Sector: Industry

GHG Platform INDIA

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Greenhouse Gases Emission Estimates for India
Industry sub-sector (2007-2012)

1. Introduction and Scope

The objective of this exercise is to contribute towards establishment of the 'India GHG platform'. This platform aims to complement the national reporting process, and to drive an informed policy dialogue within the country on the carbon emissions inventory. The larger goal is to explore the possibility identifying emissions reduction opportunities at a granular level.

This document provides details on the methodology adopted for the estimation of the Green House Gas (GHG) emissions from the industry sub-sector in India. 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).

GHG emissions from industries either come from energy consumption, or, they are process specific. Our approach illustrates emissions related to both of these contributing factors. It also highlights the information gaps, merits and de-merits of the approach observed during the GHG emissions estimation process.

Data sources adopted

In India, industry specific information is interspersed within specific ministries, departments, associations, and the individual manufacturing units. The Annual Survey of Industries (ASI) datasets, provided by Ministry of Statistics and Programme Implementation (MOSPI), is used as a prime source of information for the GHG estimations. It is a comprehensive and centralised source of information on industrial statistics in India, and is largely used for national income estimates from the organised sector.

ASI exercise is a combination of census and targeted surveys. Effectively, it represents all the registered factories[1] in India. Individual units not directly covered under the census/survey, are represented on the basis of nearest representative factory, and quantitatively accounted for through the use of multipliers. ASI provides a time series of crucial information on the fuel and material consumption/production (such as expenditure, quantity, output, etc.) at the individual factory level, which is otherwise challenging to put together from other sources. Hence, it qualifies as a best source of information for the GHG estimations related to the fuel as well as industrial processes (MOSPI, 2016a).

Alternative sources that are generally accepted and credible (refer, Annexure 1) are used to cross-verify the ASI statistics, and to plug information gaps, if any. To name a few of these data sets, we are relying on information from the following Indian Bureau of Mines (for

[1] Employing 10 or more workers (using power), or those employing 20 or more workers without using power.

mineral specific activity data) (IBM, 2015), Coal Directory of India (for reported coal off-take by industries) (Ministry of Coal, 2015), Cement Manufacturing Association of India (for cement/clinker activity data), Petroleum Planning and Analysis Cell (for domestic production of oil and natural gas) (PPAC, 2016), Ministry of Commerce (for trade related inputs on several fuel types) (Ministry of Commerce & Industry, 2016).

Methodology (illustrated with examples and stepwise assumptions):

This study estimates GHG emissions (in CO2e) for of the period 2007 to 2012. India's official reporting for the available years (2007 and 2010) is taken as a reference point to understand the unpacking of sector wise emissions and provide a useful comparison. Standard methodology prescribed by the IPCC, 2006 guideline is adopted for estimating energy and IPPU estimates. Further, reasonable assumptions are made (wherever required) to come up with sector specific activity data and the emission factors.

ASI dataset, available for the consecutive seven years 2006-07 through 2012-13 (financial year FY) was purchased and processed to extract the fuel specific energy consumption and process specific 'activity data' across the industries. All the units reported under the ASI are coded as per the standard National Industry Classification (NIC)[2] system (at a 5-digit level) (MOSPI, 2016b). Similarly, each industry reports its input/final output in terms of products and fuels specified under National Product Classification for Manufacturing Sector (NPCMS) system (MOSPI, 2016c). This makes it easier to structure the input fuels (for energy related emissions) and other carbonaceous material (for process emissions) together under specific categories across the various sub-sectors. In order to report the emissions in a standard IPCC format, a concordance was devised by CEEW between the NIC codes (2004 and 2008) and the IPCC classification system for industries (refer Annexure 2, Table 2.1 and Table 2.2 respectively).

This following section illustrates a step-by-step methodology used for translating the raw activity data from the ASI data set into meaningful emissions for the sector. For energy use, emissions are attributed to the fuel mix adopted by each of the industry. Whereas, emissions related to industrial process and product use (IPPU) largely comes from intake of carbonaceous materials (other than conventional fuel) within applicable unit operations and also from the release of GHG gases from specific processes. The approach followed and assumptions made are not without their limitations. Each information gap or limitation is addressed through practical assumptions. The opportunity to refine these assumptions, based on stakeholder discussions, is still open and will be pursued in due course.

3.1 Energy use related emissions

[2] Covers NIC 2004 and NIC 2008, as applicable to the reported year.

Emissions from the energy use come from the input hydrocarbon fuels, where their characteristic quality and the quantity under use determines the overall emissions.

Basic Equation:

$$Egas = Afuel * C.Vfuel * C.Vfuel * E.Fgas * GWPgas$$

Where:

$Egas$: Amount of greenhouse gas in tonnes

$Afuel$: Activity data of fuel (in litres/Kg/tonnes etc.)

$C.Vfuel$: Conversion factor to convert activity data to tonnes

$C.Vfuel$: Calorific value of fuel to convert tonnes into energy (TJ)

$E.Fgas$: Emission factor of GHG gas from combustion of the fuel (tonnes of gas /TJ of energy input)

$GWPgas$: Global warming potential of gas

a. **Fuel use from activity data:** There are more than 100 types of input energy source(s) reported by the factories. As we can see from Annexure 3, reported fuels range from coal (washed, rejects, peat, anthracite, coke, etc.) to a wide spectrum of the petroleum products (kerosene, light petroleum oil, diesel, high speed diesel, gasoline, petroleum coke, etc.). A sizable amount of energy input is accounted under the head of 'other fuels' in the ASI dataset, and is provided only in terms of expenditure values (Annexure 3). Limited clarity is available from the ASI on this category of fuels, as it mentions it to be constituted by biomass feedstock.

   CEEW assumption: While we continue to seek more clarity from the concerned authorities on this fuel category – in this analysis, we consider it to be a net *carbon neutral* input, assuming all of it is coming from 'commercial biomasses. Non-CO_2 emissions from biomass have also not been considered, as it is difficult to describe the technologies used to burn biomass, and given state of biomass (moist, dried, pieces, logs, etc.) while arriving at some suitable EFs or non-CO2 emissions.

b. **Applying emission factors**: Each of the fuel types are classified in terms of its source, i.e. domestic or imported (Annexure 3). This helped us in assigning specific calorific values to the fuels, for example – domestic coal (owing to its poor quality) bears a lower calorific value (19.63 TJ/Gg)[3] as compared to the default values from the imported coal (26.7 TJ/Gg) (Choudhury, Roy, Biswas, Chakraborty, & Sen, 2004). India has officially declared its country specific emission factor for coal and lignite only, rest of the fuel follows the default IPCC factors. Wherever any default emission factor is not provided, assumptions were made on the basis of closed fuel type. Refer Annexure 3 to get a detailed understanding on fuel wise calorific values, emission factors and our assumptions (wherever mentioned) for each of the input fuel reported by the industries.

c. **Accounting non-specific(ied) fuel reporting**: Some of the units/factories within the ASI dataset provide their fuel inputs at a broader level instead of specifying the granular details of the fuel type; i.e. (a) coal consumed, (b) electricity generated (captive) and/or electricity purchased, (c) all gases consumed, and, (d) petroleum products consumed. Further, they provide only the expenditure incurred on the fuel inputs. This poses a big

[3] Refer: Choudhury *et al.*, 2006; CIMFR, India

challenge in assigning a specific calorific value and an emission factor towards such generic reporting. ***For example***: emission factor ranges between 63.1 Tonnes/TJ to 107 Tonnes/TJ for various petroleum products. Similarly, no clarity is available for the gaseous fuels, whether it's LPG or natural gas or some other variants (propane, butane, etc.). To arrive at a closest possible emission estimate from such fuel reporting, following assumption was made.

CEEW assumption: We studied the fuel consumption pattern of the units reporting their energy inputs in a precise manner (refer section 3, above). Based upon the common trend demonstrated by them, we have assigned the characteristics (calorific value and emission factor) of the dominant fuel type to each other industry which failed to provide a breakdown of their common reporting (Figure 1). Since the reporting is made in terms of category wise 'energy expenditure' by such units, we have transcribed the reported purchase rate(s) from the other set of units, into a representative 'energy quantity'. Figure 1 depicts the 'liquid fuel' specifics for industry type for one such year.

Figure 1: Snapshot of categorical distribution of the liquid fuel (in 2012-13) intake across the industry type

Row Labels	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Bituminous oil	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Bituminous or oil shale and tar sands n.e.c	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%
Diesel	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel oils n.e.c.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel, aviation turbine	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Furnace oil	76%	0%	0%	99%	100%	0%	0%	0%	0%	2%	4%
Glancepitch	0%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%
High speed diesel	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kerosene	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%
Kerosene n.e.c	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Light petroleum oil	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Liquid or liquid gas fuel for lighter	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Liquidified petroleum gas (LPG)	0%	0%	0%	0%	0%	0%	0%	0%	0%	98%	2%
Medium petroleum oil, n.e.c.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Motor spirit (gasolene), including aviation spirit n.e.c	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Oil, Coal tar	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Other light petroleum oils and light oils obtained from bituminous minerals n.e.c	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%
Paraffin incl wax	5%	0%	100%	0%	0%	2%	92%	100%	0%	1%	92%
Petroleum coke	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
Petroleum coke calcined	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Petroleum jelly	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Petroleum oils and oils obtained from bituminous minerals, crude	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%
Petroleum products obtained from bitumen n.e.c.	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Propane and butanes, liquefied, n.e.c.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shale Oil	0%	0%	0%	0%	0%	27%	0%	0%	0%	0%	0%
Spirit type (gasolene type) jet fuel	0%	96%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Superior kerosene	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Wax chlorinated paraffin	0%	0%	0%	0%	0%	67%	0%	0%	0%	0%	0%
Wax polythene	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Grand Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Top row depicts industry type as per the NIC codes; whereas column values provides % share of each fuel type, and is highlighted for the dominant fuel (for representation purpose only).

Source: CEEW analysis of ASI dataset (year 2012-13)

Figure 1 illustrates that furnace oil is a dominant liquid fuel under the NIC codes 10, 13, 14 and others. Similarly, kerosene represents a major liquid fuel input for NIC 18, whereas LPG is a large portion of the inputs to industries classified under NIC 19. Thus, general fuel reporting under these NIC codes gets represented by the dominant fuel reported. While the specific breakdown may vary for each year, the dominant fuel type largely remains the same. Annexure 4 lists the details of this approach for the year 2012-13, and more or less represents a picture of other years as well. As an alternative approach, we could consider the exact proportions of specified fuel types, instead of assigning dominant fuel alone. However, this task requires significant manual interventions and is time consuming. Thus, we have chosen to adhere with dominant fuel type for the simplicity reasons.

d. **Differentiating hydrocarbon use as a fuel versus feedstock**: From the current reporting format of ASI datasets, one can't differentiate for the end use of the input hydrocarbons at the factory premise. There is no reporting on whether it is for heating purpose, or for captive power generation, or is going to be a feedstock for the secondary products. Since, hydrocarbon as a feedstock doesn't contribute to the direct emissions, two layers of analytical checks were performed to exclude the feedstock use of potential fuels:
   - Specific units having a definite fuel type (example: crude petroleum, coal) as an input and a related hydrocarbon derived products (example: paraffin wax, lubricants, coke, etc.) as an output are carefully handled. Based upon combination of fuels and industry type (refer Annexure 3, column M and N), we have excluded a part of fuel going in as feedstock in such units. Thus, only fuel use meant for the combustion/heating process is accounted for the energy emissions.
   - Further, we have consolidated such findings through active desktop research and telephonic discussions with sectorial experts. Few of such exclusions are: use of kerosene as a solvent in paint industry, use of LPG in bottling units, use of lubricants in automobile manufacturing, etc. Annexure 3 (column M and column N) maps the excluded input items/products as per the applicable industry type.

e. **Captive power generation:** As mentioned earlier in section 3.1(d), one can't differentiate the quantity of input fuel specifically meant for captive generation within the factory bounds. Thus, all the fuel input (feedstock excluded) going into a particular industry is accounted for as energy emissions with no specific accounting of electricity based generation. However, in order to standardise the results as per IPCC reporting, emissions from captive power plants have to be moved out from the industrial energy use, and must be reported under IPCC code 1A1a. ASI datasets separately reports the total captive power generation from industries in terms of what extent of self-consumption is, and, what is sold to the grid. However, the sale part is not reported in consistent units and the information seems to be meaningless. Hence, the challenge is to account for the sale component, which would have then allowed an accurate estimate of total generation from captive power plants.

***CEEW assumption*:** A part of captive generation (consumption) is reported well by ASI, and hence accounted as it is. The balance portion (captive electricity sold) is estimated by using share of generation versus sold from CEA statistics (refer Annexure 5, Table 5.4 and Table 5.5) (CEA, 2014). To translate electricity generation into emissions, we have used year-wise standard emission factors reported by the CEA, as illustrated in the Annexure 5 (Table 5.1). Alternatively, we could have used CEA statistics directly to account for captive generation at the sector level. It is worth mentioning that CEA statistics do not follow any standard nomenclature of industries (as followed by IPCC and ASI). Hence, there is no precise concordance between CEA and ASI description of industries. This makes it difficult to do a compare absolute generation and sold figures adjustment a specific sector. Comparison is possible at the aggregated level of the industrial sector as a whole.

f. **Tackling reporting errors on purchase rates and unit of measurement**: We have observed that a few of the industrial units (within the manufacturing segment) have reported dubious numbers for the landed price of their input fuels. This makes quantity of fuel input unreasonably high or low, and therefore misrepresents activity data. For example: (a) in 2007-08 statistics, the landed price of LPG ranges between INR 9.49 per Kg to INR 37722 per Kg. Clearly these need to be bounded within a certain acceptable range, based on commercial market prices. (b) Similarly, coal inputs also see a wide (possibly erroneous) range of rates, starting from INR 196/tonne to as high as INR 49,508/tonne. This makes a substantial difference in the input fuel quantity for such industries.

CEEW assumption: Since factories always report the expenditure based on landed price of fuels, adopting a prevailing market rates based adjustment will not be make sense in arriving a representative quantity of reported fuel. We have assumed that either such factory has misjudged the units for the reported rates, or there is a reporting error, resulting into such deviations. Hence, we have adjusted the decimal place for such incorrect entries (considering the reporting unit of measurements for each fuel type), in accordance to the plausible range of the fuel rates. Table 1 depicts corresponding new rate adopted against the misreported entries.

However, it is always useful to estimate the sensitivity associated with such assumptions. We have discussed the sensitivity analysis for this adjustment in the later section of this report.

Table 1: Revision of rates for the erroneous entries (all rates in INR/Unit)

			ASI Reported Data				
	Product	Unit	Example Rate	Min reported rate	Max reported rate	Std Dev of the reported rate	Corresponding New Rate
2007-08	Hard Coke	tonne	12.67	12.67	17023.84	4664.06	12670.00
	Pitch Hard/Medium	tonne	19.48	19.48	53511.45	18510.80	19480.00
	Coal Tar Pitch	tonne	18.82	18.82	22759.41	8092.05	18820.00
	Kerosene	k litres	42.03	24.00	29883.39	11597.96	42030.00
	HSD	k litres	38.62	30.44	20281.86	9044.48	38620.00
	Diesel	k litres	38.35	27.22	30094.67	10818.69	38350.00
	Petrol/MotorSpirit	k litres	48.00	25.00	38855.51	18300.96	48000.00
	Light Petro Oils	tonne	36.51	27.24	27648.79	24329.33	27240.00
	LPG	kg	35264.07	9.49	37722.79	14373.12	35.26
	Propanes & Butane liquified	tonne	37.85	37.85	33730.17	15970.15	37850.00
2006-07	Product	Unit	Example Rate	Min reported rate	Max reported rate	Std Dev of the reported rate	Corresponding New Rate
	Coal	tonne	7.00	5.00	9735323.00	662594.90	7000.00
	Coke Breeze	tonne	5.00	5.00	44307.00	6511.18	5000.00
	Lignite, not agglomera	tonne	3.00	3.00	10125.00	3824.72	3000.00
	Coal tar, pitch	tonne	16.00	6.00	36956.00	9847.32	16000.00
	Pet Coke	tonne	15.00	15.00	72000.00	14537.11	15000.00
	Kerosene	k litres	35.00	20.00	32028.00	13006.44	35000.00
	HSD	k litres	34.00	28.00	33962.00	13473.08	34000.00
	Light Petro Oil	tonne	37.00	23.00	20773.00	6905.00	37000.00

Source: CEEW analysis

g. **Inconsistent or incomplete reporting for certain sectors**: The ASI frame of industries represents manufacturing sector comprehensively. However, it underrepresents the (i) petroleum refining (ii) coal and lignite mining (1A1cii) (iii) oil and gas (O&G) exploration (1A1cii), and (iv) construction sectors (1A2k). We have used alternative source of information for estimating the emissions associated with the mining sector is used to address this data gap. However, no publically available information is evident on construction industry to translate it to emission statistics.

CEEW estimates: GHG emissions from petroleum refining is associated with fuel use for both direct and indirect heating purposes. Indian PNG stats (MoPNG, 2013-14) reports total fuel consumption by refineries, however, the data is not segregated according to the various fuel types (please refer CEEW - Workbook 1_Industry Energy Emissions, Table 8.2). To calculate emissions from different fuel types, the total fuel consumption has been split across different fuels using IOCL's (the largest public sector refinery) trend of fuel mix (refer, CEEW - Workbook 1_Industry Energy Emissions, Table 8.3).

Similarly, GHG emissions from gas exploration due to all fuel combustion activities. Activity data (fuel use) has been obtained from Indian PNG statistics (MoPNG, 2013-14), as it reports internal fuel consumption from all the operational drilling and extraction rigs (refer CEEW - Workbook 1_Industry Energy Emissions, Table 9.2).

GHG emissions from the mining sector are largely associated with the use of 'heavy machinery' for overburden removal, water pumping, and fuel extraction. This largely consumes 'diesel' as a fuel. Hence, the factor for specific fuel consumption associated with per tonne of mining output is taken from the only available source, i.e. 2006-07 annual report of *Central Coalfield Limited* (a subsidiary of Coal India Limited) for all the years. Statistics on activity data (i.e. coal production is available from the 'Coal Directories of India' for the time series (CCL, 2007).

. Construction sector related emissions displays little and insufficient information, and hence should not be considered for any comparison with national inventory.

3.2 Industry Process and Product Use (IPPU) related emissions

Basic equation:

$$Egas = Amat * C.Vmat * E.Fgas * GWPgas$$

Where:

$Egas$: Amount of greenhouse gas in tonnes

$Amat$: Activity data of material (carbonaceous) input or product output (expressed in tonnes/kg/litres/unit etc.)

$C.Vmat$: Conversion factor to convert activity data to tonnes

$E.Fgas$: Emission factor of gas emitted in the process (tonnes of gas per unit material (carbonaceous) input or product output)

$GWPgas$: Global warming potential of the gas

a. IPPU emissions are not associated with every industry sub-sector; they are largely associated with the industries which use carbonaceous material (such as limestone, carbon electrodes, dolomite, etc.) as a process input and where hydrocarbon fuels. 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, as it is not possible to quantity between actual use at the unit level in Tier-1 and Tier-2 of estimation methodology. We have observed a high degree of deviation in the ASI statistics for the 'activity data' on product output by some of the key manufacturing sectors (Aluminium, Cement, Lead, Zinc and Chemicals), as against alternative national sources. This may happen due to multiple reasons:
    - In ASI, factories report for the major input/output materials only (in terms of expenditure). Besides, there are multiple grades and value added chains followed by industry.
    - Misreporting by the factories in terms of quantity or unit of measurement
    - Industries do have balance stocks from the previous year for the input material, which does not get explicitly captured by the output in a particular year.

    Hence, at times, it becomes difficult to judge the level of accuracy, especially with the output products. To avoid this confusion, wherever possible, we have used alternative source of information (refer, **CEEW - Workbook 2_IPPU Emissions**) as an activity data for IPPU related emissions.

    CEEW assumption: Although, we assume that carryover stock in a particular year gets neutralised with the running stock entering into the next year, but often it may make certain differences. Nevertheless, we have adopted alternative source(s) of activity data information (indicated in the IPPU worksheet) for specific sectors, and hence the estimates reflect the best possible level of accuracy.

b. 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.

c. Use of lubricants, solvents, and paraffin wax for machineries and other processes also contributes to the IPPU emissions. Emissions from all such product use (including mining activities) are reported in workbook 2 and workbook 3. However, activity data for mining sector is partially available (refer section 6b, for more details) through the ASI data sets, we have adopted *specific lubricant consumption factor* from alternative sources (refer, CEEW – Workbook 2_IPPU Emissions, tab no-16) for completeness of reporting.

Reliability of data sources and methodology

This section provides an assessment on reliability of the input data sources and the methodological instrument.

Considering the incongruity observed in the industrial output for the IPPU estimates, it is prudent to compare the 'energy input/fuel consumption' records from the ASI datasets with the alternative sources of information (wherever available). A top level comparison between the ASI dataset and the nationally reported statistics (sourced from individual ministries) Annexure 6 (Table 6.1) suggests a relatively low level of digression for the aggregated fuel consumption. Moreover, a comparison of gross value added (GVA) by the factories covered under ASI dataset, with the national level industrial GVA reported by Reserve Bank of India (RBI), shows a difference in the range of **-4%** to **8%** over the time period of the analysis (Figure 2) (RBI, 2015). This suggests that a bulk of the manufacturing units in the formal/ registered sector is accounted for. The difference may be attributed to the fact that the ASI dataset is a combination of census and survey of factory units and the multipliers do no accurately capture the full scale of industrial activity in some sectors or geographies.

Figure 2: Comparison of Gross Value addition brought by industries covered by ASI and RBI statistics

Gross Value add (constant INR billion)			
Year	**RBI**	**ASI**	**Diff**
2007	84	87	-4%
2008	90	91	-1%
2009	96	93	3%
2010	98	92	6%
2011	105	99	6%
2012	111	102	8%

Source: (a) ASI database purchased from MOSPI; (b) (RBI, 2015)

Standard IPCC 2006 guideline is followed for the GHG estimation methodology. Some methodological assumptions were made to process the activity data into a more meaningful form. One such change introduced was correction of erroneous entries for reported rates of the fuels (refer subsection 3.1-f). This correction was introduced to get a reasonable estimate on ‘quantity’ of input fuels, wherever reporting error was detected. A sensitivity analysis was performed against the corrected rates by using minima and maxima values, as reported by the set of industries. The degree of variation (Annexure 7) indicates a maximum difference for 2010, ranging between -6% to +13%. We would like to keep this difference at the reader’s discretion. A quality check at the end of MOSPI for the reported information by industries will certainly help improving such errors in future.

Results (refer attached excel workbook):

Adjoining worksheet templates (1, 2 and 3) illustrates a detailed sector-by-sector result output for GHG emissions across the industry.

- **Workbook 1**: **Industry energy emissions** exhibits emissions associated with fuel consumption at the sub-sector level. Emissions are reported on a standardised format in order to compile inventories from each of the contributing sector at the national level. Since, as mentioned earlier, captive emissions are part of 1A1a (which is out of scope of this exercise), deduction is not available at the fuel specific reporting. Hence, the final emissions (in CO2e) as per IPCC guidelines are presented separately in tab-2.

- **Workbook 2: IPPU emissions** present emissions on standardised common reporting template as well as IPCC classification system.

- **Workbook 3:** This workbook provides a **consolidated comparison** of CEEW estimates across the years and with the national inventories reported for the year 2007 (INCCA) and 2010 (BUR). Since, INCCA doesn’t follow any standard template for reporting, a comparison is possible only by merging the energy and IPPU emissions together for each of the sector.

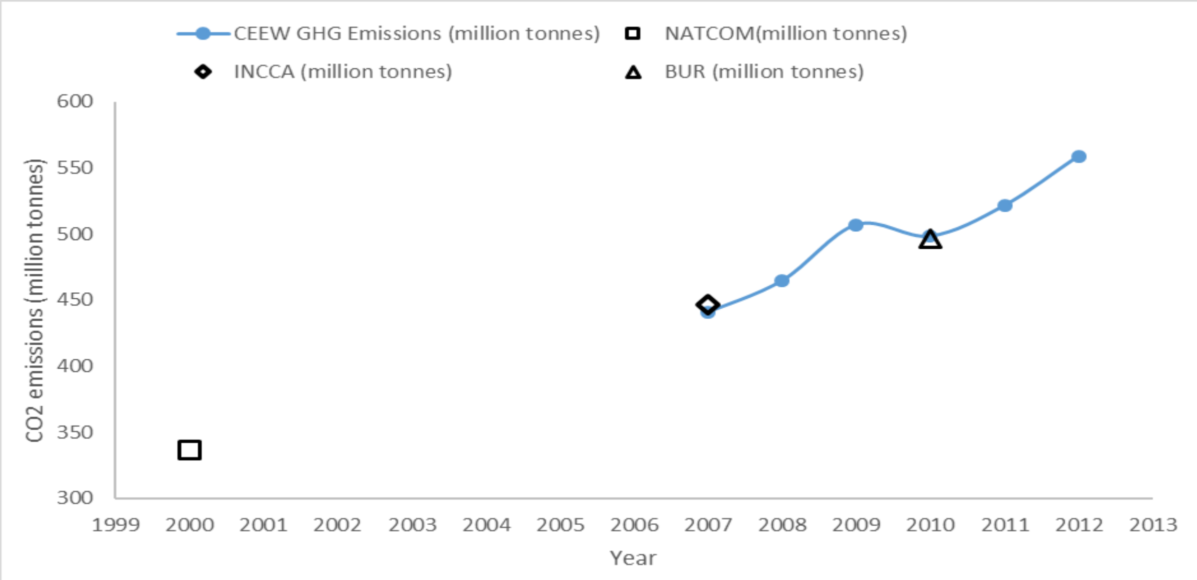
Overall the results demonstrate a CAGR of 4.76% between 2006 and 2012. However, there are big differences at the sub-sector level due to various reasons, discussed later in this report.

Workbook 3 summarizes the final output estimates from this exercise as a time series for the year 2007 to 2012.

5.1 A comparison with National Estimates:

Figure 3 below compares year on year emission trend with the two reference points available from the national reporting, i.e., (a) Indian Network for Climate Change Assessment submission (for the year 2007) (INCCA, 2010), and, (b) first Biennial Update Report to UNFCCC (for the year 2010) (MOEFCC, 2015). It also depicts top level emission number in the year 2000 from as reported by India's second National Communications. To annualise the financial year estimates into a calendar year, we have taken a weighted average of three-fourth of preceding and one-fourth of the succeeding year.

Figure 3: Comparison of estimated GHG emissions with nationally reported values



Source: CEEW analysis

Table 2 presents a detailed sub-sector level comparison between CEEW analysis and the national reporting.[4] Currently we have two reference points i.e. 2007 (INCAA reporting), and 2010 (second BUR to the UNFCCC), for comparing our estimates with the official national reporting. Since, the INCAA document provides a combined reporting for energy and IPPU related emissions, we have also clubbed our results for a sector level comparison. However, standard reporting as per the IPCC guidelines shall be accessed in the attached excel workbook.

Table 2 highlights that at the aggregated level, CEEW estimates are on a lower side compared to the national estimate by a factor of 1% in the 2007 and over-reporting a factor of less than 1% in 2010 reporting respectively. However, a sector-specific review portrays a contrasting picture for few of the sectors. In Comparison to the national estimates, we have lower emissions for certain sectors such as (a) food and beverages[5], (b) refining and manufacturing of solid fuels, and (c) ferro-alloys. Similarly, our estimates exceed the national reporting for

[4] Excluding mining and construction sectors

[5] BUR does not report for food and beverage emissions

(a) textile and leather, (b) non-ferrous metals, (c) pulp, paper and print in either or both reference year.

Table 2: Consolidated comparison between CEEW analysis with national communications (INCAA-2007 and BUR-2010)

Consolidated Comparison		***INCAA 2007 (million tonnes)***	***CEEW 2007 (million tonnes)***	***% difference***	***BUR 2010 (million tonnes)***	***CEEW 2010 (million tonnes)***	***% difference***
Sl no	***Sector Descriptions***	***CO_2e***	***CO_2e***		***CO_2e***	***CO_2e***	
1	Iron & Steel	117	173	**-48%**	96	185	**-92%**
2	Chemicals	33	50	**-51%**	36	58	**-60%**
3	Ferro Alloys	2	2	**35%**	4	3	18%
4	Non-Ferrous Metals	3	3	**-3%**	5	18	-259%
5	Non-metallic minerals	131	141	-7%	145	161	-11%
6	Non-Energy products from fuels	1	4	-392%	2	5	-195%
7	Refining	34	24	**-2%**	42	32	24%
8	Manufacturing of solid fuels		1		18	1	96%
9	Other Energy industries		10		N.R	12	
10	**Mining^, #**	1	0	**#**	4	0	**#**
11	Textile and Leather	2	14	**-660%**	3	10	-296%
12	Food & Beverages	28	4	**84%**	N.R	2	
13	Pulp, paper and Print	5	9	**-63%**	7	8	-22%
14	Transport Equipment	N.R	0		N.R	0	
15	Wood & wood products	N.R	0		N.R	0	
16	**Construction #**	N.R	0	#	N.R	0	**#**
17	Machinery	N.R	4		N.R	1	
18	**Manufacturing n.e.c***	N.R	2		N.R	2	
19	**Non specific industries**	88	N/A		135	N/A	
	Grand Total (Energy + IPPU)	***446***	***441***	***1%***	***497***	***498***	***-0.3%***

Source: CEEW analysis

^:CEEW analysis represents non-fuel mining only (due to ASI data limitation); **#**: ASI dataset is not in its entirety; N.R: Not reported; N/A: Classification do not exist

5.2 Deviation from the national estimates

As mentioned in earlier sections, the deviation between our estimates and the two reference years from national reporting is 5% and -1% respectively for 2007 and 2010. Our estimates are on a lower side for the year 2007 and nearly at par with national estimates for the year 2010. However, at the sub-sector level, the deviations are significant for certain sectors (Workbook 3, tab 4). Some of these deviations can be attributed to the limitations cited earlier and the assumptions made (to overcome these) in this study. However, once there is more transparency on the national accounting process, differences arising from assumptions can be resolved easily. Following provides a detailed explanation of observed deviation across the sectors:

(a) Sectors/areas having no information

- **Exploration activities (fossil fuels**): ASI reporting is limited in terms of reporting for exploration activities for coal, lignite, petroleum and natural gas. Neither, there is any national level understanding available for the fuel consumption records from these sectors. National reporting (INCAA and BUR) also does not specifically mentions the emissions from these activities. Unlike IPCC prescribed format, INCAA has clubbed these activities along with 'refineries' and 'solid fuel manufacturing'; whereas, BUR has simply not provided any evidence on emissions at all from this set of activities.

- **Construction activities**: Again, the ASI dataset is not available in its entirety for this sector, and neither any other publically available data source. Considering that construction activity is highly segregated and is governed under all tiers of administration (central, state, city, district, *gram panchayat*s, individual level) into multiple activities, it is indeed a challenging task to estimate fuel consumption from the wide range of construction activities across the India. Similar to exploration activities, there is no national reporting on emissions from this category as well.

(b) Sectors having inconsistent/insufficient activity data

- **Non-ferrous metals**: our analysis presents an abrupt jump in this category of emissions (largely represented by aluminium industry) in the provided time frame. This unusual jump is a result of to be due to inconsistent *fuel use* (majorly coal) reporting from the ASI. There is considerable scope of improvement in emission reporting for this sector (in the earlier years of the analysis).

- **Ferro alloys**: Since many of the industry facilities produce ferro-alloys through integrated unit operations, it is difficult to keep a measure of exact production statistics of ferro-alloys. Hence a consistent (approx. 60%) is evident from comparison for both the years.

- **Mining:** This largely represents non-fuel mining, ASI dataset is not available in its entirety for this sector. Further, there are no specific energy consumption metrics available for this sector to translate national level production into equivalent energy use.

(c) Lack of clarity from national estimates

- **Textile and leather/ Paper and pulp**: The difference between our estimates and national reporting is considerable for this sector. The prime reason could be that almost 20% to 30% of the overall industrial emissions (energy use and IPPU) by INCCA and BUR respectively are reported as classified under the category "non-specified industry". We are not clear as to whether this large basket of emissions has components that pertain to emissions from this sector. Since there is no clarity on activity data from any alternative public source, a close engagement with respective ministry is required for further improvements.

- **Food and Beverage**: Unlike the above two sectors, our estimates under reports emissions from this sector, as compared to the national reporting. However, there has been inconsistency in the national reporting (as BUR doesn't reports for this sector) as well. We seek more clarity on this sector for validating our results.

- There is no reporting for emissions from manufacturing of: **transport equipment, Wood and wood products, machinery, and manufacturing not elsewhere classified (n.e.c)**. Besides, the activity data obtained from the ASI for many of these sectors is not consistent across the years. A refined activity data from alternate sources can address these gaps efficiently.

(d) Assumption driven variations

- **Chemicals:** This sector represents a wide range of product manufacturing at the national level (including fertilisers and petrochemicals). The deviation from the national estimates in relatively larger in 2010, as compared to 2007. Nitric acid manufacturing is the single largest contributor to the overall deviation in results. There has been a lack of clarity for its manufacturing from the available data sources. Suitable information on the activity data can fetch more legitimate results. Further, just like 'petroleum refining' discussed above, a group of petroleum products (lubricants, kerosene, etc.) is considered as feedstock in manufacturing of organic chemicals/petrochemicals (refer Annexure 3). For example: manufacturing of paints, dyes, soaps, detergents, plastics, etc. Hence, those do not contribute to the emissions. We seek clarity on the precise proportion of fuel versus feedstock to further fine tune such adjustments. A close interaction with major industries can help in improving the emission reporting over here.

- **Iron and Steel and manufacturing of solid fuels**: In India, lots of industries have an integrated manufacturing set up, and hence individual product output doesn't gets reported precisely for such sectors. To avoid any such overlaps, our estimates consider iron and steel and coke manufacturing together (including standalone manufacturing units). Hence there is a difference in individual level comparison. Further, national reporting seems doubtful for specifically this sector, as emissions in 2010 (BUR) are significantly lesser than 2007 (INCCA), despite we know that iron and steel production, as well as fuel consumption is consistently rising between these two years.

(e) CEEW estimates do not account for emissions from fuels that are classified under the head 'other fuels'. As explained earlier, these are not of fossil origin and hence assumed to be carbon-neutral, with no other GHG emissions associated with their combustion.

5.3 Concluding remarks:

The adopted methodology recognises several 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.

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