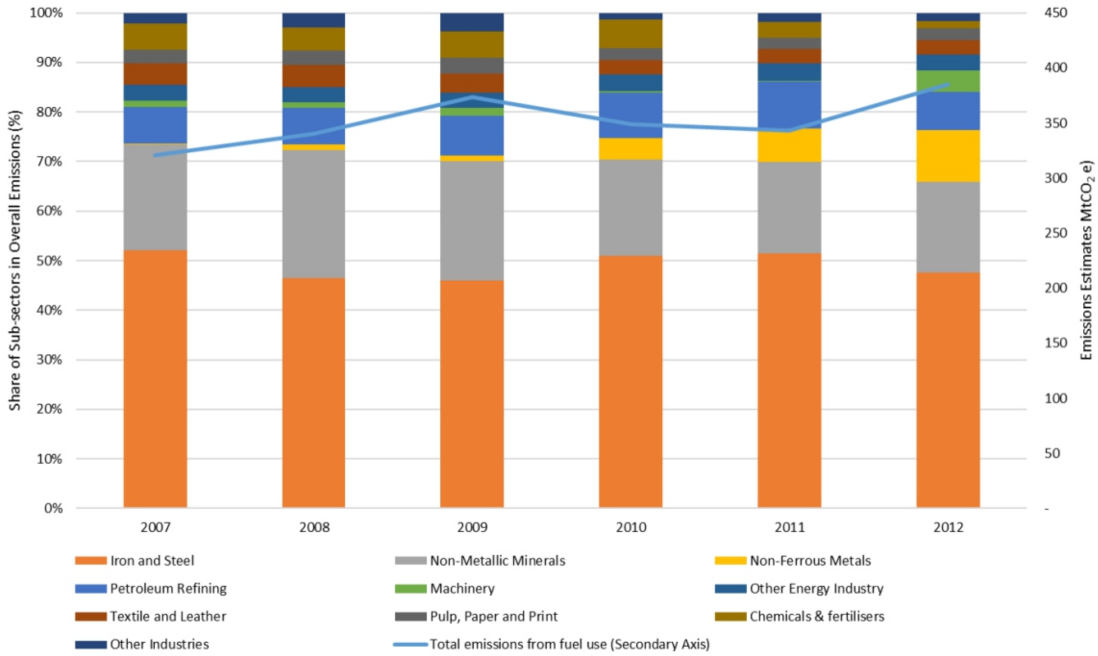

Figure 11: Sectoral Emissions of Fuel Use for the Period 2007-2012

These energy intensive industries are heavily dependent on coal and derivatives of coal. National coal consumption figures show the iron & steel and cement industry to be the second and third major consumers (behind thermal power of coal) (MOSPI, 2015). Hence, disaggregation of the emissions from fuel consumption at IPCC classified sectors also attest to the same fact; emissions from Iron and Steel industry alone accounts for more than 45%, while emissions from non-metallic minerals industry contributes to around 20% of total emissions from fuel usage.

B. Industry Process and Product Use (IPPU) related emissions

For the same duration, IPPU emissions contribute between 26% and 31% of the overall industrial emissions. IPPU emissions are not associated with every industrial sub-sector and they are mostly associated with the industries which use carbonaceous material (such as limestone, carbon electrodes, dolomite, etc.) as a process input and where hydrocarbon fuels. However, process use of various form of carbon as reducing agents (example: coke in Iron and steel industry) is already accounted in the energy use emissions. Similarly, natural gas is conventionally used as a source of fuel as well as feedstock in the ammonia/urea manufacturing process, therefore separate accounting of the energy and IPPU based GHG emissions is not possible. Hence, overall emissions from the fertiliser manufacturing (energy + IPPU) gets reported jointly under the IPPU head.

Figure 12 below shows the IPPU emissions trend from various industrial activities. Unlike emissions from fuel use, IPPU emissions grew at a higher annual growth rate of 7.04% during the period 2007-2012. Cement production, ammonia production and iron & steel production contributes to more than 80% of emissions during the period.

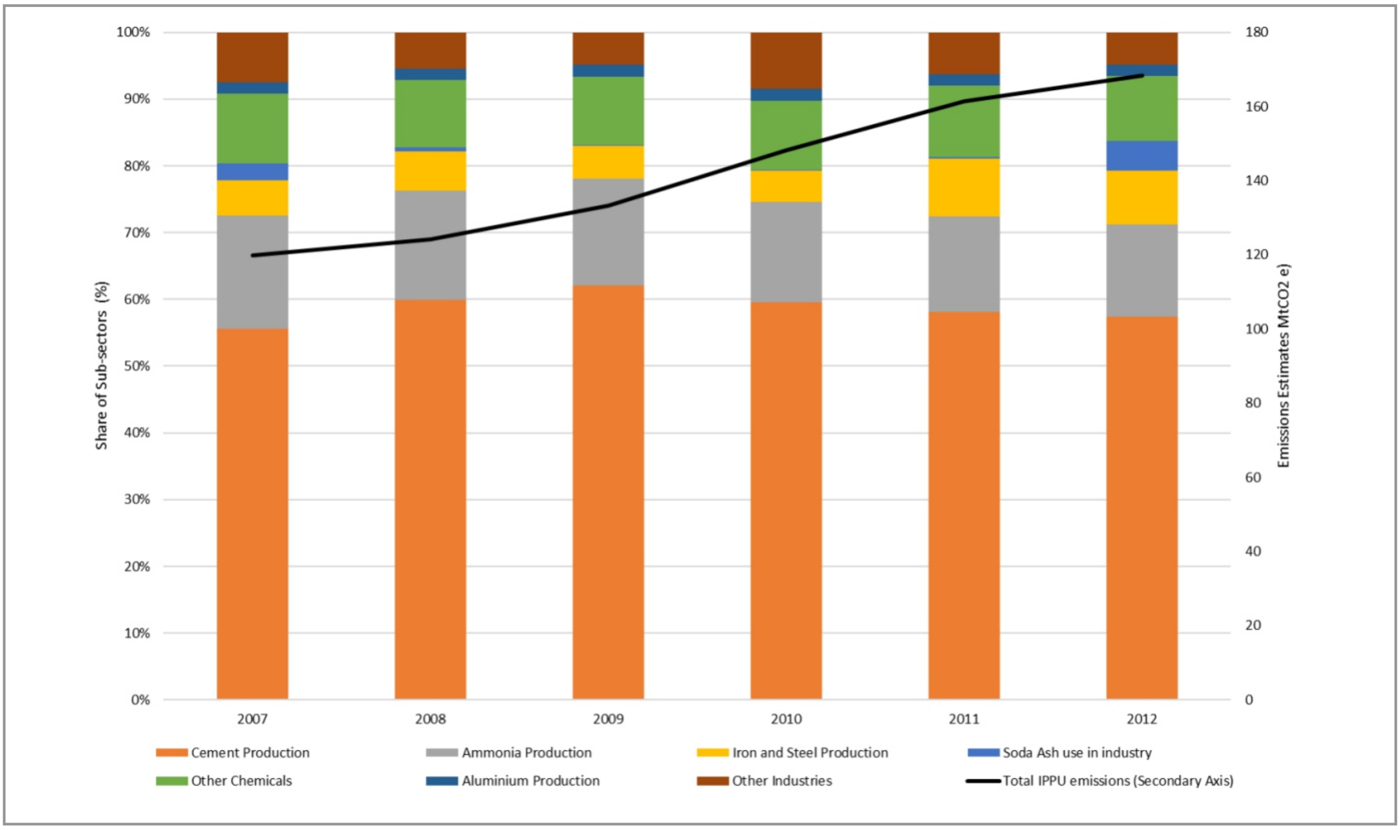

Figure 12: Sectoral Emissions from Industrial Product and Process Use for the Period 2007-2012

Cement industry conspicuously consumes more than 90% of total limestone/dolomite produced in the country (IBM, 2015) hence they contribute to more than 50% of total IPPU related emissions.

India ranks second globally in absolute consumption of nitrogenous fertilizers (FAO, 2009) and thus the fertiliser sector accounts for a large share of emissions. For the period 2007-2012, it contributes to around 16% of total IPPU related emissions. Although, the specific requirement of carbonaceous material in iron & steel production is less than cement production, the sheer volume of steel production in India has driven the emissions from this sector to be the third largest. Process emissions from iron & steel contribute to 9% of the overall IPPU related emissions.

2.2 Policy Linkages and Conclusion

In early October 2016, India has ratified the Paris Agreement on climate change. India has to take concrete actions on the voluntary pledge of reducing emissions intensity of GDP by 33-35% from 2005 levels. The industrial sector, which has a significant potential in improving the energy efficiency across different will have a telling impact on the overall efforts to reduce emissions intensity.

An analysis of the energy consumption trends of the census units (which account for more than 80% of total emissions in any given era) from Annual Survey of Industries (ASI) database shows that their energy emissions per INR billion value addition (a measure of emissions intensity) shows a decreasing trend during the period 2007-2012 (Figure 13). The decrease in emissions intensity is a result of improvement of energy efficiency while retaining the same fuel-mix over the years.

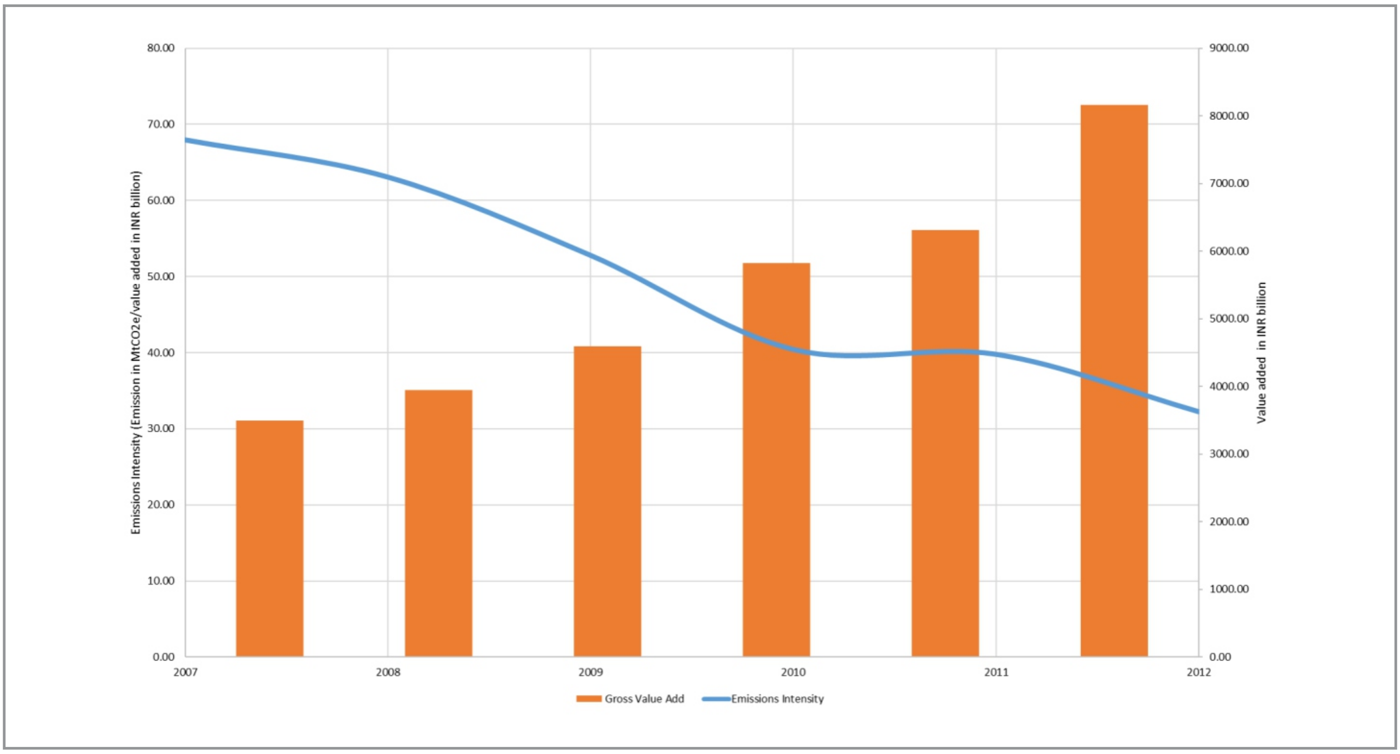

Figure 13: Emissions Intensity of the Census Factory Units from ASI Database

The Perform Achieve and Trade (PAT) scheme is a key policy under the National Mission on Enhanced Energy Efficiency (NMEEE)-one of the missions under the erstwhile National Action Plan on Climate Change (NAPCC). The first cycle of PAT began only in April 2012, while the analysis period for the study was from 2007-2012. This suggests that the decreasing emissions intensity was already the norm in the sector. As per the latest reports, energy savings 8.67 MTOE, translating to a reduction of 31 million tonnes of CO_2 emissions was achieved during the period 2012-2015 (Sustainability Outlook & AEEE, 2016).

As the PAT scheme is gradually driving firms towards achieving energy efficient manufacturing and incremental reductions in overall industrial intensity, recent policy initiatives by Department of Industrial Policy and Promotion are also providing support to the Micro, Small and Medium enterprises. The Zero Defect, Zero Effect (ZED) scheme primarily focuses on production mechanism to improve overall efficiency alongside achieving zero adverse environmental and ecological effects (Zero waste, Zero Effect, Zero air pollution/liquid discharge (ZLD)/solid waste, Zero wastage of natural resources). It is critical for the sustainable growth for these industries and to improve their competitiveness in the global marketplace.

The adopted methodology recognises some limitations with the data sources that have been used and ones that give the most complete picture of the industrial sector in India. However, there is a lack of clarity in the estimation process for emissions in the national reporting as well. Thus, a comparison with the national estimates only acts as a starting point for an informed policy dialogue with the government. The differences between our estimates and the nationally reported figures cannot be explained without a clearer idea of the assumptions that went into the national emissions inventory process. Issues (both data and methodology) are likely to exist in both estimates and these must be addressed as a priority – in order to put out reliable and transparent emissions inventory figures.

Chapter 3: Agriculture, Forestry and Other Land Use (AFOLU)

India's AFOLU sector is an important sector for the economy as it provides direct employment to around 49% of the workforce (NSSO, 2012). Despite providing direct employment to around half of India's workforce, the contribution of the AFOLU sector to India's overall emissions is fairly low.

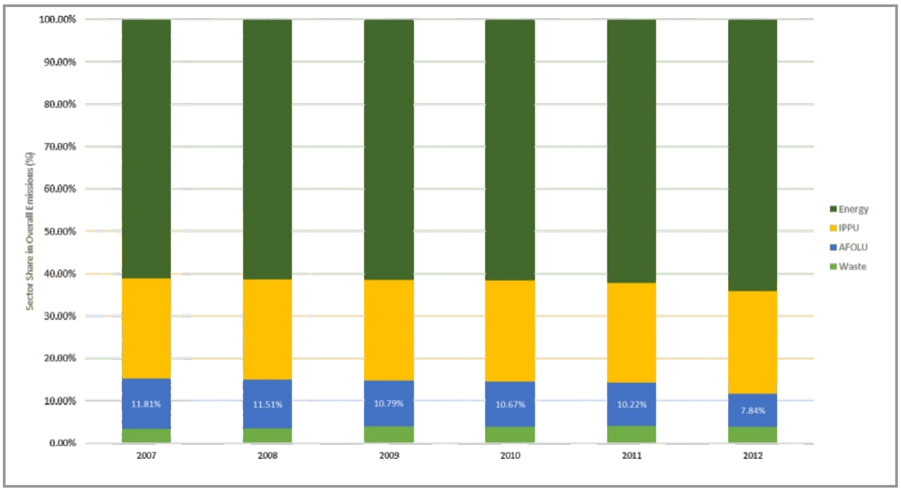

Figure 14: Sector wise GHG Emission Estimates from 2007-2012

While in 2007 the AFOLU sector contributed around 12% of India's overall GHG emissions, this had gradually dropped to around 8% by 2012. This trend can be expected to hold since energy and IPPU emissions are expected to continue to rise in absolute terms while emissions from the AFOLU sector can be expected to not change much and remain steady as the Indian economy diversifies and the Indian workforce moves away from the primary (agriculture) sector to the secondary and tertiary sectors. Despite this, however, there are mitigation opportunities that can be pursued in the AFOLU sector that could make an important contribution to the overall mitigation effort by India in pursuit of its Nationally Determined Contributions to the Paris Agreement.

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

1. Emissions from the Livestock Sector
2. Emissions from the Farm Sector
3. Emissions from the LULUCF Sector

Figure 15 below explains the emission estimates from these three sub-sectors.

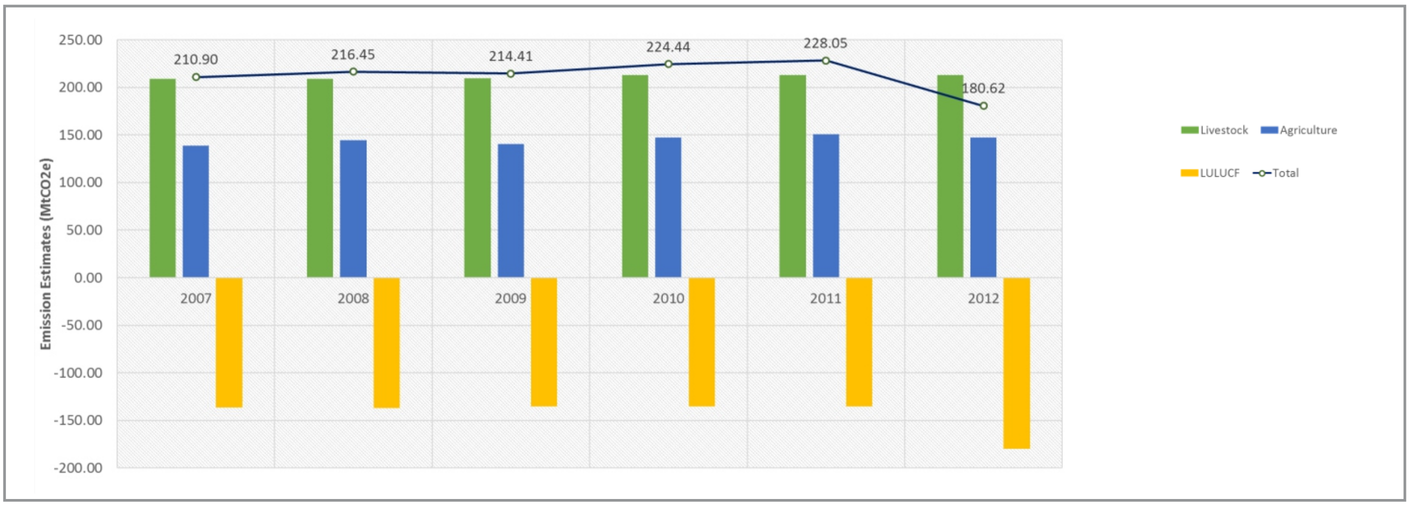

Figure 15: Emission Estimates from AFOLU Sector 2007-2012

The relative contribution of these three sectors to the overall emissions is shown in Figure 16 below. The livestock sector is the largest contributor from the AFOLU sector to the overall economy wide emissions in India ranging between 12% in 2007 to 9% in 2012. The Farm sector follows with emissions ranging between 8% in 2007 to 6% in 2012. The LULUCF sector is a sink for emissions and was absorbing around 8% of national emissions in 2012, the same proportion of emissions that was being absorbed in 2007, with a minor decline in the intervening years.

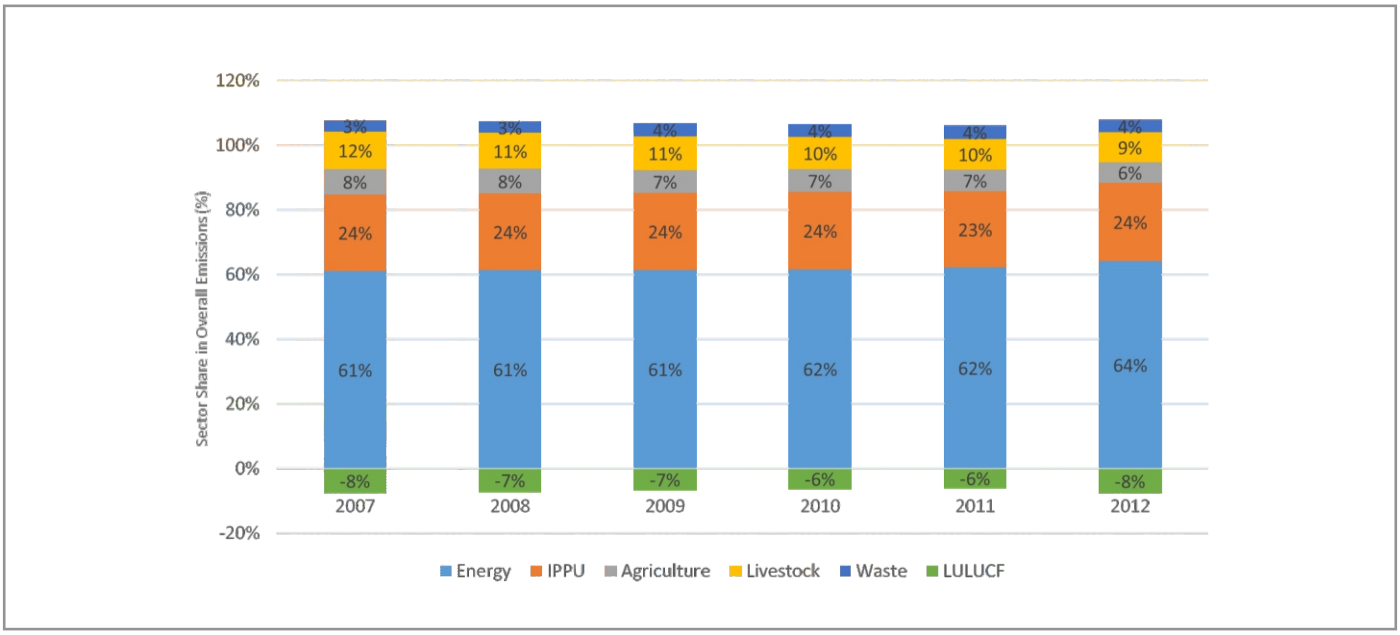

Figure 16: Contribution of AFOLU Sector Emissions to India's Emissions

3.1 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. Livestock Emission Trends and Analysis

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.

Figure 17: Trends of Emissions from the Livestock Sector

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 Figure 18.

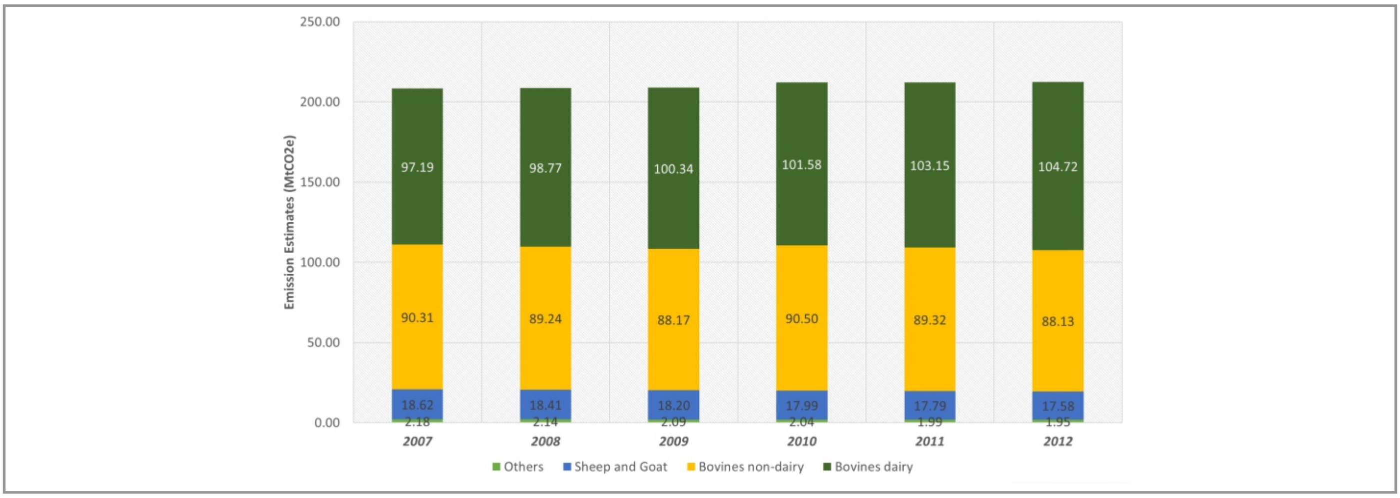

Figure 18: Sub-sector wise Emission Estimates from Livestock Sector

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 to reduce or minimize the emissions from enteric fermentation.

Agriculture Emission Trends and Analysis

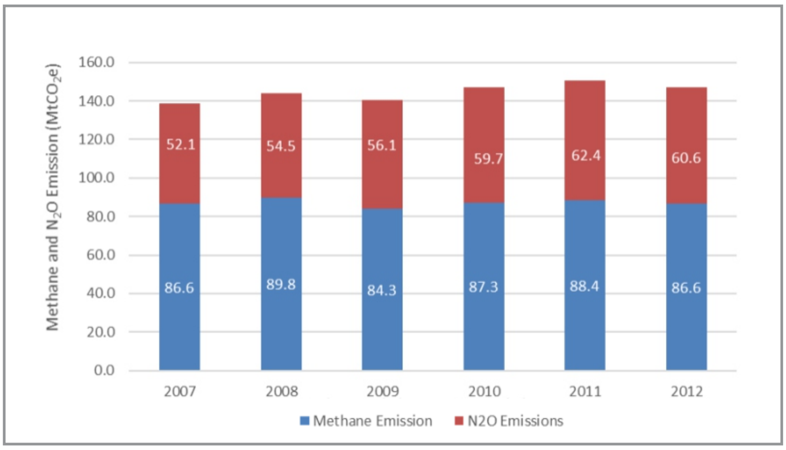

Figure 19: Agriculture Sector Emissions 2007-2012

Emissions from the farm sector are primarily of methane and nitrous oxide. Their relative shares, in carbon dioxide equivalent emissions are shown in Figure 19.

Methane emissions are a major constituent of emissions from the farm sector. However, the relative contribution of nitrous oxide emissions has been gradually increasing, perhaps because of greater fertilizer use.

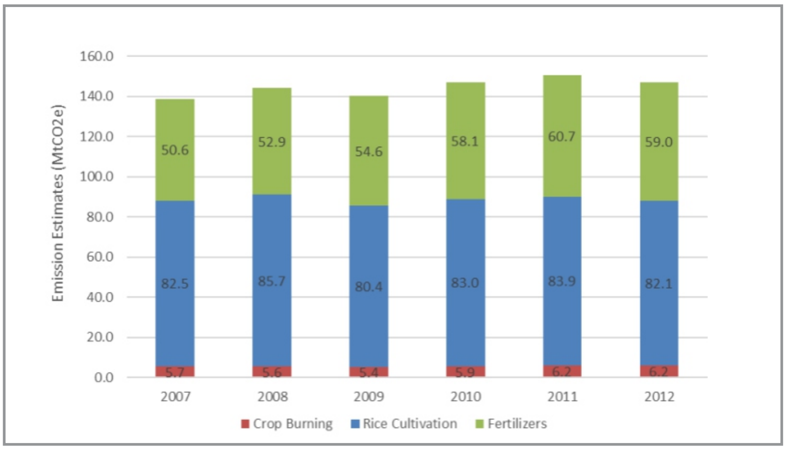

Figure 20: Activity wise Emissions from Agriculture Sector 2007-2012

From among the farm activities that contribute towards emissions from this sector, rice cultivation is the main contributor, followed by fertilizer use. A very small proportion of the overall emissions is contributed by burning of crop residues.

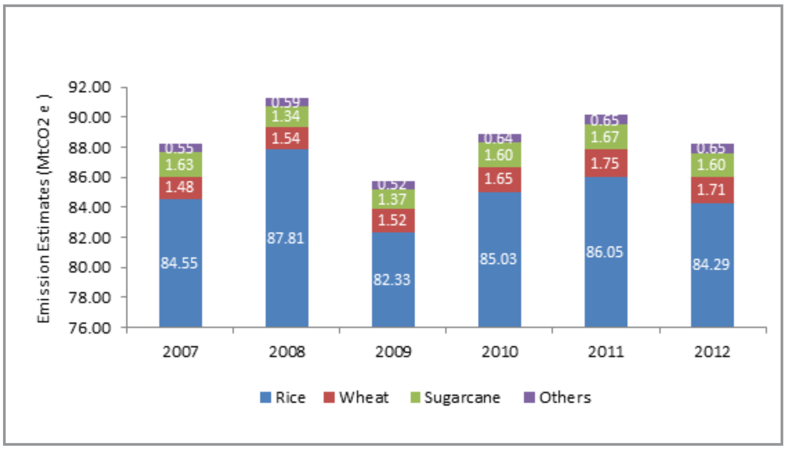

Figure 21: Crop-wise Emissions from the Agriculture Sector 2007-2012

From among the major crops, an overwhelming proportion of emissions emanates from rice cultivation, as is evident from Figure 21. Thus, any major policy interventions for emissions reduction would have to be targeted at rice cultivation.

A. LULUCF trends and analysis

The trends from 2007 to 2012 under this sub-sector are shown in the table below. The dominant theme of this sub-sector is the sequestration of emissions by forests to the extent that relatively small amounts of emissions from crop lands and grasslands are dwarfed by the negative emissions from forest land.

The relative importance of forests in sequestering carbon and thus creating negative emissions from this sub-sector is further depicted in Figure 22.

Table 7: Emissions from the LULUCF Sector 2007-2012

Category	2007	2008	2009	2010	2011	2012
Forestland	-146	-146	-146	-146	-146	-189
Cropland	8	8	9	9	9	8
Grassland	1	1	1	1	1	1
Settlements	0	0	0	0	0	0
Biomass Burning	0	0	0	0	0	0
Total	**-137**	**-137**	**-135**	**-135**	**-136**	**-180**

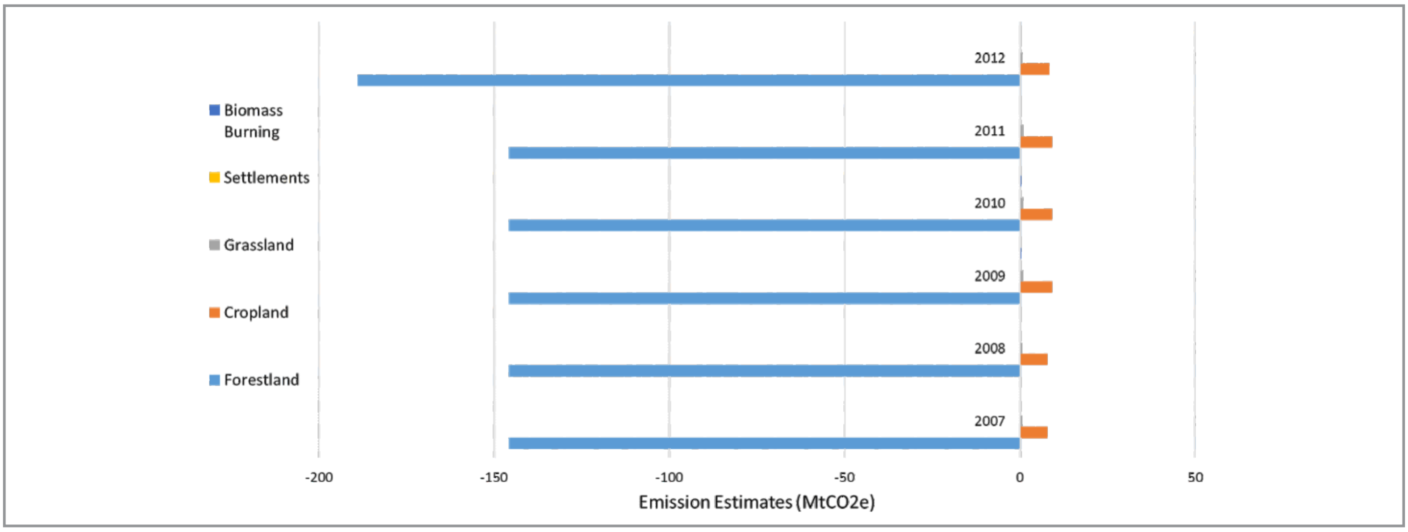

Figure 22: Sub-Sector wise Emissions from LULUCF Sector 2007-2012

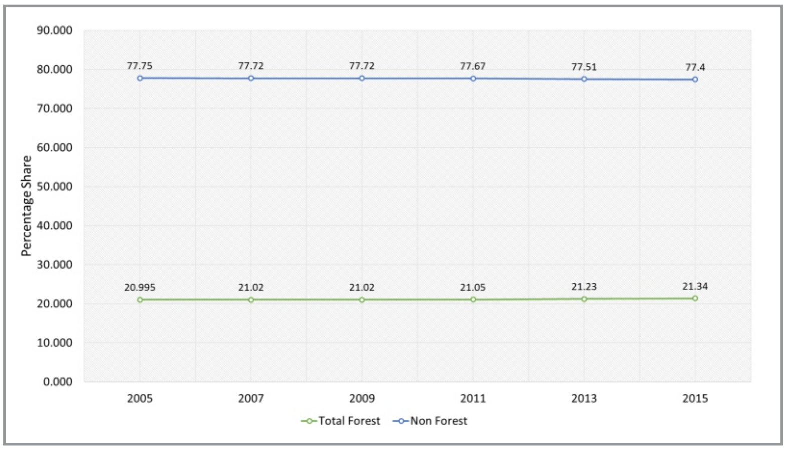

Figure 23: Share of Forest Cover in India 2005-2015

This is primarily due to India's success in avoiding deforestation during the period under consideration. Between 2005 and 2015, India's forest cover[5] remained at a level of around 21% of the total land available in the country, as shown in Figure 23.

While the news is good regarding India being able to maintain its overall forest cover, and thus the ability to maintain its carbon sinks, there is a need to improve upon the quality of the forest cover. Thus, the proportion of what is termed Open Forest needs to be reduced, while at the same time increasing the share of very dense and moderately dense forests in the country.

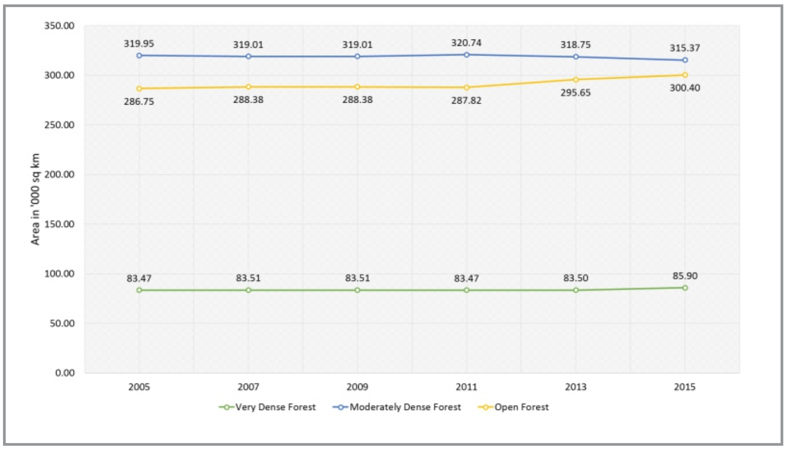

Figure 24: Forest Cover Trend In India

Figure 24 shows that while there is a marginal increase in the area under Very Dense Forests[6] of around 2000 sq. km. between 2005 and 2015, there has been a decline of around 5000 sq. km. of the area under moderately dense forests between 2011 and 2015. This has also been accompanied by an increase of the area under Open Forests of around 3000 sq. km. between 2011 and 2015. This in any case is not withstanding the massive increase, to the tune of upto 10% over and above the existing 20% of India's land that would need to be brought under forest cover to meet with the target of creating an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent that India has put forth in its Intended Nationally Determined Contributions to the global effort to deal with climate change.

3.2 Conclusions and Policy Implications for Mitigation

The AFOLU sector's contribution to the overall GHG emissions in the economy shows a steady decline. Yet, there are significant opportunities for mitigation in this sector that could also offer environmental and socio-economic co-benefits. Some of these are:

1. The dominant contribution to GHG emissions from the livestock sector is from indigenous cattle, crossbred cattle, and buffaloes i.e. bovines. However, an aspect that stands out when comparing these three categories of livestock, is that the population of indigenous cattle is the highest. For instance, in 2012, the population of indigenous cattle was around 151 million, of which, only around 31% or 48 million was milk yielding. The population of buffaloes and crossbred cattle was much less i.e. 108 million and 39 million respectively and the proportion of milk yielding cattle was much higher i.e. 46% and 48% respectively. Further, indigenous cattle are also less productive in terms of milk yield when compared with buffaloes and crossbred cattle. Thus, one aspect of mitigation that would also have environmental and socio-economic co-benefits could be to boost the productivity of indigenous cattle while at the same time aiming for reduction in flock sizes. In addition, pursuing feed management from the point of view of reduced methane emissions from enteric fermentation could also be done to reduce GHG emissions from the bovine population.

5-Forest Survey of India: State of Forest Report from 2001-2015
6-Forest Survey of India: State of Forest Report from 2001-2015

2. Methane emissions from the cultivation of rice are the most dominant emissions from the farm sector. Emissions from rice cultivation can be controlled through alternate water management of rice farms through the adoption of techniques such as direct-seeding of rice (DSR) and system of rice intensification (SRI). Reportedly, there are challenges in adopting these techniques at the farm level. However, these can be overcome through effective outreach and extension. The potential savings in emissions GHGs from rice cultivation by adopting DSR and SRI techniques ranges between 35-75% and could be a major mitigation opportunity with environmental (through water saving) and socio-economic (yield improvements) benefits (Pathak, 2015). Additional mitigation opportunities exist in better management of rice straw by avoiding burning and utilizing for alternate uses such as incorporating rice straw into fields before next production cycle, or removing rice straw from the field and using it for growing mushrooms, producing energy or biochar (Adhya *et al,* 2014). Another aspect of mitigation is to improve the absorption of nitrogen, potassium and phosphorus through the use of neem-coated fertilizer. Reportedly, this can also have additional benefits since this measure increases yields and inhibits diseases as has been indicated by some farm studies that have been undertaken in some parts of north India (Baboo, 2015).

3. Further, while measures to reduce GHG emissions from rice production ought to be pursued, in the medium to longer term, there is a need to pursue strategies for creating a demand for foods such as millets that have a much lower climate and environmental footprint than rice. To illustrate, area under rice cultivation, which in 2012 was 42.75 million hectares, led to emissions 84.29 $MtCO_2e$, while combined area under millet cultivation, which was 15.40 million hectares in the same year, led to emissions of only 0.11 $MtCO_2e$. In addition, these coarse cereals are also more nutritious than rice.

4. India's forests have been acting as valuable carbon sinks and absorb around 8% of its emissions. Pursuing the strategy of improving the quality of existing forests, coupled with adding to the existing forest cover especially through the expansion of dense and moderately dense forests would not only provide climate benefits but would yield additional benefits of soil and moisture as well as biodiversity conservation.

Chapter 4: Waste

The Waste Sector contributes to about 3.5 percent of India's total GHG emission (Ministry of Environment, Forest and Climate Change, 2015). 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 2007-2012 by the GHG Platform – India indicate that India's Waste Sector contributed to GHG emission of 86.8MtCO_2e in the year 2012 (see Table 8) (Chaturvedula, 2016). Treatment and discharge of industrial wastewater is the largest source of GHG emission over the years, contributing to 62% of the GHG emissions from the country's Waste Sector in 2012. Treatment and discharge of domestic wastewater was the second largest contributor to GHG emissions in the Waste Sector, with a share of 22% in 2012, followed by municipal solid waste disposal which contributed to 16% of India's Waste GHG emission.

Table 8: GHG emission estimates for Waste Sector in India 2007-2012

Sub-sector	GHG emission (MtCO_2e)					
	2007	2008	2009	2010	2011	2012
Solid Waste Disposal	10.76	11.47	12.16	12.85	13.52	14.18
Domestic Wastewater Treatment and Discharge	16.86	17.18	17.43	17.75	18.24	18.6
Industrial Wastewater Treatment and Discharge	32.51	36.02	49.52	48.76	58.96	54.02
Total Waste Sector	60.13	64.68	79.11	79.35	90.72	86.8

Waste

4.1 Analysis of GHG Emission Trends for the Waste Sector

A. Municipal Solid Waste

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 (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 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, wood 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). With a significant amount of vegetables being produced, consumed and disposed in the Indian scenario, biodegradable waste (including food and garden waste) makes up a major proportion of the MSW that goes to the disposal sites in Indian cities.

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%

Waste composition in Indian cities has undergone a change over the years with urbanization and changing lifestyles– leading to an increase in the consumption of paper, paper packaging, plastics and consumer products (see Table 9). Consequently, the DOC content in MSW has increased from 0.088 in 1971 to 0.114 in 2005 (Chaturvedula, 2016). Driven by changing consumption patterns, the per capita solid waste generation has been growing by 1.3% per year (Joshi, 2016). **Changing lifestyles in Indian cities have impacted the intensity of GHG emission due to MSW disposal over the decades as well – disposal of a tonne of MSW led to GHG emission of 89,077 tCO_2e during 1951-1961, which has now increased by over 2.5 times to 237,099 tCO2e for every tonne of MSW disposed during 2007-2012** (Figure 25, refer next page). It is important that effective practices and technologies are put in place for MSW management with regards to segregation at source, collection, biological treatment, recovery and scientific disposal of MSW to tackle rising GHG emission and address environmental degradation.

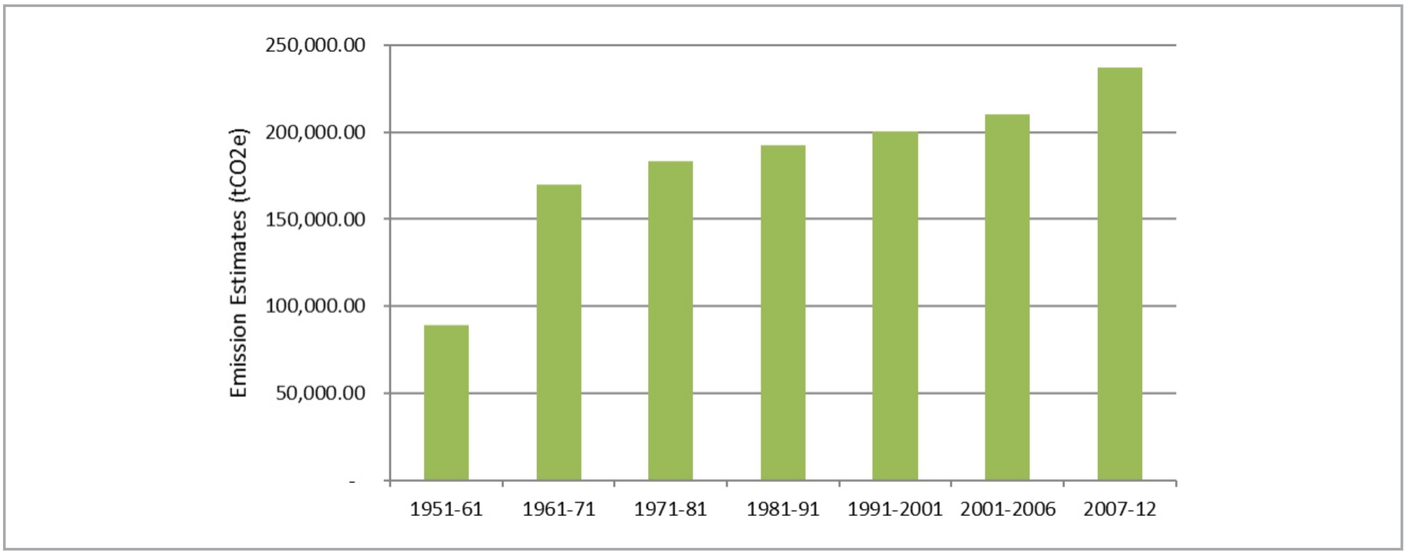

Figure 25: Increase in GHG Emission per Tonne of MSW Disposed in India over the Years

Wastewater from domestic, commercial and industrial 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). GHG emission from wastewater is increasing largely due to population growth in the case of domestic wastewater and increased generation of industrial wastewater due to industrial growth (Aswale, 2010).

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, water supply status, treatment systems and climatic conditions of the area. Wastewater handling systems are largely not available in villages and small towns in India, where collection, transportation, treatment and disposal of wastewater is seldom practiced. Thus most of the domestic wastewater in rural areas of the country decomposes under aerobic conditions and does not contribute to any significant CH_4 emissions (Aswale, 2010).

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. **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 and direct discharge to sea, lake or river) and its associated MCF value, and the proportion of the resident population that uses these different wastewater treatment/discharge pathways or systems (IPCC, 2006).**

In the national emission estimates for domestic wastewater prepared by the GHG Platform- India, to factor in the differences in wastewater treatment system/pathway usage by income groups, the urban population is categorized into urban-high income group and urban-low income group and domestic wastewater emissions have been estimated for both these categories as per the 2006 IPCC Guidelines for National GHG Inventories (Figure 26, refer next page). The extent of anaerobic and aerobic treatment of domestic wastewater that is collected through sewers is factored into the estimates, based on a recent study on Sewage Treatment Plants (STPs) in India by the Central Pollution Control Board (CPCB)[7]. **It is important to ensure proper collection and treatment of domestic wastewater, particularly for the low-income settlements and to adopt technologies to recover and utilize methane from the wastewater to reduce GHG emissions.**

7- CPCB (2007): Inventorization of Sewage Treatment Plants in India. In this study, 84 STPs (spread across 9 states and 30 cities) out of a total of 175 STPs in urban areas in the country were assessed and it indicates that 14% of treatment capacity installed is using anaerobic method.

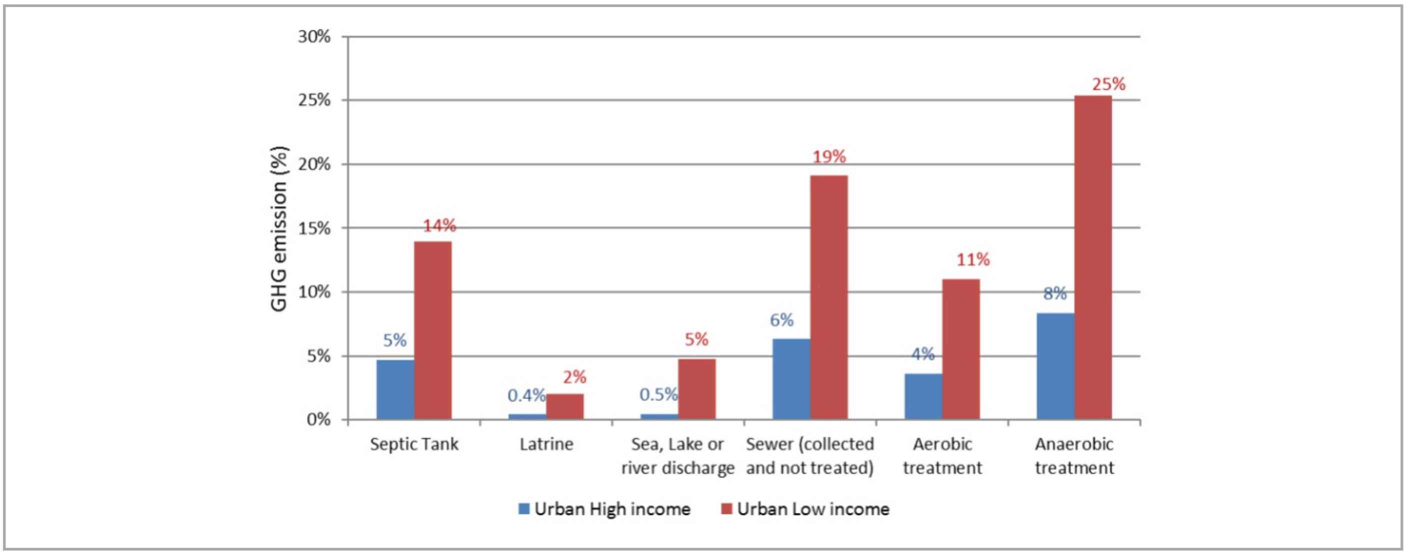

Figure 26: GHG Emission by Type of Domestic Wastewater Discharge/Treatment System for Urban-High Income and Urban-Low Income Groups in India (2012)

The national emission estimates for industrial wastewater prepared by the GHG Platform- India include 12 industrial sectors- Fertilizers, Meat, Sugar, Coffee, Pulp and Paper, Petroleum, Beer, Soft Drinks, Rubber, Dairy and Tannery, Iron and Steel- having substantial organic wastewater generation and CH_4 emission.

The analysis reveals that the GHG emission intensity due to industrial wastewater generation and treatment is notably high in the Pulp & paper, Coffee, Soft drink, Meat and Tannery sectors, which are critical industrial sectors to be targeted to mitigate emissions from industrial wastewater (see Table 10)[8].

Table 10: Average industrial Wastewater GHG Emission per Tonne of Product and per m^3 of Wastewater Generated for Industrial Sectors in India 2007-2012

Industry Sector	GHG emission per tonne of product (kg of CO2e)	GHG emission per m3 of wastewater generated (kg of CO2e)
Coffee	189	37.8
Soft drink	139.9	37.8
Pulp & Paper	4,014.40	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
Dairy	7.1	2.4

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[9] by industry sector and the CH_4 emission resulting from its degradable organic concentration (COD) and the treatment technology used.

8- 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 CH4 emissions from wastewater treatment. Thus, the Iron & Steel, Petroleum and Rubber sectors are not included in the Table.

9- 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

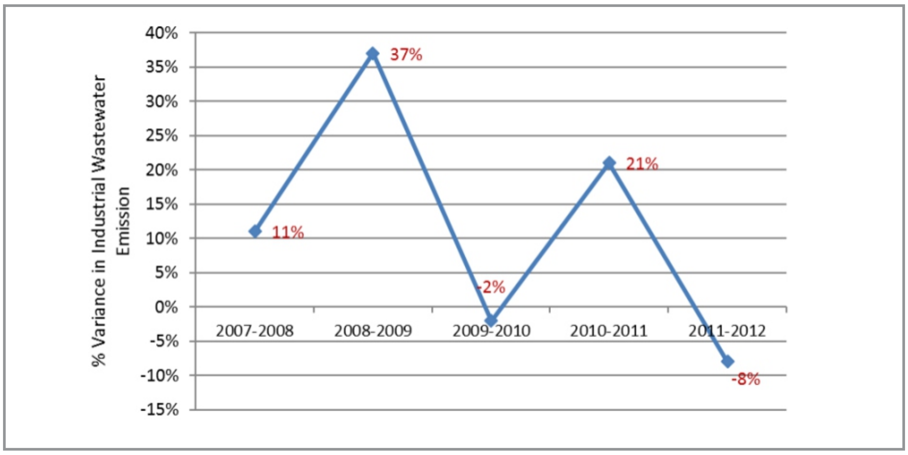

Figure 27: Variance Observed in Industrial Wastewater GHG emissions 2007-2012

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. High variance is observed year on year in the industrial wastewater emission estimates prepared by the GHG Platform-India (see Figure 27). 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 (Handbook of Industrial Policy and Statistics) 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.

Besides reliability of data, lack of requisite information was a major constraint evident during the emission estimation exercise for the Waste Sector. With regards to MSW, limited updated information exists on waste composition, degradable organic content, per capita waste generation rates, and quantum of MSW that is going to disposal sites. In the case of industrial wastewater, it is likely that wastewater generation per tonne of product and therefore wastewater generation may vary over the years with changes in production processes and technologies. However, due to the lack of such updated information, constant values of wastewater generated per tonne of product have been used for all the years (2007-2012) in the emission estimates GHG Platform India. Similarly, critical year-on-year data on domestic wastewater generation and population served by different wastewater treatment technologies is not available.

There is a need for periodic reporting of information such as physical and chemical characteristics of MSW and its generation and treatment, domestic and industrial wastewater generation and prevalent treatment technologies and performance of wastewater treatment plants by Central and State Pollution Control Boards, and on the status of on-ground developments and improvements in sanitation and solid waste management. Robust data management systems need to be put in place and existing data management processes such as the Annual Survey of Industries (ASI) and the annual reports on waste management submitted by States to the State Pollution Control Boards need to be made use of for capturing relevant information required to accurately estimate GHG emissions for the Waste Sector. Improved transparency with regards to availability of the underlying datasets and assumptions used for India's National emission reporting in the public domain will help identify and address any limitations, enable better comparability, and improve accuracy of the Waste Sector estimates prepared by the GHG Platform India as well as official National emission estimates for India.

4.2 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 brought about by 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.

Solid waste and waste water management form key components addressed under the GoIs 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)[10].

10- 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.

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 regards 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. During 2012, nearly 68% of rural households and 24% of urban households reported no garbage collection arrangements compared to 75% of rural households and 21%of urban households during 2008-2009 (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 in solid waste management with regards to coverage, waste segregation, recovery and scientific disposal of MSW (MoUD, 2015) (see Table 11).

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)

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 severe 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 disposal sites. More than 80% of waste generated (117.2 kilo tonnes per day) is dumped at disposal sites without any treatment or processing. India had only 69 sanitary landfill sites constructed and operational in 2013-2014, 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[11] (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[12] 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[13] 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 and 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 in Indian MSW in India is also growing. 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 for Indian cities to 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 2008-2009 based on the National Sample Survey of India, shows that during 2012 nearly 50% of rural households and 12.5% of urban households had no wastewater collection facility compared to 56% of rural households and 15% of urban households during 2008-2009.

11- The Solid Waste Management Rules have been amended recently in 2016.

12- 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.

13- 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.

Waste

During 2012, waste water was directly discharged without treatment to open low lands, ponds and nearby rivers by nearly 67% households in rural areas and 18.5% 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, most of the time, domestic sewage and industrial effluent are untreated, and their discharge contaminates locally available water courses (surface as well as ground water) while leading to significant amount of methane emissions and potentially jeopardizing both public health and the ecosystem. The MoUD's pilot study on assessment of service levels for sewerage and sanitation services on implementation of the SLBs further reiterates 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 12).

Table 12: SLB's Pilot Initiative Results for Solid Waste Management

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)

The GoI has also taken 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 like 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 treated by augmenting treatment infrastructure and improving performance efficiency of STPs. Significant opportunities exist for emission mitigation in STPs in the country, particularly the ones using anaerobic process for domestic wastewater treatment, with around 30% 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.

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 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.

Among the industries adopting anaerobic treatment for wastewater are 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 Sector 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, eleven registered CDM projects on methane avoidance and utilization from industrial wastewater in India contributed to annual average emission reduction of about 300,000 tCO_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).**

Overall Conclusion

India's emissions have grown from 1802.24 $MtCO_2e$ in 2007 to 2297.32 $MtCO_2e$ in 2012. The energy sector is the largest contributor to GHG Emissions in India accounting to 60% of the total GHG Emissions of India in 2012, not taking into account the land use and land use change emissions, followed by the industry sector accounting to 22% of the total emissions, with the AFOLU and Waste Sectors contributing to 15% and 3% of the total emissions of India in that year. Within the energy sector, the sub-sector that has seen a fairly rapid rise in emission is the electricity generation sector.

While it seems evident that India's emissions will continue to grow in the coming years, there are also significant mitigation opportunities that exist in all sectors and sub-sectors, as can be seen from the detailed sector wise emissions estimations contained in this paper. Our observation is that in many cases, policy frameworks have been created to tap the potentials for mitigation and are being pursued, while in other instances, policy frameworks exist but the implementation is perhaps not as effective as it should for several reasons and in some cases, perhaps the mitigation potentials are being met, but are not evident due to lack of availability of reliable information available in public domain.

Nevertheless, with the Paris Agreement coming into force from 4th November 2016, much sooner than what was anticipated in December 2015, there is likely to be pressure on countries including India to increase its ambition on mitigation and importantly, put in systems for a robust system of measuring, reporting and verification of all its actions to address climate change.

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GHG Platform INDIA

The GHG Platform India is a collective civil society initiative providing an independent estimation and analysis of India's greenhouse gas (GHG) emissions across key sectors, namely, energy, industry, agriculture, livestock, forestry, and land-use and land-use change, waste sectors.

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CSTEP – Center for Study of Science, Technology & Policy
ICLEI – Local Governments for Sustainability
Shakti Sustainable Energy Foundation
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