Greenhouse Gases Emission Estimates from the Manufacturing Industries in India
National level estimates: 2005 to 2013
(Energy use, Industrial Processes and Product Use)

Authors
Vaibhav Gupta, Tirtha Biswas, Karthik Ganesan

Organisation
Council on Energy, Environment and Water (CEEW)

Usage Policy	Any re-production or re-distribution of the material(s) and information displayed and published on this Website/GHG Platform India/Portal shall be accompanied by appropriate citation and due acknowledgment to the CEEW and the GHG Platform India for such material(s) and information. You must give appropriate credit, provide a link, and indicate if changes were made. You may do so in any reasonable manner, but not in any way that suggests the GHG Plaform-India endorses you or your use. Data sheets may be revised or updated from time to time. The latest version of each data sheet will be posted on the website. To keep abreast of these changes, please email us at info@ghgplatform-india.org so that we may inform you when data sheets have been updated.
Citation	Gupta, V., Biswas, T., & Ganesan, K. (2017). Industrial Emissions (Ver 2.0) September 28, 2017, Retrieved from GHG Platform- India: http://ghgplatform-india.org/data-and-emissions/industry.html ; In instances where this sheet is used along with any other sector sheet on this website, the suggested citation is “GHG platform India 2005-2013 National Estimates - 2017 Series”
Disclaimer	The data used for arriving at the results of this study is from published, secondary sources, or wholly or in part from official sources that have been duly acknowledged. The veracity of the data has been corroborated to the maximum extent possible. However, the GHG Platform India shall not be held liable and responsible to establish the veracity of or corroborate such content or data and shall not be responsible or liable for any consequences that arise from and / or any harm or loss caused by way of placing reliance on the material(s) and information displayed and published on the website or by further use and analysis of the results of this study.

Credits and Acknowledgements

At the outset, Council on Energy Environment and Water (CEEW) would like to thank the GHG Platform India for recognizing the need for such studies – especially for an informed debate on the climate change matters. The study would not have been possible without the generous grant support from the Shakti Sustainable Energy Foundation.

We would like to acknowledge the constant feedback and critical inputs received from the partner institutes at the GHG Platform India, during all the review meetings hosted by the Secretariat, Vasudha Foundation.

We profoundly thank, Ministry of Statistics and Programme Implementation (MOSPI) for promptly responding to our feedback and queries on their Annual Survey of India (ASI) statistics, which is a cornerstone to our estimation methodology.

CEEW would like to recognise the cooperation of several individuals, organisations, and government departments in providing useful insights and information, which helped us in arriving at meaningful estimates. We deeply appreciate the time they have spent to share their knowledge, experience, and perspectives with the research team.

Last, but not the least, we express our appreciation to the WRI India for a comprehensive review of this study at par with standard IPCC guidelines.

Abbreviations

AFOLU	Agriculture, Forestry and Other Land Use
ASI	Annual Survey of Industries
ASICC	Activity & Commodity Classification Code
BUR	Biennial Update Report
CEA	Central Electricity Authority
CIL	Coal India Limited
CMA	Cement Manufacturers' Association
FAO	Food and Agriculture Organization of the United Nations
GHG	Greenhouse Gas
IBM	Indian Bureau of Mines
INCCA	Indian Network on Climate Change Assessment
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use
MCX	Metals Commodities Exchange
MoC	Ministry of Coal
MoPNG	Ministry of Petroleum and Natural Gas
MoRTH	Ministry of Road, Transport and Highways
MOSPI	Ministry of Statistics and Program Implementation
MSME	Micro, Small and Medium Enterprises
NIC	National Industrial Classification
NPCMS	National Product Classification for Manufacturing Sector
RBI	Reserve Bank of India
SCCL	The Singareni Collieries Company Limited
UNFCCC	United Nations Framework Convention on Climate Change

Contents

List of Figures:

List of Tables:

Version	Date	Description
2.0	**28th September 2017**	*This draft methodology note includes an estimation and analysis of India's annual national-level GHG emissions for the period 2005-2013 for Manufacturing Industries, prepared by Council on Energy, Environment and Water (CEEW) under the GHG Platform India initiative (www.ghgplatform-india.org).* *This document is undergoing a peer review process, however, any changes that may be made further will not have a significant impact on the figures and estimates. Once the review process is completed, the final document will be uploaded and the same shall be updated in this section.*

Document Information

Executive Summary

This study provides an in-depth assessment of GHG emissions from the manufacturing sector (including construction) in India. Manufacturing here refers to the firms coming from the formal sector only, i.e. registered under sections 2m(i) and 2m(ii) of the Factories Act, 1948. Often, the term 'industry' is used interchangeably with 'manufacturing.' However, as per India's national accounting procedure, manufacturing is a subset of industry, which otherwise also covers 'mining' and 'electricity, gas and water supply activities.' This reporting follows the standard guidelines issues by the Intergovernmental Panel on Climate Change (IPCC) in 2006.

The Council on Energy, Environment and Water (CEEW) has followed a bottom-up approach, making full use of secondary datasets predominantly obtained from the Ministry of Statistics and Programme Implementation (MOSPI). MOSPI provides a detailed information on the industrial energy consumption through Annual Survey of Industries (ASI). ASI reportedly covers only the formal manufacturing activity in India, as per the definitions of the Factory Act, 1948. We have resorted to alternative source of information and appropriate data assumptions, wherever felt needed. Methodology for estimation is common across all years of estimation. 2005 is investigated as a base year for the GHG estimates, whereas 2013 is the latest reporting year.

Brief information of GHG estimates

Over the past few years, Greenhouse gas emissions (GHG) from the manufacturing activities in India have increased at a rapid rate of 8% (CAGR); i.e., rising from ~315 Million Tonnes (MMT) of carbon dioxide equivalent (CO_2e) in 2005, to ~623 MMT in 2013. This includes combined emissions from the energy-use, as well as industrial process and product-use (IPPU). It excludes any emissions arising from captive power generation units that are located within manufacturing facilities, as they are reported under a separate category prescribed in the IPCC guidelines (2006)[1].

Major Inventory developments and Calculations

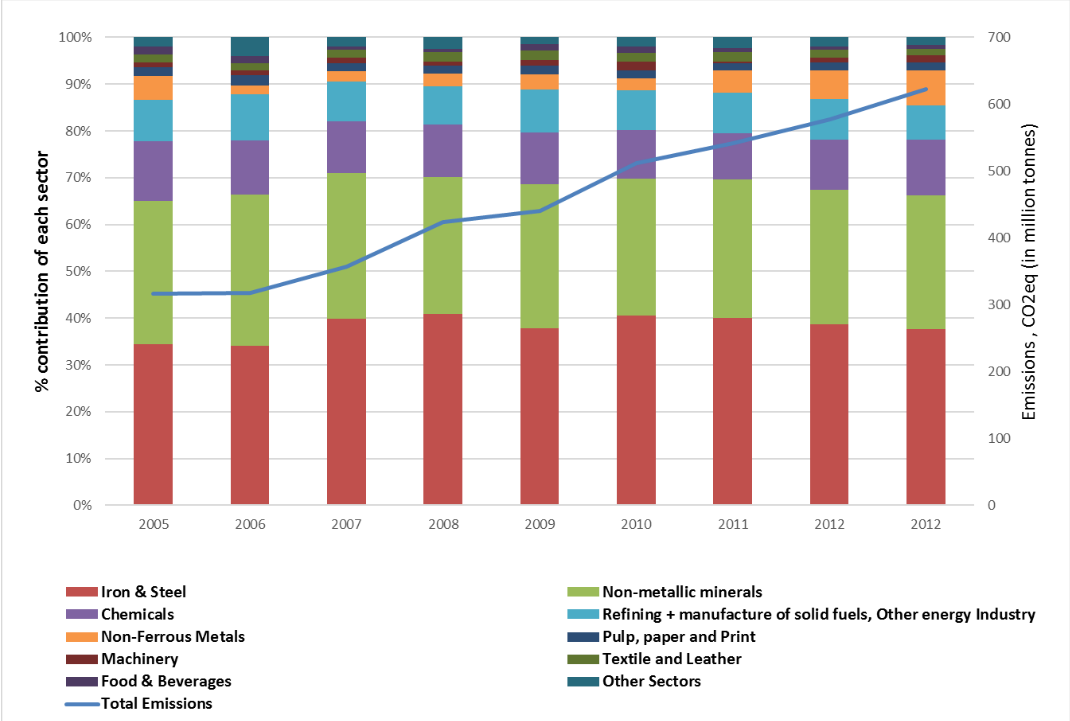
This report is a revised and updated version of CEEW's previous estimates (version 2.0) made available at the GHG Platform India. In this version, underlying methodology, data sources, emission factors, as well as choice of tiers remains same as of previous. However, as an update, choice of proxies and assumptions are now more advanced and considers state specific substance (refer methodology section of 'energy-use emissions'). Similarly, as another major development, exclusion of captive power related emissions is ensured from the ASI database itself, unlike previous way of discounting by use of Central Electricity Authority (CEA) estimates. This makes final emission numbers slightly different for the previously accounted years.

1 Unless otherwise mentioned, IPCC guidelines throughout this report will refer to the 2006 version

Summary of GHG trends

Figure 1 portrays the share of emissions of the various sub-sectors and the overall growth of emissions over the period 2005 to 2013. Besides a slight dip observed for 2009, the growth trend is almost linear and is comparable to the growth of manufacturing in India, per se.

Figure 1: Year on year growth of CO_2e emissions and dominant sectors

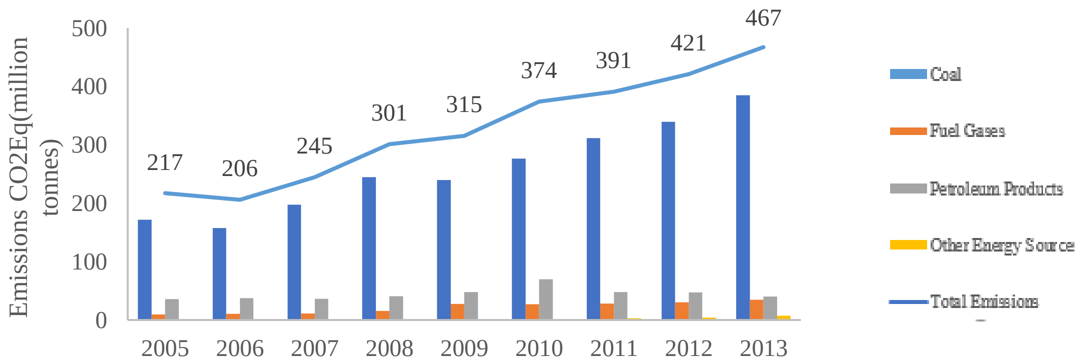


Source: CEEW analysis

Highlights on major emitting source categories:

Manufacturing (and processing) of *iron and steel* and *non-metallic minerals* (primarily cement) have remained the major contributors to GHG emissions. Together they represent 38% and 29% respectively for 2013, as illustrated by Figure 1. Speaking of energy use, which primarily dictates the manufacturing sector emissions, coal (use) continues to be the dominant source of energy across the sectors. Hence, its share in the energy derived emissions grew from 171 MMT of CO_2e in 2005 to 385 MMT CO_2e in 2013; i.e. nearly 80% of the total energy use emissions (Figure 2).

Figure 2: Energy use emission estimates from the manufacturing activities



Source: CEEW analysis

Introduction

The objective of this study is to contribute towards establishment of India's first joint civil society initiative – GHG platform India – to measure and track Greenhouse Gas estimates across economic sectors of India. This platform aims to complement the national reporting process, and to drive an informed policy dialogue within the country on the GHG emissions estimates. The larger goal of this platform is to explore the scope of emission mitigation opportunities at a granular level of manufacturing segment.

This study covers three key greenhouse gases, namely - carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). These three gases account for a large share of anthropogenic emissions from India. 2006 IPCC Guidelines for National GHG Inventories cover many more gases (or group of gases) having relatively very high global-warming potential (GWP), such as: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6), etc. (collectively known as F-gases). This study doesn't cover these F-gases, as their total contribution is known to be very small (or unmeasured) in India for the period under investigation.

GHG emissions from industrial activity is in large part from the combustion of fuels. Non-energy use of fuels (as feedstock or raw material) can also result in GHG emissions from specific industrial processes. Here, chemical or physical transformation of materials, result in the emission of GHGs. Such emission sources are commonly referred to as 'Industrial Process and Product Use (IPPU)'. The overall scope of this study covers - *manufacturing industries and construction* (1A2)[2]; 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)[3]. We are not covering 2B9, 2B10, 2D3, 2E, 2F, 2G, and 2H categories[4] of the IPPU emissions, as little or no information is publicly available for these industrial activities, many of these activities don't even existed in India until 2010-11.

The period for which emissions estimates are made ranges from 2005 to 2013 and represent emissions in each calendar year. Wherever datasets were available in financial year format only, appropriate conversions and manipulations were carried out to represent the data in a calendar year format. 2005 is the earliest year for which this study estimates GHG emissions, as India has chosen this as base year for measuring the impact of climate change mitigation actions, as have many other developing countries.

2 The representation within parentheses refers to the IPCC classification of these sectors and emissions categories

3 2A: Mineral Industry, 2B:Chemical Industry, 2C: Metal Industry, 2D: Non-Energy Products from Fuels and Solvent Use; No information is available on industry specific solvent use (2D3), hence not accounted

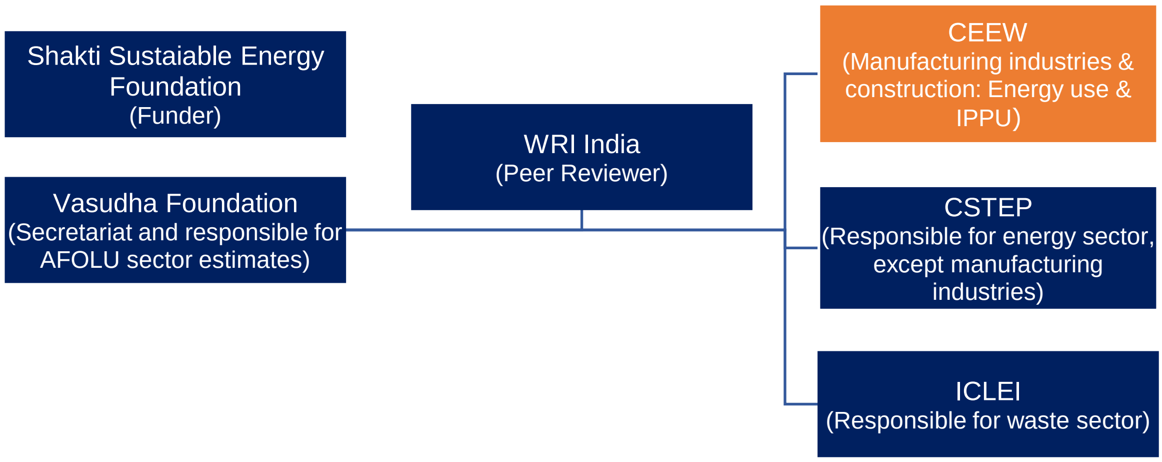
4 2E: Electronics Industry, 2F: Product Uses as Substitutes for Ozone Depleting Substances, 2G: Other Product Manufacture and Use, 2H: others.

Institutional Arrangement and Capacity

GHG Platform India, an Indian civil society initiative, aims to establish a system that will enable an independent and periodic estimation of India's greenhouse gas estimates and providing a time series for consumption of the broader public. It also, aims to facilitate sub-national process for GHG inventory by providing a suitable analytical framework. The framework will serve multiple purposes including improved comparability, strengthening transparency, building capacities by disseminating the results. It will also, provide key inputs towards advancing domestic mitigation objectives, standards, regulations, and policies.

CEEW is the lead partner of this platform for development of emission estimates from 'manufacturing industries and construction activities: energy use and IPPU.' For smooth and timely development of the GHG estimates, a secretariat is appointed to coordinate with all lead partners, whereas external peer review ensures quality assurance and independent nature of estimates from the GHG Platform India. Figure 3 illustrates the overall institutional arrangement at the platform; Annexure 1 provides a clear demarcation of activity and sources covered by each institution:

Figure 3: Institutional Arrangement at the GHG Platform India



Source: GHG Platform India

GHG Estimation Preparation, Data Collection, Process and Storage

Karthik Ganesan, Research Fellow at CEEW, supervised the inventory building process for the manufacturing industry and construction activities. Vaibhav Gupta, Senior Programme lead at CEEW, and Tirtha Biswas (Programme Associate) were responsible for the data processing, core analytics and its quality-control. Sumit Prasad and Shruti Nagbhushan supported them in various capacities, which includes a review of other sources of inventories available in country, testing and formatting the outcomes. The entire process of GHG estimation was conducted in-house, based on desktop research and secondary data obtained from authentic public sources.

A decision on the time-period (2005 to 2013) for the estimates was made in consensus of other partners at the platform. The scope or boundary for industrial emissions is limited to the formal (or registered) units only, as the information on the informal/unregistered firms is not available in a consistent manner for the various years covered in this analysis. Wherever required, sectoral experts and relevant ministries/departments were extensively consulted to ensure certainty of methodology and data sets used for estimations.

The Annual Survey of Industries (ASI) datasets, obtained from the Ministry of Statistics and Programme Implementation (MOSPI), are the primary source of information for the GHG estimations. The survey covers the entire formal manufacturing sector in India, through a census cum survey approach. It is by-far the most exhaustive and periodic data set available for Indian manufacturing on a yearly basis. The prime objective of ASI data set is to provide insights into the economic aspects of the manufacturing sector by capturing attributes of factories/ units like value addition, employment, capital investments, etc. However, it also captures information on energy use by industries, though not in a manner that is entirely suitable for the purposes of this study. To ensure better quality control, we developed mathematical algorithms and analytical checks to process information available from the ASI. We cross validated our assumptions and proxies with the data source ministry (MOSPI) as a measure of quality check. We have discussed the quality control protocols and the limitations arising from the dataset, in the later sections of this report.

Wherever ASI derived information was found inadequate (mostly while estimating emissions from industrial process and product use), alternative sources of information were used to ensure comprehensiveness in the estimations and reporting. Information on mining, construction sectors, and ferro-alloy production (IPPU related) was found to be sparse; and thus, estimates based on the best available data were made for these sectors. It is very likely that the GHG emissions from these sectors have been underestimated. Further improvements need to be made for these sectors.

A transparent inventory process requires effective data management process to enable users to reproduce emission estimates from the scratch. This ask for a systematic data archiving process. Here in this case, ASI datasets forms the backbone of the entire estimation procedure as an underlying activity data. MOSPI follows a sound practice of recordkeeping and archiving, which makes data available for as early as 1980s at any point of time, upon request to the ministry. Since it is a unit level information and needs considerable effort on transforming it to usable form, CEEW provides basic assumptions made for this study to enable such remodelling at users' end. The other minor sources of information are mainly (a) Indian Bureau of Mines, (b) Cement Manufacturing Association, (c) Ministry of Coal, etc. which does provide archived information in common templates on their website for the period from beginning of available information.

General description of methodology and data sources

GHG estimates from the manufacturing activities arises from the energy use within manufacturing activities, and from certain industrial processes and product use. GHG emissions are arrived at by combining activity data with a related emissions factor. The emissions factor in turn is driven by attributes such as calorific value, carbon content associated with fuels, extent of combustion, etc. Activity data could be the amount of fuels combusted in a process, or the amount of carbonaceous material entering a system. These could be directly specified or computed based on overall production or input materials consumed.

In our study, the energy use emission estimates are based on activity data at the unit level and hence derived from a bottom-up approach. For IPPU, we have adopted a mix of bottom up and top down approach, depending upon the granularity of available information. Since ASI is a mix of survey and census, activity data itself can be categorised into two tiers Tier-2 and Tier-3, along the lines of the tiers defined in the emissions inventory estimation process by IPCC guidelines.

ASI also captures the extent of imported and domestic fuels that are consumed in the process. This enabled us to make use of country specific emission factors where possible.

Brief description of key source categories

Official government estimates of GHG emissions suggest that manufacturing represents almost a fourth of India's total GHG emissions. A breakdown of total emissions into energy and IPPU reveals that *energy-use* is a dominant cause of manufacturing emissions - it represents 65% to 70% of the overall emissions. Within energy, manufacturing of iron and steel, and non-metallic minerals are the dominant sub-sectors. IPPU emissions mostly arise from non-metallic minerals followed by the chemical industry. Collectively, iron and steel (including coke manufacturing), non-metallic minerals (primarily cement industry), and refining process represents more than 80% of the manufacturing emissions.

As mentioned earlier, by definition (of the coverage of the datasets used) our estimates represent the formal/ registered manufacturing sector in its entirety. Mining, construction, and ferro-alloys manufacturing sector(s) are underestimated on the account of insufficient data.

Uncertainty Evaluation

ASI represents a tier-3 level data, where probability of direct uncertainty is very low (as per IPCC guidelines). Therefore, we are evaluating any possible uncertainty by means of sensitivity analysis of our assumptions on data interpretation and data improvements.

Information on activity data is mainly sourced from MOSPI, which is a well-established and credible government source of information. The data is predominantly secondary in nature, and is based on self-reporting by manufacturing firms; hence, it also leaves a considerable scope of uncertainties. Some inaccuracies and data inconsistency were observed across the sectors and/or specific states for all the years, such as: (a) reported units were not in sync with reported fuel rates, (b) decimal oversight by field supervisors, etc. This also raises some questions on the ASI data security mechanisms, and clearly establishes that the survey instrument is not entirely suited to the needs of an energy/ emissions accounting process. Moreover, alternative sources of information were highly aggregated with lesser idea at the sub-sector levels. Hence, ASI remained as the best choice available for the manufacturing sector emissions estimates, and efforts shall be made by the MOPSI towards improving their data collection process.

To tackle this misreporting by firms/ factories, we have made rules based adjustments in reported consumption of fuel quantities. This is done by:

a) reconciling reported expenditure, quantity and rates; for example: in some instances, fuel rates are not reported due to data entry errors. These blank entries can create a skewness while estimating the median rates, which is used for the adjustments. We are estimating these rates by dividing the reported expenditure with corresponding quantities

b) adjusting any conflict between reported unit of measurements and related fuel rates; for example: a factory reporting the rate of diesel as INR 54, while reporting the unit of measurement as kilo litres. Here, we are readjusting the reported rates as according to representative unit of measurement.; and,

c) fine-tuning reported rates of input (& output) activity data, if they were found out of the order, based on reporting from other years and/or other firms within each state; The final 'fuel-rates' has an important role in determining the overall energy intake of the system, which is why, reported fuel rates (price at which fuels are purchased) could fall within a permissible bound, and the rest of erroneous entries were adjusted at a median value. We have allowed a 50% deviation from the median values as a permissible bound. This adjustment duly captures all the variable costs, such as transportation cost incurred in bringing a fuel at the factory gate, which is over and above of actual cost of fuel. It may vary for each state, depending upon their proximity of closest supply centres. Hence, we have allowed this adjustment at a state specific level also. For example: A firm located in Haryana might be paying higher coal price compared to its counterpart located in West Bengal, due to proximity of mines, and hence lower cost of transportation.

Additionally, we are performing consistency checks for fuel rates reported for the different industrial sector like iron & steel across various states and the time period. Coal rates vary with grade; we have observed significant variation of rates between plants having captive generation units and iron & steel industries. Hence, to further normalise the rates for these plants we using similar adjustments with the median rates pertaining to these plants.

Considering a likelihood of adjusted entries to fall anywhere within the defined bound, and not just at the median, we performed an uncertainty analysis to investigate the margin of deviation. However, this test was run after eliminating any incoherence between magnitude of rates and/or associated Unit of measurement. As observed – for the 25^{th} and 75^{th} interquartile range of probable rate values (in place of the adjusted median rate), the overall 'all-fuel' based emissions could see a deviation within a range of 5% to 20%, after excluding the outliers. At 'fuel-specific' level, this could be even lower.

General Assessment of Completeness

ASI represents the entirety of the formal/ registered manufacturing sector of India through census and survey based approach. Despite its exhaustive nature, inadequate reporting by manufacturing firms is not seldom. In this study, we have adopted various corrective measures against poorly reported information. Further, a top line comparison of energy use with national records characterises the extent of coverage by our estimates. Regardless of various measures taken, mining and construction sectors are still under-represented (and hence underestimated), similarly information on ferro alloys production is highly sporadic for IPPU estimates. A systemic change in the ASI system can only bring further improvements in the quality and comprehensiveness of industrial statistics.

This section highlights some of the challenges witnessed in making use of the ASI datasets. It further reflects the level of completeness for the emission estimates from the manufacturing sector. Some of the limitations associated with our GHG estimates are as follows:

a) Mining sector (1A2i): ASI does not explicitly covers mining activities. Further, limited information is available on mining sector's energy consumption. Though we have obtained some insights by filing RTIs at the Indian Bureau of Mines, translating such information into usable numbers would require more time and resources and not covered in this update of the emissions.

b) Construction sector (1A2k): ASI does not explicitly covers construction sector activities. The Ministry of Road, Transport and Highways (MORTH) provides activity data for this sector. However, it is challenging to directly obtain emission estimates from the current format of their reporting, especially when much of it potentially falls under unregistered economic activities. By next revision, we will be making an extensive outreach to get more clarity on this sector.

c) Ferro-alloys production (2C2): ASI reporting is not uniform across the years ferro-alloys production. This information is required for measuring IPPU emissions. Hence, we are no providing any IPPU estimates from this category.

d) Reporting on *other fuels:* ASI reports for expenses incurred on 'other fuels' by factories. Ideally this should also be a part of energy intake by industries, and hence partly or fully contribute to emissions. However, as mentioned by ASI, much of it relates to biomass feedstock, material transportation, as well as the procurement of water. Segregating the expenses into each of these is not possible. In any case, we assume biomass to be commercially harvested and completely combusted, thus remaining net carbon neutral.

e) Manufacturing of Solid Fuels (1A1ci): A significant portion of this manufacturing activity is included within the 'Iron and Steel sector emissions.' This is due of presence of several captive coking units and integrated steel manufacturing plants, where share of coal going towards coking process is difficult to obtain, unless we maintain a Tier-3 of reporting. Hence, emission accounting is not incomplete, but gets reported along with 'Iron and Steel sector'

f) Captive electricity based emissions: ASI provides reporting on 'electricity generation' by fully owned captive plants, as well as group captives. Part of this information does not explicitly disclose the nature of firm, or the sector it belongs to. It also does not disclose the source (& quantity) of fuel going towards captive generation exclusively. Hence, we adopted suitable assumptions to derive amount of fuel (specifically coal and diesel, and to some extent, natural gas) at the sector level. In most cases, captive adjusted energy/emission numbers are making good sense, while in a few cases, final number appears to be negative. This is due to apparent consumption of more energy than the supplies, and can be seen as an impact of certain assumptions. Hence, captive adjusted numbers should be read at a broader level (national or state), as it might not make sense at a factory or specific sector level.

We are not covering 2B9, 2B10, 2D3, 2E, 2F, 2G, and 2H categories[5] of the IPPU emissions, as little or no information is publicly available for these industrial activities, many of these activities don't even existed in India until 2010-11.

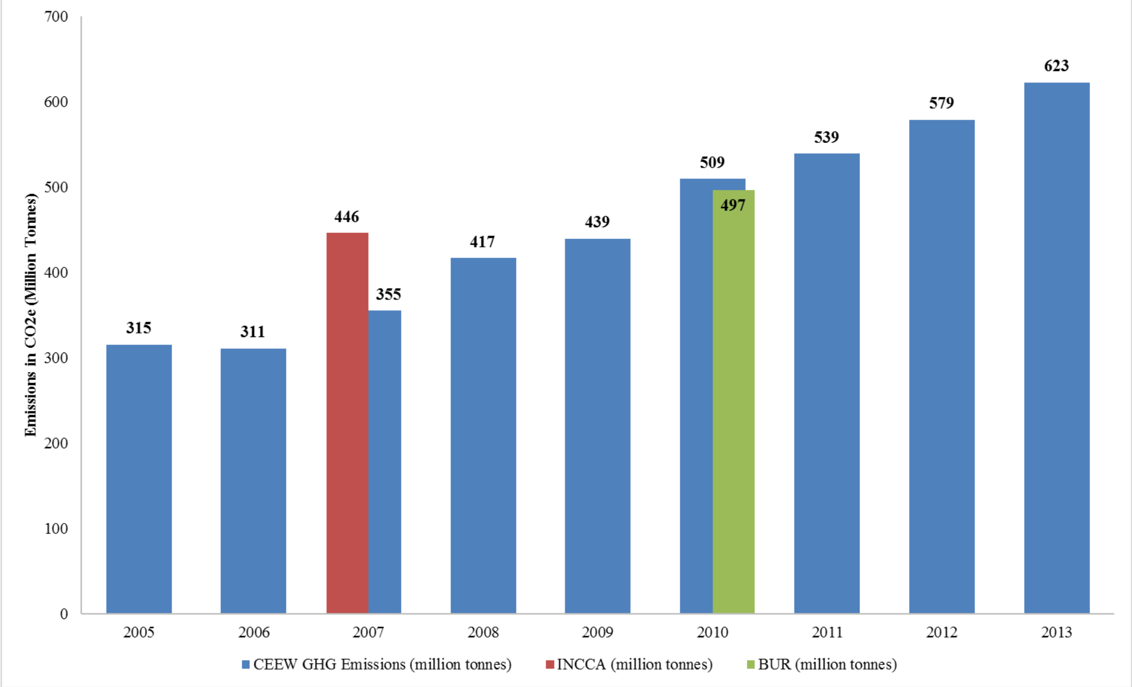
As a test of completeness, we compared ASI derived energy consumption with the energy statistics (for industries) officially published by the MOSPI. Divergence between the two estimates falls close to 20% for most years. Here ASI is on a lower side, as it represents only the formal sector output, whereas offtake side reporting considers every possible source of consumption, and hence obviously covers unorganised sector as well. For all that, it is still early to arrive at a conclusion for any difference between ours' and the government estimates. MOSPI numbers are also under question in many ways, as it doesn't show consistency in its reporting for certain fuels. Asymmetry between MOSPI and NITI Aayog's energy balance estimates questions the credibility of government's estimates itself.

[5] 2E: Electronics Industry, 2F: Product Uses as Substitutes for Ozone Depleting Substances, 2G: Other Product Manufacture and Use, 2H: others.

Trends in Emissions

This study estimates GHG emissions (in CO_2e) for of the period 2005 to 2013. Standard IPCC guidelines (2006) have been followed for estimating energy and IPPU estimates. Figure 4 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).

Figure 4: Comparison of estimated GHG emissions with nationally reported values

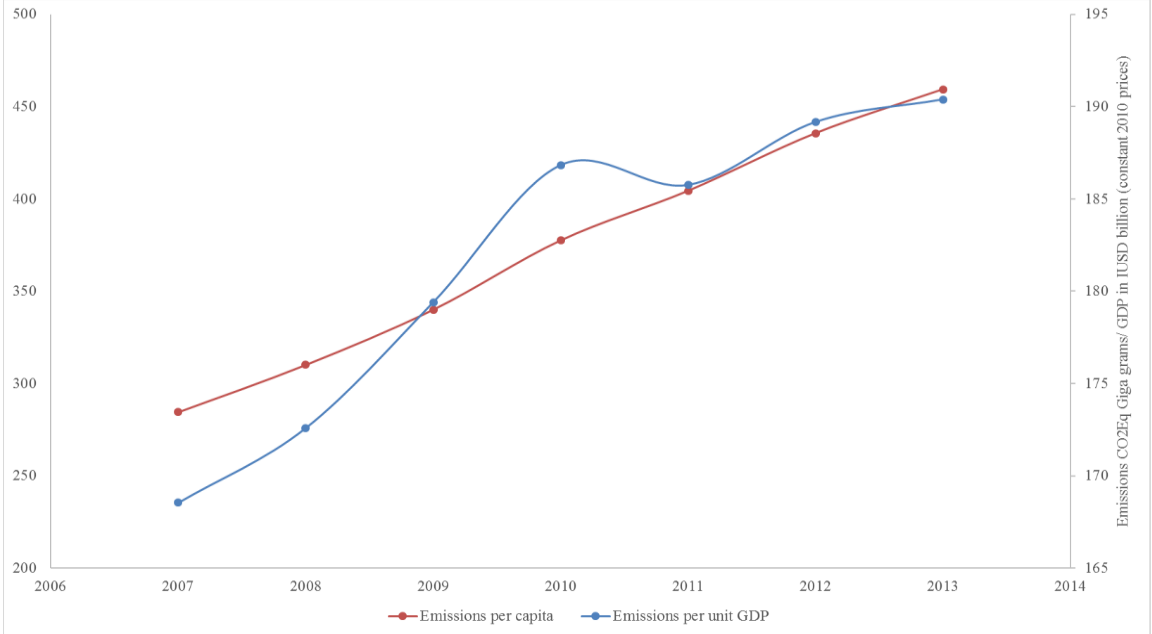


Source: CEEW analysis

Iron & steel and non-metallic minerals industries stand out to be major contributors, with a collective share of ~70% in the overall industrial emissions. Deviation between our estimates and government reporting is low (less than 3%) for 2010, but surprisingly high (20%) for 2007. Our estimates suggest that India's overall industrial GHG emissions increased at an annual rate (CAGR) of ~ 9% between 2005 and 2013, whereas government figures reflect a meagre growth at 4%.

The trend in manufacturing industry emissions per capita and per unit manufacturing GDP is shown in Figure 5 below. In order to come up with emissions trends (in the figure below), we have used a three-year moving average to minimise the variances observed in the GDP. During the estimation period, per capita manufacturing sector emissions shows a rising trend with a CAGR of 8.3%. Similarly, emissions intensity trend is on a consistent rise, except for 2010-11, with a sudden dip. Global economic slowdown could be one among many reasons behind this behaviour. Hence, an overall rising trend depicts increasing industrial activity and subsequent rise in energy demand.

Figure 5: Trend in overall manufacturing industry emissions

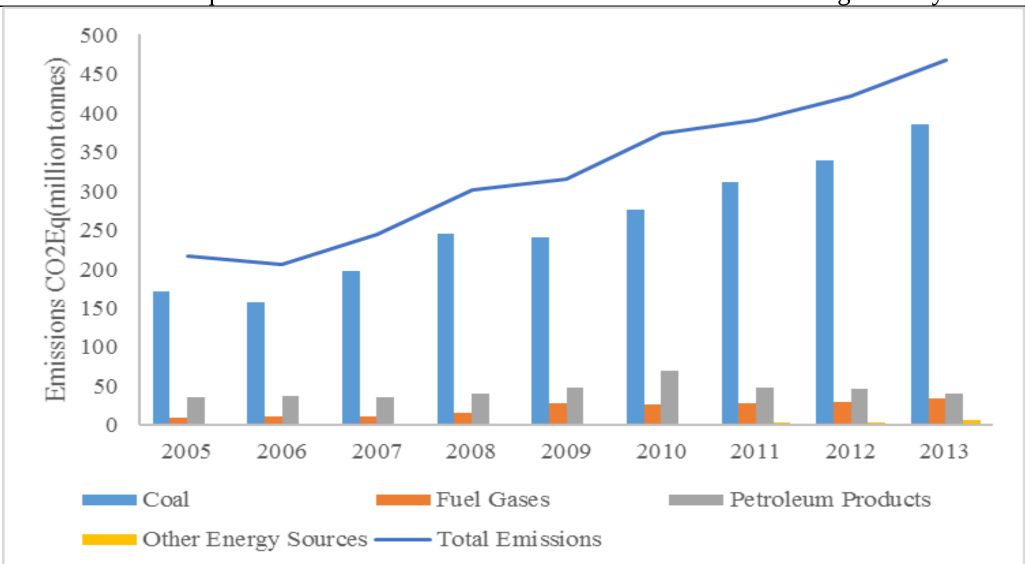


Source: CEEW analysis, (World Bank, 2017), (RBI, 2015)

Energy sector emissions: Industrial emissions from energy-use

Final GHG emissions from the manufacturing industry is a sum of energy based (IPCC sectors 1A1b, 1A2a to 1A2m) and IPPU based emissions (IPCC sectors 2A to 2D). Over the years, emissions from fuel use increasingly contributed to the overall manufacturing industries emissions. It's share to overall emissions ranges between 65% and 75% during the period. We have analysed more than 80 different types of fuel inputs reported by industrial units. It was observed that the emissions from coal contribute close to 70% of the overall emissions from fuel consumption (Figure 6). 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 manufacturing industry has remained relatively constant during the period.

Figure 6: Overall CO2eq emissions due to various fuel use within the manufacturing industry

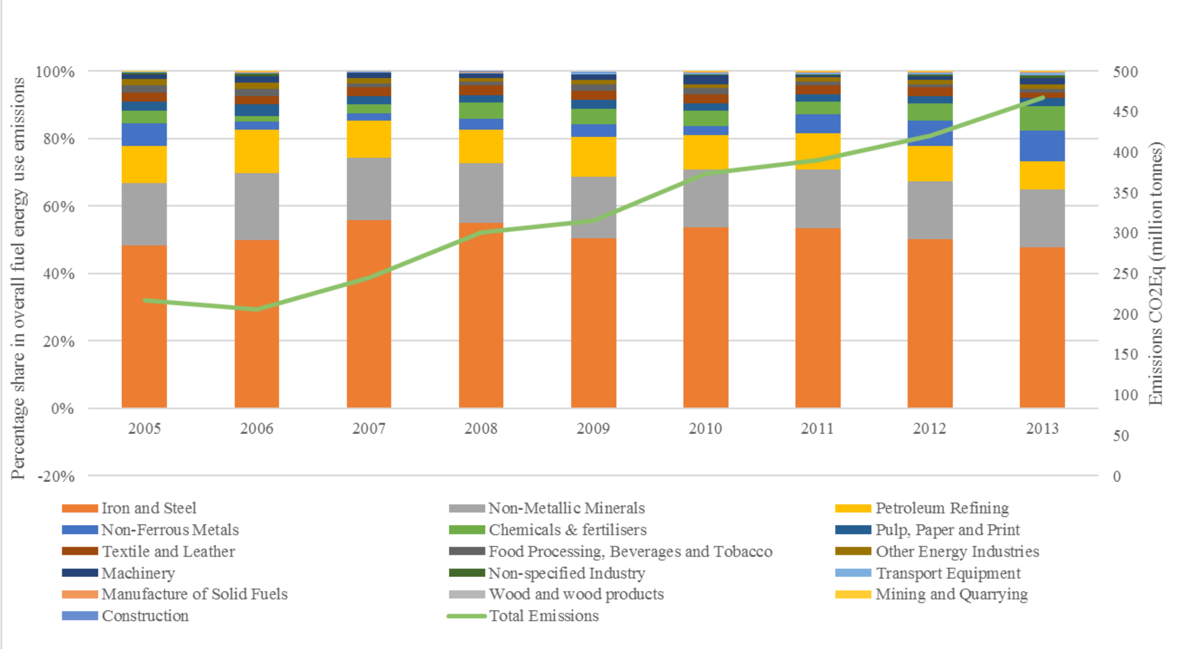


Source: CEEW analysis

Between 2005 and 2013, emissions from fuel use in manufacturing industry grew at an annual rate of 10%. Figure 7 below shows the trend of emissions from fuel use by various industrial sectors. approximately 70% of total fuel use emissions can be attributed to iron & steel and non-metallic minerals sectors only.

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; for 2013, emissions from Iron & Steel industry alone accounts for roughly **50%**, while emissions from non-metallic minerals industry contributes to around **20%** of total emissions from fuel usage (Figure 7).

Figure 7: Sectoral emissions of fuel use for the period 2005-13



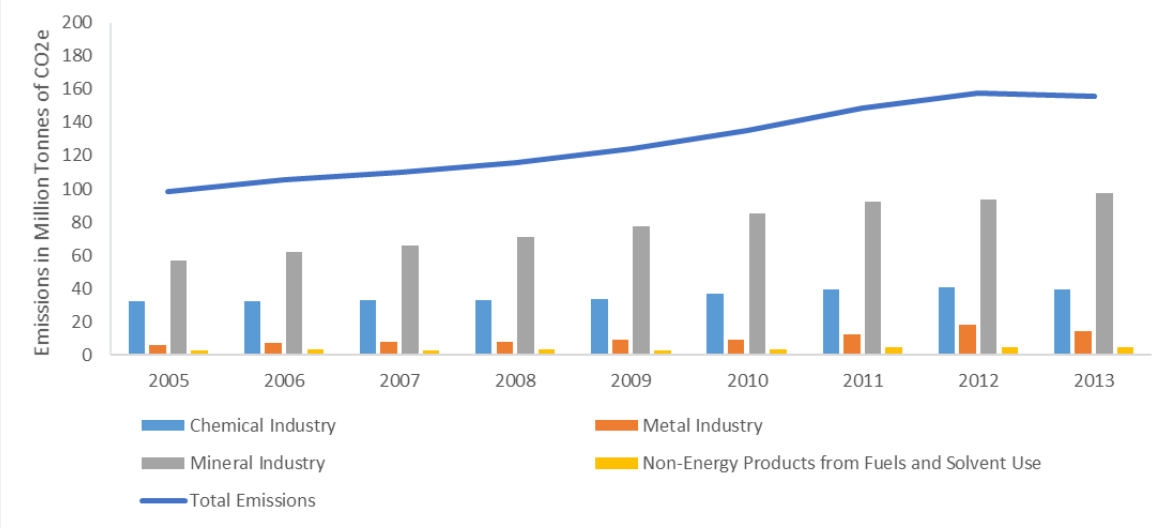
Source: CEEW analysis

Emissions from Industrial Process and Product Use in Industries

Over the analysis period, IPPU emissions contribute between **25%** to **35%** of the overall industrial emissions. Figure 8 below shows the IPPU emissions trend from various industrial activities. Unlike emissions from fuel use, IPPU emissions grew at a lower annual growth rate of 6% from 2005 till 2013. Cement production, ammonia production and iron & steel production contributes to more than 80% of emissions during the period.

Cement industry consumes more than 90% of total limestone/dolomite produced in the country (IBM, 2015) and thus contributes to more than **50%** of total IPPU related emissions.

Figure 8: Sectoral emissions from industrial product and process use for the period 2005 to 2013



Source: CEEW analysis

India ranks second globally in absolute consumption of nitrogenous fertilizers (FAO, 2009) and on account of this, the fertiliser sector accounts for a large share of emissions. For the period 2005-13, fertiliser production (read as ammonia production) contributes to around **17%** of total IPPU emissions. Although, the specific requirement of carbonaceous material in iron & steel production is less than cement production, ever increasing demand of steel in India has driven the emissions from this sector to be the third largest. Process emissions from iron & steel contribute to ~**6%** of the overall IPPU related emissions.

Manufacturing Sector Emissions (covers Energy Use and IPPU)

In this study, the terms manufacturing or industry have been used in accordance to the IPCC guidelines, where we have focused towards emissions resulting from energy as well as product and process use (IPPU). Hence the scope shall be considered as: Manufacturing Industries and construction (category 1A2 with its sub codes), energy industries (only for 1A1b and 1A1c),6 and IPPU (2A to 2H)7. Apart from manufacturing, mining (coal as well as non-fuel mining) and construction activities are also covered by this study as per IPCC reporting norms.

Overview of the emissions from manufacturing industry

Between 2005 and 2013, the overall GHG emissions from the manufacturing industry has almost doubled from 315 million tonnes (MMT) to 623 MMT. Table 1 depicts that Energy use has remained the biggest contributor to the emissions, with almost 70% of emissions contributed by the Iron & Steel segment alone.

Table 1: A time series of greenhouse gases emission estimates for the manufacturing sector

IPCC codes	*Sector/Subsector - as per IPCC, 2006 classification*	*2005*	*2006*	*2007*	*2008*	*2009*	*2010*	*2011*	*2012*	*2013*
Energy Use Emissions (in Million Tonnes of CO2e)										
1A1	**Fuel Combustion Activities > Energy industries**	**28**	**31**	**31**	**35**	**40**	**43**	**47**	**50**	**46**
1A1a	Main Activity Electricity and Heat production (utility +									
1A1b	Petroleum refining	24	27	27	30	37	38	42	44	39
1A1c	Manufacture of Solid Fuels and other Energy Industries									
1A1ci	Manufacture of Solid Fuel	0	1	0	0	-0	1	1	1	2
1A1cii	Other Energy Industry	4	4	4	4	4	4	5	5	6
1A2	**1A2: Manufacturing Industries and Construction**	**189**	**175**	**214**	**267**	**275**	**330**	**344**	**371**	**421**
1A2a	Iron and Steel	105	103	137	166	160	201	209	212	223
1A2b	Non-Ferrous Metals	15	5	6	9	12	10	23	33	42
1A2c	chemicals	8	4	6	14	15	17	14	21	34
1A2d	Pulp, Paper and Print	6	7	6	7	8	9	8	10	11
1A2e	Food Processing, Beverages and Tobacco	5	5	3	3	6	7	5	4	5
1A2f	non-metallic minerals	40	41	45	53	58	64	68	71	81
1A2g	Transport Equipment	1	1	1	1	2	2	3	2	4
1A2h	Machinery	3	3	4	4	5	10	2	5	10
1A2i	Mining (excluding fuels) and Quarrying	0	0	0	0	0	0	0	0	0
1A2j	Wood and Wood Products	0	0	0	0	0	0	0	0	0
1A2k	Construction	0	-0	0	0	1	0	-0	0	0
1A2l	Textile and Leather	5	5	6	9	9	9	11	11	8
1A2m	Non-specified Industry	1	2	0	-0	-0	1	1	2	3
Industrial Process and Product Emissions (IPPU), (in Million Tonnes of CO2e)										
2A	**2A Mineral Industry**	**57**	**62**	**66**	**71**	**78**	**85**	**92**	**94**	**97**
2B	**Chemical Industry**	**32**	**33**	**33**	**33**	**34**	**37**	**39**	**41**	**39**
2C	**Metal Industry**	**6**	**8**	**8**	**8**	**9**	**9**	**12**	**18**	**14**
2D	**Non-Energy Products from Fuels and Solvent Use**	**3**	**3**	**3**	**3**	**3**	**4**	**5**	**5**	**4**
2E	**Electronics Industry**	**Not estimated: Information unavailable at the national (or state) level**								
2F	**Product Uses as Substitutes for Ozone Depleting Substances**									
2G	**Other Product Manufacture and Use**									
2H	**Other**									
TOTAL IPPU + Energy (for Mfg); excluding electricity		**315**	**311**	**355**	**417**	**439**	**509**	**539**	**579**	**623**

Note: Information is in-sufficient for the non-ferrous metals (1A2b), mining & quarrying (1A2i), and the non-specified industry. Since we are deducting any emissions due to captive power generations from all sectors, a negative value indicates that the energy use information is inadequate for these sectors.

Source: CEEW analysis

6 Rest of the 'Energy Industries' are computed as a separate study, computed by CSTEP. Available at the GHG Platform India. Weblink: http://ghgplatform-india.org/

7 IPPU is covered for categories 2A to 2D only. Information is not available for rest of the categories.

Boundary of GHG estimates

This report provides GHG estimation at the national level, which is an aggregation of factory level activity data, and assumptions made at state and sector specific levels. A bottom up aggregation of all states represents emission estimates for the entire India. In terms of numbers, it represents coverage of approximately 3.28 million sq.km area, 1.2 billion population (2011 census), and a GDP of INR 106.44 trillion in 2014-15 at constant (2011-12) prices. In 2014-15, economic share of industry, in terms of Gross Value Addition (GVA) was 29.7% - considering manufacturing as well as construction, at factor cost and current price (2011-12 series).[8]

Overview of Source Categories and Methodology

The year 2005 is set as a baseline for the estimates available till 2013, as it also marks as a base year for India's INDC targets. Activity data information was available latest for 2013-14 from the ASI statistics, MOSPI, hence it has been taken as a terminal reporting year.

IPCC guidelines were fittingly used for the overall emission estimates from the manufacturing sector. ASI statistics were used as a prime source of activity data information, and was purchased from the MOSPI for the reported years. Other source of information, such as (a) Indian Bureau of Mines, (b) Ministry of Coal, (c) Ministry of Petroleum and Natural Gas (MOPNG), (d) Cement Manufacturing Association, etc. were judiciously used to fill the information gaps, wherever required. Refer Annexure 1 for a detailed source directory.

ASI provides information at the factory level, where all the units bear a unique factory Identity, and are classified according to the National Industry Classification (NIC) system. Factories were collated to represent state specific emissions, which further gets aggregated to form country level estimates. Every unit (or firm) specifies the activity data (in terms of fuel use, or input products) as per the National Product Classification for Manufacturing Sector (NPCMS) system. Adoption of standard industrial and product nomenclature systems by ASI has made it simpler for us to made a concordance between ASI reporting and IPCC classification system (Refer Annexure 2 & 3).

We have provided a step-by-step methodology for estimating GHG emissions separately from the energy and Industrial Process and Product Use (IPPU). For energy use, emissions are linked to the fuel mix adopted by each of the industry. Whereas, IPPU emissions largely comes from the intake of carbonaceous materials (other than conventional fuel), and from specific product conversion processes releasing GHG emissions. We have addressed every identifiable limitation through pragmatic set of assumptions. Further, the recommendation section details out more opportunities to refine our assumptions, as well as improving the national data collection processes. Comments from stakeholders and readers are always welcome to make improvements in the next edition(s) of this study.

8 India's first Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC), available at: http://unfccc.int/resource/docs/natc/indbur1.pdf; accessed on 06 June 2017

Energy Use emissions (1.A.1: Energy Industries, and 1.A.2: Manufacturing industries and construction)

Category Description

Table 2 features key source categories for the activity data used in emission estimations. It further highlights the indicative quality of data sources. For more details, Annexure 1 shall be referred.

Most of the 'low/medium' quality source categories are known to be contributing incomparably lower emissions than the high-quality source categories. Besides sector level quality assessment, we have observed that data quality issues are prominent for certain fuel types (example: natural gas), and throughout the sectors.

Table 2: Category wise source and quality of activity data for the energy use emissions

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
1.	**Energy**			
1A1	**Fuel Combustion Activities**			
1Ab	Petroleum refining	Secondary	High	MoP&NG
1A1ci	Manufacture of Solid Fuel	Secondary	Medium	ASI
1A1cii	Other Energy Industry- includes emissions from energy use in coal mining and oil & gas extraction	Secondary	Low	MoP&NG, SCCL Annual Reports
1A2	**Manufacturing Industries and Construction**			
1A2a	Iron and Steel	Secondary	High	ASI
1A2b	Non-Ferrous Metals	Secondary	High	ASI
1A2c	Chemicals	Secondary	High	ASI
1A2d	Pulp, Paper and Print	Secondary	Low	ASI
1A2e	Food Processing, Beverages and Tobacco	Secondary	Medium	ASI
1A2f	Non-metallic minerals	Secondary	High	ASI
1A2g	Transport Equipment	Secondary	High	ASI
1A2h	Machinery	Secondary	High	ASI
1A2i	Mining (excluding fuels) and Quarrying	Tertiary	Low	ASI
1A2j	Wood and Wood Products	Secondary	Medium	ASI
1A2k	Construction	----	-----	ASI
1A2l	Textile and Leather	Secondary	High	ASI
1A2m	Non-specified Industry	Secondary	Medium	ASI

Source: CEEW illustrative

Methodology

IPCC lists out three level of tiers for the activity data, and emission estimation methodology. Each tier differs from the other based on the origin and quality of underlying information. Tier-1 represents a generic and international level of understanding, whereas Tier-2 is more of a country specific representation. Tier-3 brings supreme level of details at the plant/factory level. Emission factors could either be country specific, or as per the prescription of IPCC guidelines.

Table 3: Tier approach followed for the energy use emission category

IPCC ID	GHG SOURCE & SINK CATEGORIES	CO_2		CH_4		N_2O	
		METHOD APPLIED	**EMISSION FACTOR**	**METHOD APPLIED**	**EMISSION FACTOR**	**METHOD APPLIED**	**EMISSION FACTOR**
1A1	**Fuel Combustion Activities**						
1Ab	Petroleum refining	T2	CS, D	T2	CS, D	T2	CS, D
1A1ci	Manufacture of Solid Fuel	T2	CS	T2	CS	T2	CS
1A1cii	Other Energy Industry	T2	CS, D	T2	CS, D	T2	CS, D
1A2	**Manufacturing Industries and Construction**						
1A2a	Iron and Steel	T2	CS, D	T2	CS, D	T2	CS, D
1A2b	Non-Ferrous Metals	T2	CS, D	T2	CS, D	T2	CS, D
1A2c	Chemicals	T2	CS, D	T2	CS, D	T2	CS, D
1A2d	Pulp, Paper and Print	T2	CS, D	T2	CS, D	T2	CS, D
1A2e	Food Processing, Beverages and Tobacco	T2	CS, D	T2	CS, D	T2	CS, D
1A2f	Non-metallic minerals	T2	CS, D	T2	CS, D	T2	CS, D
1A2g	Transport Equipment	T2	CS, D	T2	CS, D	T2	CS, D
1A2h	Machinery	T2	CS, D	T2	CS, D	T2	CS, D
1A2i	Mining (excluding fuels) and Quarrying	T2	CS, D	T2	CS, D	T2	CS, D
1A2j	Wood and Wood Products	T2	CS, D	T2	CS, D	T2	CS, D
1A2k	Construction	T2	CS, D	T2	CS, D	T2	CS, D
1A2l	Textile and Leather	T2	CS, D	T2	CS, D	T2	CS, D
1A2m	Non-specified Industry	T2	CS, D	T2	CS, D	T2	CS, D

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

Source: CEEW compilation

The characteristic quality of input hydrocarbon fuels, and associated consumption determines the energy use emissions for manufacturing sector.

Basic Equation:

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

Where:
$Egas$: Emission of greenhouse gas(es) in tonne
$Afuel$: **Activity data** of fuel (in litres/Kg/tonne etc.)
$C.Vuni$: Conversion factor(s) to convert activity data to tonne (please refer to Annexure 4.)
$C.Vfuel$: Calorific value of fuel (tonne of energy in Tera Joule per tonne of fuel)
$E.Fgas$: **Emission factor** of GHG gas due to combustion of the fuel (tonne of gas /TJ of energy input)
$GWPgas$: Global warming potential of gas

Activity data – Fuel consumption for the energy use purpose

Here, fuel shall be classified under three broader categories, i.e. solid fuels, liquid fuels, and gaseous fuels. Annexure 5 illustrates more than 80 different variants of these fuels, which were considered for our analysis. As it can be seen, a sizable amount of fuel use (in terms of expenditure) is reported by industries as 'other fuels.' It is a challenge to translate this reporting into a meaningful interpretation. However, ASI does provides a crude description of this category being comprised mainly of biomass feedstock and material transit expenses. In this analysis, we have considered biomass to be commercial in nature, which makes it net carbon-neutral, whereas 'material transit' related fuel expenses were dropped from the manufacturing sector, as they should be included elsewhere.

Emission factor(s)

As mentioned earlier, each fuel type corresponds to a specific calorific value and carbon/hydrocarbon content. Hence, emissions vary with the same amount of energy consumption with different fuels. ASI provides a good understanding on the domestic and imported category of input fuels. Hence, we have assigned country specific emission factors (wherever applicable), while using default values for the rest of fuel inputs. Annexure 5 provides a list of input fuels in accordance to their assigned emission factors for this study. For example – domestic coal (owing to its poor quality) bears a lower calorific value (19.63 TJ/Gg) as compared to the default values from the imported coal (26.7 TJ/Gg) (Choudhury, Roy, Biswas, Chakraborty, & Sen, 2004). India has endorsed country specific emission factors for only coal and lignite; rest of the fuel follows the default IPCC factors. Wherever any default emission factor is not provided by the IPCC guidelines, we have assigned the characteristics of closest resembling fuel to it.

Calculation of energy use emissions from the manufacturing sector

Essentially, only the energy use of an input fuel contributes to the direct GHG emissions. Any other non-energy use – be it feedstock, or interconversion of one form to other – does not contribute to the energy use emissions. Hence, it is crucial to understand the typical form of fuel usage as 'energy' or 'non-energy.' This may vary across specific manufacturing segments.

The current form of ASI reporting does not elucidate the end use of input fuels within the factory premise. A user can not differentiate a specified quantity of fuel-use for heating purpose, captive power generation, and/or as a feedstock for non-energy uses. We have made some perceptible assumptions based on desktop research and expert consultation. Annexure 6 provides a combination of fuel use as a feedstock in relation to certain manufacturing activities. For example:

a) Coal is considered as a feedstock for coke-oven plants/cookeries, and hence emissions from secondary fuel (coke) is considered in place of coal (at certain places), to avoid double-counts, and maintaining the fullness of estimates.
b) Similarly, crude oil inputs from the refining activities is considered as a non-energy/feedstock use, and hence no emissions from 'crude oil'. However, in this process, any use of 'petroleum product use' is considered responsible for GHG emissions.
c) Natural gas is notably known for its non-energy use in fertiliser industry (for urea manufacturing). Hence no emissions from this use.
d) Many industry operations make use of 'petroleum products' beyond its use for energy. Such as, Kerosene is used by printing, paints, and varnishing industries as a solvent, similarly LPG bottling industry never burns it, rather it transformed into a further usable form. Such operations do not generate energy related emissions due to direct burning of input hydrocarbons. Hence any such kind of fuel consumption is considered as feedstock, and is dropped from emission accounting.

Calculation of net emissions by exclusion of captive power generation

From the available dataset (i.e. ASI), it is cumbersome to determine the precise quantity of input fuel specifically meant for captive generation within the factory bounds. Hence, firstly all the fuel input (feedstock excluded) towards a manufacturing sector is accounted for energy emissions with no specific accounting of electricity based generation. But, in order to standardise the results as per IPCC reporting – emissions from captive power plants have to be moved out from the manufacturing activities, and must be reported under IPCC code 1A1a (electricity generation).

ASI datasets separately reports the total electricity consumption (as captive and/or purchased from grid), as well as amount of electricity sold to the grid by each manufacturing firm. All of this gets reported in the form of standard electricity units (kWh), and not in terms of fuel type. Hence, we have made plausible assumptions (as follows) to deduct captive emissions from the consolidated emission figure:

- Coal, natural gas and diesel are only considered as the principal sources of captive generation within the manufacturing industry.
- The maximum generating capacity of a diesel fired captive units is assumed to be 15MW. Any factory reporting electricity generation higher than the maximum generation possible from 15MW diesel fired unit (assuming a run of 365 days, 24 hours and an efficiency of 45%) is assumed to use coal or natural gas (Argelwar & Dani, 2017).
- The natural gas fired captive power are easily identified by looking at the factory's input fuels. If any factory reports to consume natural gas, and is generating captive electricity, we have designated energy source to be 'natural gas.' Otherwise, we have assigned source fuel as coal or diesel, as according to the above-mentioned threshold of generation.
- Finally, to convert the electricity units to their corresponding input energy, we are using the heat rates of coal, diesel and gas as reported by CEA (A review of performance of Thermal Power Stations) (please refer to annexure 7).

An alternative approach of using Central Electricity Authority (CEA) statistics for net deductions exogenously didn't worked well, as it is always difficult to adjudge relevant sector for group captive thermal power stations, which brings errors in representation of estimates. Hence, we made a methodological improvement in this version of GHG emission estimates.

Uncertainties

The fundamental use of ASI is never meant for compiling energy statistics for the country. Traditionally it has been used in determining the macro-economic performance of the manufacturing sector; in terms of productivity, and, employment. Since, it seeks information on material consumption in form of quantity, expenditure or both – we have made an intelligent use of this system for emission estimation purpose.

However, due to secondary nature of information and self-reporting process by industries, sometimes irregularity prevails in provided information. We have neutralised several reportable errors by closely examining the cause, and applying suitable set of assumptions. This section highlights grey areas of reporting, and evaluate the level of uncertainty associated with estimated results.

1) Erroneous reporting of fuel rates: Uncertainty of input activity data

ASI provides valuable insights on consumption of raw material/energy inputs by factories, as well as report for expenditure associated with input items. Compared to reporting on fuel quantity, the expenditure figures have a relatively high reliability coefficient; as it can be seen that some factories only provide expenses, and not the corresponding quantity. To arrive at reasonable estimates, we require quantity figures for each reported fuel.

We have observed flawed reporting by a few industries on fuel rates, which is measured at the factory gate and is inclusive of transportation cost, taxes and subsidies. Reported range is very wide for certain fuels, for example:

(a) in 2007-08, the landed price of LPG ranges between INR 9.49 per Kg to INR 37722 per Kg. Clearly this need to be bounded within a certain acceptable range.

(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.

We developed a systematic approach for identifying all such spurious entries, and thereby adjusting the multipliers of them to make it within possibility of reported unit of measurement. Further, to counter any probable deviation due to external costs embedded in fuel expenses, we have used median rates for entries where only expenses are reported by firms.

<u>CEEW assumption</u>: To translate reported expenditure into measurable fuel quantity, use of prevailing market price of fuel is not justifiable. This is so, as factories report their expenses as net cost, which is inclusive of transportation, taxes, or given subsidies. As a first layer of course correction, we have adjusted the decimal values, where numbers are out of order as compared to corresponding unit of measurement. Further, we have calculated the median of all reported rates, and assigned that rate, wherever rates are unavailable. Since, landed price of fuel may vary between states located in close proximity of fuel sources, as compared to states positioned at a significant distance. We have assigned median rates at each and every state level. Further to this, activity based distinctions have been made in application of medians rates, specifically for captive generation, Iron and Steel and rest of the industries. This is to ensure a qualified conversion of expenses into fuel specific energy/quantity terms.

Uncertainty analysis

We did a sensitivity analysis to measure the size of deviation in emission estimates due to our assumptions. Here the reference points for uncertainty are median versus maxima and minima value of fuels as reported by industries. Our logic is, any uncertainty should fall between the maxima and minima rate based calculations. All of this is after performing the decimal correction, which is adjudged as a simple mathematical oversight from industries.

Overall deviation, collectively for all fuels falls within a range of 5% to 25% for 25th and 75th interquartile range, from the median values. This signifies a considerable band of deviation for emission estimates, however, we need to consider the element of state specific deviation in this analysis. Practically, probability of all states following *all-India* level of minimum or maximum rate reported is out of the question. This is to illustrate, that even considering these odds, deviation in estimates could be as high as observed values in Table 4.

Table 4: Percentage uncertainty due to assumptions on reported fuel rates across all sectors

Deviation of net emissions from the median				
Years	Minimum	P25	P75	Maximum
2004-05	52%	7%	12%	43%
2005-06	72%	15%	17%	49%
2006-07	98%	14%	13%	55%
2007-08	96%	14%	11%	48%
2008-09	183%	24%	18%	59%
2009-10	383%	32%	11%	49%
2010-11	569%	342%	10%	34%
2011-12	1940%	25%	15%	53%
2012-13	197%	22%	12%	44%
2013-14	103%	19%	10%	43%

Source: CEEW analysis

2) **Unspecified reporting of fuel: Uncertainty on applied emission factor(s)**

Some factories report their fuel inputs at a much broader level, without indicating the characteristic fuel type in inputs, and hence imparts insufficient information to the ASI. Typically, such firms report their fuel inputs as: (a) coal consumed, (b) electricity generated (captive) and/or electricity purchased, (c) all gases consumed, and, (d) petroleum products consumed. Further, such firms administer only the expenditure incurred on the fuel inputs. This poses a big challenge in assigning a distinct calorific value and corresponding emission factor(s) 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.).

In order to arrive at a proximate value of emissions from such fuel reporting, we studied the fuel consumption pattern of factories who reported specific energy inputs in each manufacturing segment over a period of time. Thus, we derived a definitive fuel consumption trend across the manufacturing sectors, and thereby assigned default characteristics (calorific value and emission factor) to the generic fuel expenditure reported by a few firms. For each specific fuel type, associated median fuel rates were used to interpret the quantity of fuel consumption, and hence resultant emissions. Table 5 depicts the 'liquid fuel' specifics for each industry type (as per NIC codes) for 2012-13. Please refer to Annexure 8 for details.

Table 5: 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)

Uncertainty analysis: It is usual that a generic interpretation of fuel characteristics would create some uncertainty in the overall results. Hence, we performed a test to gauge the impact of such assumptions. Liquid fuel is the only group with highest level of ambiguity, as the spectrum of fuels is considerably wide. Hence, we inspected the deviation of our result against the possibilities of getting entire expenses under each dominant fuel type individually. Please refer to Annexure 9 for details.

Table 6: Uncertainty analysis of assumptions on assigning emission factors to the unspecified fuel reporting

Year	% Variance (all Diesel)	% Variance (all Furnace oil)	% Variance (all Petroleum Coke)
2004-05	4%	-3%	-7%
2005-06	4%	-2%	-10%
2006-07	2%	1%	-13%
2007-08	2%	1%	-9%
2008-09	2%	-1%	-3%
2009-10	2%	-2%	-4%
2010-11	-2%	-3%	-14%
2011-12	-1%	-1%	-6%
2012-13	0%	1%	-6%
2013-14	2%	2%	-5%

Source: CEEW analysis

Table 6 elucidate the enormity of uncertainty associated with emission factor(s) based assumptions for the entire manufacturing sector. Although, the degree of uncertainty with 'petroleum coke' as a prime fuel is comparatively very high; but we know this for a fact that its consumption is limited mainly to the cement sector only. Thus, high uncertainty number should be ignored for the petroleum coke based deviation.

Quality Control

A significant amount of time was spent on the Quality Control process of this exercise. We have used QC as a technique to located any specific data or calculation related errors, and have ensured highest level of accuracy in the arrived estimates. Each round of QC has helped us in improving the overall results. In general, QC process was common across all source categories, as the underlying data source (& format) and process were the same.

ASI provides a unit level information (activity data), which has quality issues with some of the factories, as they report out-of-order information on fuel and electricity consumption. For instance, some of the units cites inappropriate *rates* for input fuels which doesn't matches with the order of respective unit of measurement. As a QC procedure, we have developed algorithms to identify such errors and fix them up to arrive at reliable estimates. For the ease of further review, we have maintained a list of factories with such erroneous reporting, and have performed subsequent rate adjustments. This has resulted into better comparison of emission estimates at the state and sectoral level for a period of time.

A national level view of emission estimates suggests a lack of activity data (or perhaps, decline in industrial productivity) for 2006, whereas at the sectoral level, inconsistencies were found in energy use emissions for non-ferrous, construction and mining sector, due to poor quality (or unavailability) of activity data.

A specific attention is given on deduction of any emission due to captive power generation activity. This is to avoid overlaps with reporting on electricity emission under a different category, as prescribed in IPCC guidelines.

The final results are clearly highlighted in excel spreadsheets (accessible from the GHG Platform India website), where subsequent tabs provide clarity on calculations, data points (emission factors, activity data), units of measurement in an easily understood manner. A user can reproduce same results by using information (from the spreadsheets) and the formulae mentioned in the methodology section of this study.

Hence, the entire GHG estimates were measured through a quality control process in a transparent manner for its accuracy, completeness, comparability and consistency across the years.

Quality Assurance

As a measure of quality assurance, the entire process of emission estimation and reporting is duly peer reviewed by third party, here in this case – WRI India. Periodic consultations and review cycles were organised with them to ensure that methodology, assumptions and proxies, and prudent to reflect best possible GHG estimates for the sector. The review process involved multiple rounds of communication with a continuous stream of feedback from their expert team. Regional consultation (Bangalore, Kolkata, and New Delhi) were also conducted to further validate our methodology and assumptions by inviting Industry experts, and other research community at those events. Corrective actions were duly incorporated in the estimation process for an overall improvement of the GHG estimates.

Recalculation

Estimation methodology has remained same and consistent with the good practice guidelines from IPCC. Yet, CEEW's final estimates (version 3.0) differ from the previous version due to specific recalculations, the reasons are mentioned and discussed below:

a) <u>Refinement in data processing approach and correction of errors</u>

As discussed in previous sections (quality control), some of the factories/units reports unexpectedly high or low rates for their input fuels due to lack of understanding on associated 'unit of measurement.' However, good part is that they do report final expenses and quantity (in most cases) as well. This helped us in making suitable adjustments on reported rates, and remodelling the quantity of input fuels. In earlier estimates, we applied those rate correction measures at the national level only, state specific deviation in rates (due to transportation cost and other embedded taxes) were not considered due to limitations in scope of work. However, in this version, we have made distinct adjustments at each state specific level. Reapportionment of fuels with 'reported values' only is also taken care at the state specific level. Hence, final aggregated sum-of-states at the national level provides improved values.

b) New data source for captive power emission readjustments

In ASI data series, industry activity associated with captive power generation is not clearly specified for most of the units, hence we make use of CEA datasets for captive readjustments. However, it was later observed that ASI reports captive power generation in two separate parts, and deduction was partially possible because many units doesn't directly report their industry activity associated with captive electricity generation. Hence, we were missing out a substantial amount of energy consumption (and hence emissions) from the core ASI data interpretation.

In this version, we have ensured a correct mapping between captive power generation and associated units by developing a concordance based on input raw materials. Therefore, we are using ASI as a source of information and are avoiding CEA numbers to maintain consistency and uniformity in estimations. This has resulted into significant increase in overall emissions, as earlier we were missing that portion of fuel consumption.

Verification

The objective of verification exercise is to ensure consistency in terms of scope, emission sources, emission factors and underlying assumptions between all the years of reporting. While CEEW has follows a standard practice for each year with full disclosure of any specific exclusions, we need a reference point to verify our results.

As a measure of verification, we compared our estimates with national level inventories reported by the government of India. Sadly, we have only two reference points from the government to draw any comparison, and both talks about national level estimates.

We can see a proximity between ours' and official estimates (BUR-1) within 3% for 2010. On contrary, for 2007, CEEW estimates are 20% lower than the government estimates. Between 2007 and 2010, GOI estimates suggests a CAGR of 3%, whereas our estimates reflect a CAGR of 13% for the manufacturing sector energy consumption.

To make a conclusive remark, we seek more clarity on the methodology and assumptions behind government's estimates as well. But broadly speaking, 2007 estimates (INCCA) is not an official GOI submission to the UNFCCC, and does not adheres to the IPCC guidelines. Hence, going by the reference of BUR, our estimates (methodology and activity data) are verifiable to a certain extent.

Further to make a point of difference, government estimates follows a top down (supply side) view of energy estimates at Tier-1 and Tier-2 levels; whereas CEEW estimates deals with more granular level of information (Tier 3) in terms of activity data, and is a bottom-up aggregation.

Planned improvements

ASI reporting for the forthcoming years is expected to be more precise with improved quality of activity data. We have made an extensive outreach the MOSPI with a proposed set of process improvements. Upon consideration, it would take at least three to four years to get reflected in the ASI statistics. CEEW has suggested them to give a specific focus on the energy data reporting, which would minimize the reporting on 'un-specified fuels' as well as incorporate better system checks to avoid erroneous reporting on fuel rates.

Industrial Process and Product Use Emissions (IPCC codes: 2A to 2D)

Category Description

IPPU emissions are not associated with every manufacturing industry. It is largely associated with the manufacturing activities which use non-fossil carbonaceous material (such as limestone, carbon electrodes, dolomite, etc.) as a process input, and from non-energy uses of fossil fuel carbon. In addition, GHG often uses in products such as refrigerants, also ascribe to the IPPU based emissions. In certain processes, feedstock or reducing agent used in process may get combusted to produce emissions, and makes it difficult to separate between energy use and IPPU emissions. This can lead to uncertainty in reporting, hence we have recorded any combustion related emissions (direct or indirect) within the energy use category. Table 7 depicts category wise source of activity data statistics. Since, this information is reported by national agencies in a straightforward manner, quality is generally high.

Since, ASI presents a relatively high degree of deviation for the product output related information in some industries (especially, aluminium, lead, zinc and chemicals), alternative data sources from national agencies has been referred (Table 7) to maintain thoroughness of study.

Table 7: Category wise sources and quality of activity data for the IPPU emissions

IPCC ID	GHG SOURCE & SINK CATEGORIES	TYPE	QUALITY	SOURCE
2.	**Industry**			
2A	**Mineral Industry**			
2A1	Cement Production	Secondary	High	CMA
2A2	Lime Production	Secondary	High	ASI
2A3	Glass Production	Secondary	High	ASI
2A4a	Ceramics		High	
2A4b	Other Uses of Soda Ash	Secondary	High	ASI
2A4c	Non-Metallurgical Magnesia Production	Secondary	High	ASI
2A4d	Other uses of carbonates	Secondary	High	ASI
2B	**Chemical Industry**			
2B1	Ammonia Production	Secondary	High	ASI, Annual Report, Ministry of Chemicals and Fertilizers
2B2	Nitric Acid Production	Secondary	High	ASI
2B3	Adipic Acid Production	Secondary	High	ASI, Annual Report, Ministry of Chemicals and Fertilizers
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production	Secondary	High	
2B5	Carbide Production	Secondary	High	
2B6	Titanium Dioxide Production	Secondary	High	
2B7	Soda Ash Production	Secondary	High	
2B8a	Methanol Production	Secondary	High	
2B8b	Ethylene Production	Secondary	High	
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer Production	Secondary	High	
2B8d	Ethylene Oxide Production	Secondary	High	
2B8e	Acrylonitrile Production	Secondary	High	
2B8f	Carbon Black Production	Secondary	High	
2C	**Metal Industry**			
2C1	Iron and Steel Production	Secondary	High	ASI

2C2	Ferroalloys Production	Secondary	Low	ASI
2C3	Aluminium Production	Secondary	High	MCX, IBM Mineral Yearbook
2C4	Magnesium Production	Secondary	High	
2C5	Lead Production	Secondary	High	IBM market survey report & Mineral Yearbook
2C6	Zinc Production	Secondary	High	
2C7	Other- emissions from carbonates usage in copper production	Secondary	High	ASI
2D	**Non-Energy Products from Fuels and Solvent Use**			
2D1	Lubricant Use	Secondary	Medium	ASI
2D2	Paraffin Wax Use	Secondary	Medium	ASI
2D4	Other – Lubricant use in coal mining activities	Secondary	Low	SCCL Annual Reports

Source: CEEW Compilation

Methodology

This section outlines the methodology for the IPPU estimates. Table 8 Provides insights on the tier level of methodology and emission factors used in estimating GHG emissions.

Table 8: Tier approach followed for the IPPU category

IPCC ID	GHG SOURCE & SINK CATEGORIES	CO_2		CH_4		N_2O	
		METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR	METHOD APPLIED	EMISSION FACTOR
2A	**Mineral Industry**						
2A1	Cement Production	T1	CS, D	T1	CS, D	T1	CS, D
2A2	Lime Production	T2	CS	T1	CS	T1	CS
2A3	Glass Production	T1	D	T1	D	T1	D
2A4a	Ceramics	T1	D	T1	D	T1	D
2A4b	Other Uses of Soda Ash	T1	D	T1	D	T1	D
2A4c	Non-Metallurgical Magnesia Production	T1	D	T1	D	T1	D
2A4d	Other	T1	D	T1	D	T1	D
2B	**Chemical Industry**	T1					
2B1	Ammonia Production	T1	D	T1	D	T1	D
2B2	Nitric Acid Production	T1	D	T1	D	T1	D
2B3	Adipic Acid Production	T1	D	T1	D	T1	D
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production	T1	D	T1	D	T1	D
2B5	Carbide Production	T1	D	T1	D	T1	D
2B6	Titanium Dioxide Production	T1	D	T1	D	T1	D
2B7	Soda Ash Production	T1	D	T1	D	T1	D
2B8a	Methanol	T1	D	T1	D	T1	D
2B8b	Ethylene	T1	D	T1	D	T1	D
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer	T1	D	T1	D	T1	D
2B8d	Ethylene Oxide	T1	D	T1	D	T1	D
2B8e	Acrylonitrile	T1	D	T1	D	T1	D
2B8f	Carbon Black	T1	D	T1	D	T1	D

2C	**Metal Industry**						
2C1	Iron and Steel Production	T2	CS, D	T2	CS, D	T2	CS, D
2C2	Ferroalloys Production	T1	D	T1	D	T1	D
2C3	Aluminium Production	T1	D	T1	D	T1	D
2C4	Magnesium Production	T1	D	T1	D	T1	D
2C5	Lead Production	T1	D	T1	D	T1	D
2C6	Zinc Production	T1	D	T1	D	T1	D
2C7	Other	T1	D	T1	D	T1	D
2D	**Non-Energy Products from Fuels and Solvent Use**						
2D1	Lubricant Use	T1	D	T1	D	T1	D
2D2	Paraffin Wax Use	T1	D	T1	D	T1	D
2D4	Other	T2	CS, D	T2	CS, D	T2	CS, D

Notes:
T1: Tier 1; T2: Tier 2; T3: Tier 3; CS: Country-specific; PS: Plant-specific; D: IPCC default
*T2 methodology is modelled on the basis of some estimates on clinker factors, still it does not qualifies as T2 as per IPCC guidelines.

Source: CEEW compilation

Basic equation:

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

Where:
$Egas$: Amount of greenhouse gas in tonne
$Amat$: **Activity data** of material (carbonaceous) input or product output (expressed in tonne/kg/litre/unit etc.)
$C.Vmat$: Conversion factor to activity data units in tonne
$E.Fgas$: **Emission factor** of gas emitted in the process (tonne of gas per unit of carbonaceous material input or product output)
$GWPgas$: Global warming potential of concerned gas

All sources of information are secondary in nature obtained from national authorities. In order to maintain completeness in overall reporting, certain assumptions were made in IPPU calculations, and are as follows:

a) 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 and IPPU) gets reported jointly under the IPPU head.
b) 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 illustrated in supporting excel workbooks. However, activity data for mining

sector is partially available through the ASI data sets, we have adopted specific lubricant consumption factor from alternative sources for completeness of reporting.

Uncertainties

Uncertainties are typically low for IPPU estimates, as emission are directly derived from available information (activity data and emission factors) without much assumptions. The data source are also considerably reliable as it directly comes from national records, leaving nominal scope of deviation.

However, in case of cement sector, emission varies with each type of cement composition. The activity data for cement production is sourced from the Cement Manufacturing Association (CMA), and the Indian Bureau of Mines (IBM). CMA provides a highly-detailed level of information for each variant of cement, that gets manufactured in India. It also reports for clinker factors associated with each cement type. But, CMA reporting is available only till 2007-08. For the remaining years, we have to rely upon IBM as a prime source of information, which is not as granular as CMA is. Hence, we have made certain assumptions to estimate emissions from the cement sector for the remaining years. Since, composition of cement manufacturing in India hasn't reportedly changed much, we disaggregated the total cement production (reported by IBM) into the same proportion, as it was used to be reported by CMA for previous years. Information on calculation and detailed clinker factors is available in the CEEW calculation worksheets (refer worksheet 2) accessible from the GHG Platform India.

The assumptions (for later years) made for cement sector could only lead to any noticeable uncertainty for the IPPU estimates. To measure the degree of uncertainty, we calculated the overall emissions by using aggregated cement production figures, and average clinker factor (as prescribed by IPCC in cases of limited information). Overall uncertainty came out to be 3%, as depicted in Table 9.

Table 9: Emissions from Cement Production (Million tonnes CO2Eq)

Year	Current Method	IPCC Default	Deviation
2008-09	74	77	3%
2009-10	82	85	3%
2010-11	87	90	3%
2011-12	92	95	3%
2012-13	94	97	3%
2013-14	103	106	3%

Source: CEEW Analysis

Another chance of uncertainty in estimates could arise due to lack of clarity on carryover stocks, and inventory of stocks from preceding year. However, we have adopted a standard rule of thumb, where carryover stocks are supposed to get neutralised by the running stock entering from previous years. Hence the estimates for a specific year represent the best possible level of accuracy.

Quality Control:

A quality control process has been followed on the use of data, its time-series, methodology, and final reporting of arrives emission estimates. Under this category of emissions (IPPU), for most sub-categories, activity data is sourced from the ASI database, which provides a unit level information on the process output and consumption of specific material inputs, which leads to the IPPU emissions. Wherever, information from the ASI database is not available, or doesn't confirms well with other reference national estimates; as a measure of quality control, we have used alternative source of information to avoid any discrepancies. The methodology section clearly highlight such sections, where ASI is not a principle source of information on the activity data. Similarly, information on the emission factors is derived from standard IPCC guidelines, and is ensured to appropriately represent right set of industry process.

The final results are clearly highlighted in excel spreadsheets (accessible from the GHG Platform India website), where subsequent tabs provide clarity on calculations, data points (emission factors, activity data), units of measurement in an easily understood manner. A user can reproduce same results by using information (from the spreadsheets) and the formulae mentioned in the methodology section of this study.

Hence, the entire GHG estimates were measured through a quality control process in a transparent manner for its accuracy, completeness, comparability and consistency across the years.

Quality Assurance

As a measure of quality assurance, the entire process of emission estimation and reporting is duly peer reviewed by third party, here in this case – WRI India. Periodic consultations and review cycles were organised with them to ensure that methodology, assumptions and proxies, and prudent to reflect best possible GHG estimates for the sector. The review process involved multiple rounds of communication with a continuous stream of feedback from their expert team. Regional consultation (Bangalore, Kolkata, and New Delhi) were also conducted to further validate our methodology and assumptions by inviting Industry experts, and other research community at those events. Corrective actions were duly incorporated in the estimation process for an overall improvement of the GHG estimates.

Recalculation

Estimation methodology has remained same and consistent with the good practice guidelines from IPCC. Hence, CEEW's final estimates (version 3.0) does not differ from the previous version for IPPU calculations.

Verification

Same as previous source category (energy use emissions).

Planned improvements

As a factor of improvement, we would prefer to see ASI to be more comprehensive in terms of its coverage. While it has limitations in terms of coverage, alternate data sources (at the national and state level) should complement the availability of activity data information in a comprehensive manner. A common source of information across the years and across the sectors is always a preferred choice, unlike the current practice of using segregated sources of information.

Public Consultation & Outreach

We co-hosted two roundtables with C-STEP (in Bangalore) and ICLEI-South Asia (in Kolkata) during 2017. The objective was to discuss our findings with a larger group of stakeholders, to incorporate their feedback in our study. We also presented our work at a roundtable hosted by one of partner organisation (Vasudha Foundation) in New Delhi, and got a positive response from a representative of MOEFCC's NATCOM cell.

Some of the industry representatives raised very specific arguments on following:

a) Inclusion of mining emissions disaggregated by location or mineral in the estimates
b) Estimations for iron and steel should include emissions from cupola furnace and sponge iron manufacturing.

In our response, we mentioned that while such details are useful for industry as well as researchers, India is yet to structure its reporting at Tier-3 level. Perhaps, industry should voluntary start keeping such records at their end, so that in future such nuances would be easier to capture.

There were few suggestions as well in terms of data usage. Following sources were recommended by audience for cross-verifying our activity data:

- Annual economic review for India
- State Directorates of Economics and Statistics, and other public records
- State Planning Board
- State Bureau of Applied Statistics and Economics

We have referred some of the above-mentioned sources already, and have kept them for consideration during state level inventory estimates.

S. No.	Comment	Received from			Relevance (Y/N)	Response
		Name	e-mail ID	Contact No.		
1						

Recommendation

This study is first of its kind, in terms of providing a time series of emission estimates for India's manufacturing sector in a transparent manner. It makes full uses of existing information with appropriate measures on correcting the data flaws, and assumptions on information gaps. However, in future, we should aspire for much better quality of information from government sources, and should make effort in apprising relevant ministries/departments for the benefit of improved datasets.

For the national level estimates, the early challenges faced by us was unavailability of segregated data on industrial energy consumption with the ministries of direct relevance; such as ministry of coal, ministry of petroleum and natural gas, ministry of power, etc. Thereafter, we explored the bottom-up information collected by the MOSPI through its ASI exercise for the want of better segregation of industrial energy consumption. The datasets were comprehensive but poor in quality. We have incorporated several corrective layers on the ASI datasets for this analysis. However, in future, we expect such quality checks to be embedded in the ASI system intrinsically. We have forwarded a set of recommendations to the MOSPI to improve their data collection process, and follow a dedicated section on energy data in their surveys.

References:

ASI. (2016, December 11). *Central Statistics Office; Industrial Statistics Wing* . Retrieved from Ministry of Statistics and Program Implementation: http://www.csoisw.gov.in/cms/cms/Files/243.pdf

CERC. (2017). *Operating Guidelines for Diesel Power Generation Units.* Retrieved from CERC: http://www.cercind.gov.in/oper2.htm

Choudhury, A., Roy, J., Biswas, S., Chakraborty, C. C., & Sen, K. (2004). Determination of carbon dioxide emission factors from coal combustion. In A. P. Mitra (Ed.), *In Climate Change and India: Uncertainty Reduction in Greenhouse Gas Inventory Estimates.* Hyderabad: Universities Press.

FAO. (2009). *Livestock's Long Shadow: Environmental Issues and Options.* Rome: United Nations. Retrieved 10 14, 2016, from ftp://ftp.fao.org/docrep/fao/010/a0701e/a0701e03.pdf

IBM. (2015, 3 1). *Indian Minerals Yearbook 2013.* Retrieved 4 22, 2016, from Indian Bureau of Mines: http://ibm.nic.in/index.php?c=pages&m=index&id=481

INCCA. (2010). *India: Greenhouse Gas Emissions 2007.* New Delhi: INCCA.

MOEFCC. (2015). *India: First Biennial Update Report to the United Nations Framework Convention on Climate Change.* New Delhi: Government of India.

MOSPI. (2015). *Energy Statistics 2015.* New Delhi: Central Statistics Office, Ministry of Statistics and Programme Implementation, Government of India.

MOSPI. (2016b). *National Industries Classification*. Retrieved 2016, from Ministry of Statistics and Programme Implementation: http://mospi.nic.in/Mospi_New/site/inner.aspx?status=2&menu_id=129

MOSPI. (2016c). *National product classification*. Retrieved 2016, from Ministry of Statistics and Programme Implementation: http://mospi.nic.in/Mospi_New/site/inner.aspx?status=2&menu_id=158

RBI. (2015, 9). *Handbook of Statistics on Indian Economy*. Retrieved 4 12, 2016, from Reserve bank of India: https://www.rbi.org.in/Scripts/AnnualPublications.aspx?head=Handbook%20of%20Statistics%20on%20Indian%20Economy

World Bank. (2017, April 19). *World Bank Data Bank - India*. Retrieved from World Bank: http://data.worldbank.org/country/india

Annexures:

<table>
<tr><td colspan="12">Annexure 1: Data sources for the energy and IPPU activity Data</td></tr>
<tr><td colspan="2"></td><td>2005</td><td>2006</td><td>2007</td><td>2008</td><td>2009</td><td>2010</td><td>2011</td><td>2012</td><td>2013</td><td>2014</td></tr>
<tr><td>IPCC codes</td><td>Sector/Subsector</td><td colspan="10">Data Sources Used for Emission Estimation</td></tr>
<tr><td>1A1b</td><td>Petroleum refining</td><td colspan="10">PNG Statistics - MoPNG</td></tr>
<tr><td>1A1ci</td><td>Manufacture of Solid Fuel</td><td colspan="10">ASI Data</td></tr>
<tr><td>1A1cii</td><td>Other Energy Industry</td><td colspan="10">Specfic fuel consumption CIL annual reports, MoPNG</td></tr>
<tr><td>1A2a</td><td>Iron and Steel</td><td colspan="10" rowspan="13">ASI Data</td></tr>
<tr><td>1A2b</td><td>Non-Ferrous Metals</td></tr>
<tr><td>1A2c</td><td>chemicals</td></tr>
<tr><td>1A2d</td><td>Pulp, Paper and Print</td></tr>
<tr><td>1A2e</td><td>Food Processing, Beverages and Tobacco</td></tr>
<tr><td>1A2f</td><td>non-metallic minerals</td></tr>
<tr><td>1A2g</td><td>Transport Equipment</td></tr>
<tr><td>1A2h</td><td>Machinery</td></tr>
<tr><td>1A2i</td><td>Mining (excluding fuels) and Quarrying</td></tr>
<tr><td>1A2j</td><td>Wood and Wood Products</td></tr>
<tr><td>1A2k</td><td>Construction</td></tr>
<tr><td>1A2l</td><td>Textile and Leather</td></tr>
<tr><td>1A2m</td><td>Non-specified Industry</td></tr>
<tr><td>2A1</td><td>Cement Production</td><td colspan="4">Cement Manufacturing Association</td><td colspan="6">Indian Mineral Yearbook (2009-14)</td></tr>
<tr><td>2A2</td><td>Lime Production</td><td colspan="10" rowspan="7">ASI Data</td></tr>
<tr><td>2A3</td><td>Glass Production</td></tr>
<tr><td>2A4a</td><td>Ceramics</td></tr>
<tr><td>2A4b</td><td>Other Uses of Soda Ash</td></tr>
<tr><td>2A4c</td><td>Non Metallurgical Magnesia Production</td></tr>
<tr><td>2A4d</td><td>Other</td></tr>
<tr><td>2A5</td><td>Other</td></tr>
<tr><td>2B1</td><td>Ammonia Production</td><td colspan="10">ASI Data- Ministry of chemicals and fertilizers</td></tr>
</table>

2B2	Nitric Acid Production	ASI Data		
2B3	Adipic Acid Production	Chemicals and Petrochemicals statistics 2014 (Ministry of chemicals and fertilizers)		
2B4	Caprolactam, Glyoxal and Glyoxylic Acid Production			
2B5	Carbide Production			
2B6	Titanium Dioxide Production			
2B7	Soda Ash Production			
2B8a	Methanol			
2B8b	Ethylene			
2B8c	Ethylene Dichloride and Vinyl Chloride Monomer			
2B8d	Ethylene Oxide			
2B8e	Acrylonitrile			
2B8f	Carbon Black			
2C1	Iron and Steel Production	ASI Data		
2C2	Ferroalloys Production			
2C3	Aluminium Production	USGS	Aluminium MCX India	IBM Mineral Yearbook (2010-14)
2C5	Lead Production	IBM Mineral Yearbook (2009-14)		
2C6	Zinc Production			
2C7	Other	ASI Data		
2D1	Lubricant Use	ASI Data		
2D2	Paraffin Wax Use			
2D4	Other	Specific Lubricant consumption CIL		

Source: CEEW

Annexure 2: Concordance between NIC-04 and IPCC codes

NIC-04	Group	**IPCC codes**
10,11	2 digit	1A1cii
12	2 digit	1A2m
13,14	2 digit	1A2i
15,16	2 digit	1A2e
17,18,19	2 digit	1A2l
20	2 digit	1A2j
21,22	2 digit	1A2d
23101	5 digit	1A1ci
23109	5 digit	1A1ci
232	3 digit	1A1b
24	2 digit	1A2c
25	2 digit	1A2m
26	2 digit	1A2f
271	3 digit	1A2a
272	3 digit	1A2b
27310	5 digit	1A2a
27320	5 digit	1A2b
28,29,30,31,32	2 digit	1A2h
33	2 digit	1A2m
34,35	2 digit	1A2g
36	2 digit	1A2m
45	2 digit	1A2k

Source: CEEW

Annexure 3: Concordance between NIC-08 and IPCC codes

NIC08		**IndCodeIPCC**
05,06	2 digit	1A1cii
07100	5 digit	1A2i
07210	5 digit	1A2m
0729	4 digit	1A2i
08	2 digit	1A2i
09	2 digit	1A1cii
10,11,12	2 digit	1A2e
13,14,15	2 digit	1A2l
16	2 digit	1A2j
17,18	2 digit	1A2d
191	3 digit	1A1ci
19201	5 digit	1A1b
19202	5 digit	1A1b
19203	5 digit	1A1b
19204	5 digit	1A1ci
19209	5 digit	1A1b
20,21	2 digit	1A2c
22	2 digit	1A2m
23	2 digit	1A2f
241	3 digit	1A2a
242	3 digit	1A2b
24311	5 digit	1A2a
24319	5 digit	1A2a
24320	5 digit	1A2b
25	2 digit	1A2h
261,262,263,264	3 digit	1A2h
265,267,268	3 digit	1A2m
27,28	2 digit	1A2h
29,30	2 digit	1A2g
31,32	2 digit	1A2m
41,42,43	2 digit	1A2k

Source: CEEW

Annexure 4: Conversion factors used for different fuel types

Description	UnitConversion
Anthracite (raw coal)	1
Benzol	1
Briquettes and similar solid fuels manufactured from coal, n.e.c.	1
Briquettes, coal, coal dust	1
Briquettes, coke	1
Coal	1
Coal (under sized)	1
Coal ash	1
Coal bed Methane	1
Coal compressed (middlings)	1
Coal consumed	1
Coal for carbonisation	1
Coal gas	1
Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons;n.e.c	1
Coal rejects	1
Coal slack	1
Coal tar by-product	1
Coal tar crude	1
Coal tar Oil	1
Coal tar peat	1
Coal tar processed	1
Coal tar product	1
Coal tar, crude	1
Coal tar, pitch	1
Coal washed	1
Coal, not agglomerated, n.e.c.	1
Coke and semi-coke of coal, of lignite or of peat; retort carbon n.e.c	1
Coke breeze	1
Coke cp	1
Coke dust	1
Coke hard	1
Coke mixed	1
Coke peat	1
Coke seme	1
Coke soft	1
Diesel	0.837520938
Fuel oils n.e.c	0.9765625
Fuel, aviation turbine	0.798722045
Furnace oil	0.000976563

Gas compressed natural	0.000711238
Gas consumed	
Gas oils	0.856164384
Gas, n.e.c	1
High speed diesel	0.826446281
Kerosene	0.798722045
Kerosene n.e.c	0.798722045
Kerosene type jet fuel	1
Light petroleum oil	0.862068966
Lignite briquettes	1
Lignite, agglomerated	1
Lignite, not agglomerated	1
Liquid or liquid gas fuel for lighter	1
Liquidified petroleum gas (LPG)	1
Liquified natural gas	0.000711238
Medium petroleum oil, n.e.c.	0.825082508
Motor spirit (gasolene), including aviation spirit n.e.c	0.734214391
natural gas	1
Oil, coal tar	1
Other coal tar oil pitch products, n.e.c.	1
Other gaseous hydrocarbons	1
Other light petroleum oils and light oils obtained from bituminous minerals n.e.c	0.862068966
Other than petroleum gas	1
Peat, hard/medium	1
Peat, n.e.c.	1
Peat, other than hard/medium	1
Petrol / motor spirit/ gasoline	1
Petrol, diesel, oil, lubricants consumed	
Petroleum coke	1
Petroleum coke calcined	1
Petroleum products obtained from bitumen n.e.c.	1
Pitch other than hard/medium	1
Pitch, hard/medium	1
Propane and butanes, liquefied, n.e.c.	1
Re-gasified LNG	1
Shale Oil	1
Spirit type (gasolene type) jet fuel	0.8
Superior kerosene	0.778210117
Tar from Coal or Lignite	1
Water gas	1

Source: CEEW

Annexure 5: Detailed topology of fuel wise (a) emission factors, (b) calorific value

Detailed description of fuel material	Domestic = H Imports = I	CalorificValue (TJ/Gg)	Emission Factors T/TJ		
			CO_2	CH_4	N_2O
Coal gas, water gas, producer gas and similar gases, other than petroleum gases and other gaseous hydrocarbons;n.e.c	H/I	38.7	44.7	0.001	0.0001
Gas consumed	H/I	0	0	0.001	0.0001
Gas, n.e.c	H/I	48	56.1	0.001	0.0001
Gas, n.e.c	H/I	48	56.1	0.001	0.0001
Liquid or liquid gas fuel for lighter	H/I	40.4	73.3	0.003	0.0006
Other gaseous hydrocarbons	H/I	38.7	44.7	0.001	0.0001
Other than petroleum gas	H/I	38.7	44.7	0.001	0.0001
Propane and butanes, liquefied, n.e.c.	H/I	47.3	63.1	0.001	0.0001
Water gas	H/I	38.7	44.7	0.001	0.0001
Anthracite (raw coal)	H	19.63	95.81	0.001	0.0015
Anthracite (raw coal)	I	26.7	98.3	0.001	0.0015
Briquettes and similar solid fuels manufactured from coal, n.e.c.	H	19.63	95.81	0.001	0.0015
Briquettes and similar solid fuels manufactured from coal, n.e.c.	I	26.7	98.3	0.001	0.0015
Briquettes, coal, coal dust	H/I	9.69	106.5	0.001	0.0015
Coal	H	19.63	95.81	0.001	0.0015
Coal	I	25.8	94.6	0.001	0.0015
Coal (under sized)	H	19.63	95.81	0.001	0.0015
Coal (under sized)	I	19.63	95.81	0.001	0.0015
Coal ash	H/I	9.69	106.5	0.001	0.0015
Coal compressed (middlings)	H	19.63	95.81	0.001	0.0015
Coal compressed (middlings)	I	26.7	98.3	0.001	0.0015
Coal for carbonisation	H	24.06	93.61	0.001	0.0015
Coal for carbonisation	I	28.2	94.6	0.001	0.0015

	Coal slack	H/I	9.69	106.5	0.001	0.0015
	Coal, not agglomerated, n.e.c.	H	19.63	95.81	0.001	0.0015
	Coal, not agglomerated, n.e.c.	I	26.7	98.3	0.001	0.0015
	Peat, hard/medium	H/I	9.76	106	0.001	0.0015
	Peat, n.e.c.	H/I	9.76	106	0.001	0.0015
	Peat, other than hard/medium	H/I	9.76	106	0.001	0.0015
	Benzol	H/I	28	80.7	0.001	0.0015
	Briquettes, coke	H/I	28.2	107.0	0.001	0.0015
	Coal gas	H/I	38.7	44.7	0.001	0.0001
	Coal rejects	H/I	9.69	106.5	0.001	0.0015
	Coal tar by-product	H/I	28	80.7	0.001	0.0015
	Coal tar crude	H/I	28	80.7	0.001	0.0015
	Coal tar Oil	H/I	28	80.7	0.001	0.0015
	Coal tar peat	H/I	28	80.7	0.001	0.0015
	Coal tar processed	H/I	28	80.7	0.001	0.0015
	Coal tar product	H/I	28	80.7	0.001	0.0015
	Coal tar, crude	H/I	28	80.7	0.001	0.0015
	Coal tar, pitch	H/I	28	80.7	0.001	0.0015
	Coal washed	H	19.63	95.81	0.001	0.0015
	Coal washed	I	25.8	94.6	0.001	0.0015
	Coke and semi-coke of coal, of lignite or of peat; retort carbon n.e.c	H/I	28.2	106.5	0.001	0.0015
	Coke breeze	H/I	38.7	44.7	0.001	0.0001
	Coke cp	H/I	28.2	107.0	0.001	0.0015
	Coke dust	H/I	9.69	106.5	0.001	0.0015
	Coke hard	H/I	28.2	106.5	0.001	0.0015
	Coke mixed	H/I	28.2	106.5	0.001	0.0015
	Coke peat	H/I	9.69	106.5	0.001	0.0015
	Coke seme	H/I	9.69	106.5	0.001	0.0015
	Coke soft	H/I	28.2	106.5	0.001	0.0015
	Lignite briquettes	H/I	9.69	106.5	0.001	0.0015
	Oil, coal tar	H/I	28	80.7	0.001	0.0015
	Other coal tar oil pitch products, n.e.c.	H/I	28	80.7	0.001	0.0015

Pitch other than hard/medium	H/I	28	80.7	0.001	0.0015
Pitch, hard/medium	H/I	28	80.7	0.001	0.0015
Tar from Coal or Lignite	H/I	28	80.7	0.001	0.0015
Coal consumed	H	19.63	95.81	0.001	0.0015
Coal consumed	I	25.8	94.6	0.001	0.0015
Lignite, agglomerated	H/I	9.69	106.5	0.001	0.0015
Gas compressed natural	H/I	48	56.1	0.001	0.0001
Gas natural	H/I	48	56.1	0.001	0.0001
Petrol, diesel, oil, lubricants consumed	H/I			0.003	0.0006
Diesel	H/I	43	74.1	0.003	0.0006
Fuel oils n.e.c	H/I	40.4	77.4	0.003	0.0006
Fuel, aviation turbine	H/I	44.3	69.3	0.003	0.0006
Furnace oil	H/I	40.4	77.4	0.003	0.0006
Gas oils	H/I	43	74.1	0.003	0.0006
High speed diesel	H/I	43	74.1	0.003	0.0006
Kerosene	H/I	43.8	71.9	0.003	0.0006
Kerosene n.e.c	H/I	43.8	71.9	0.003	0.0006
Kerosene type jet fuel	H/I	44.1	71.6	0.003	0.0006
Light petroleum oil	H/I	42.3	73.3	0.003	0.0006
Liquidified petroleum gas (LPG)	H/I	47.3	63.1	0.001	0.0001
Medium petroleum oil, n.e.c.	H/I	42.3	73.3	0.003	0.0006
Motor spirit (gasolene), including aviation spirit n.e.c	H/I	44.3	69.3	0.003	0.0006
Other light petroleum oils and light oils obtained from bituminous minerals n.e.c	H/I	42.3	73.3	0.003	0.0006
Petrol / motor spirit/ gasoline	H/I	44.3	69.3	0.003	0.0006
Petroleum coke	H/I	32.5	97.5	0.003	0.0006
Petroleum coke calcined	H/I	32.5	97.5	0.003	0.0006
Petroleum products obtained from bitumen n.e.c.	H/I	8.9	107	0.003	0.0006
Shale Oil	H/I	38.1	73.3	0.003	0.0006
Spirit type (gasolene type) jet fuel	H/I	44.3	69.3	0.003	0.0006
Superior kerosene	H/I	44.1	71.6	0.003	0.0006

Source: CEEW

Annexure 6: Classification of hydrocarbons as feedstock

	Treat as feedstock (if output NPCMS/ASICC is matching as fuel/non-energy product form this list)	
Detailed description of fuel material	**NIC-08 codes (to be treated as a feedstock and later have to perform mass balance)**	**NIC-04 codes (to be treated as a feedstock and later have to perform mass balance)**
Anthracite (raw coal)	191, 35	231, 40
Coal	191, 35	231, 40
Coal (under sized)	191, 35	231, 40
Coal ash	191, 35,2394	231, 40, (new: 2694)
Coal compressed (middlings)	191, 35	231, 40
Coal for carbonisation	191, 35, 22	231, 40, 25
Coal slack	191, 35	231, 40
Coal, not agglomerated, n.e.c.	191, 35	231, 40
Briquettes, coal, coal dust	191, 35	231, 40
Briquettes and similar solid fuels manufactured from coal, n.e.c.	191, 35	231, 40
Peat, hard/medium	191, 35	231, 40
Peat, other than hard/medium	191, 35	231, 40
Peat, n.e.c.	191, 35	231, 40
Lignite, not agglomerate	191, 35	231, 40
Lignite, agglomerated	191, 35	231, 40
Gas compressed natural	19203, 35, 20121, 20122, 20123	23203, 40, 24123, 24124, 24122, 24121
liquified petroleum gas	19203,35	23203, 40
natural gas	19203, 35, 20121, 20122, 20123	23203, 40, 24123, 24124, 24122, 24121
Gas, n.e.c	19203, 35, 20121, 20122, 20123	23203, 40, 24123, 24124, 24122, 24121
Shale Oil	19201, 19202, 19209, 35, 2022, 2023, 2211	23201, 23202, 23209, 40, 2422, 2424, 2511
Lignite briquettes	191, 35	231, 40
Coal gas	191, 35	231, 40
Other gaseous hydrocarbons	19203, 35	23203, 40
Briquettes, coke	191, 35	231, 40
Coal rejects	191, 35	231, 40
Coal washed	191, 35	231, 40
Coke breeze	191, 35	231, 40
Coke cp	191, 35	231, 40
Coke dust	191, 35	231, 40
Coke hard	191, 35	231, 40
Coke mixed	191, 35	231, 40
Coke peat	191, 35	231, 40
Coke seme	191, 35	231, 40
Coke soft	191, 35	231, 40
Coke and semi-coke of coal, of lignite or of peat; retort carbon n.e.c	191, 35, 22	231, 40, 25
Benzol	191, 35, 20, 21	231, 40, 24, 2423
Coal tar by-product	191, 35	231, 40

Coal tar crude	191, 35	231, 40
Coal tar Oil	191, 35	231, 40
Coal tar peat	191, 35, 22, 27	231, 40, 25, 31
Coal tar processed	191, 35	231, 40
Coal tar product	191, 35	231, 40
Tar from Coal or Lignite	191, 35	231, 40
Fuel, aviation turbine	19202, 19209, 2021, 2022, 2023, 1811	23202, 23209, 2421, 2422, 2424, 2221
Light petroleum oil	19202, 19209, 2022, 2023	23202, 23209, 2422, 2424
Other light petroleum oils and light oils obtained from bituminous minerals n.e.c	19202, 19209, 2022, 2023	23202, 23209, 2422, 2424
Kerosene	19202, 19209, 2021, 2022, 2023, 1811	23202, 23209, 2421, 2422, 2424, 2221
Superior kerosene	19202, 19209, 2021, 2022, 2023, 1811	23202, 23209, 2421, 2422, 2424, 2221
Kerosene n.e.c	19202, 19209, 2021, 2022, 2023, 1811	23202, 23209, 2421, 2422, 2424, 2221
Kerosene type jet fuel	19202, 19209, 2021, 2022, 2023, 1811	23202, 23209, 2421, 2422, 2424, 2221
Medium petroleum oil, n.e.c.	19202, 19209, 2022, 2023	23202, 23209, 2422, 2424
Gas oils	19202, 19209, 2022, 2023	23202, 23209, 2422, 2424
Fuel oils n.e.c	19202, 19209, 2022, 2023	23202, 23209, 2422, 2424
Furnace oil	19202, 19209, 2022, 2023	23202, 23209, 2422, 2424
Compressed natural gas (CNG)	19203, 35, 20121, 20122, 20123	23203, 40, 24123, 24124, 24122, 24121
Gas natural	19203, 35, 20121, 20122, 20123	23203, 40, 24123, 24124, 24122, 24121
Liquid or liquid gas fuel for lighter	19203,35	23203, 40
Liquidified petroleum gas (LPG)	19203, 35	23203, 40
Propane and butanes, liquefied, n.e.c.	19203, 35	23203, 40
Petroleum coke	23994, 24202, 19202, 19209, 35, 2022, 2023, 2211	26994, 27203, 23202, 23209, 40, 2422, 2424, 2511
Petroleum coke calcined	23994, 24202, 19202, 19209, 35, 2022, 2023, 2211	26994, 27203, 23202, 23209, 40, 2422, 2424, 2511
Petroleum products obtained from bitumen n.e.c.	19201, 19202, 19209, 2022, 2023	23201, 23202, 23209, 24124, 24122, 24121
Coal tar, crude	191, 35	231, 40
Coal tar, pitch	191, 35	231, 40
Oil, coal tar	191, 35	231, 40
Pitch other than hard/medium	191, 35	231, 40
Pitch, hard/medium	191, 35	231, 40
Other coal tar oil pitch products, n.e.c.	191, 35	231, 40
Gas consumed	19203, 35, 20121, 20122, 20123	23203, 40, 24123, 24124, 24122, 24121

Source: CEEW

Annexure 7: Heat rates used for captive power plants

Fuel Type	Captive Heat Rates (kCal/kWh)										Source
	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	
Coal	2927	2884	3004	2839	2749	2746	2740	2733	2670	2653	Annual Performance Review of Thermal Power Stations (2005-14)
Diesel	2100	2100	2100	2100	2100	2100	2100	2100	2100	2100	http://www.cercind.gov.in/oper2.htm
Gas	2260	2226	2319	2191	2122	2120	2115	2110	2061	2048	http://www.cercind.gov.in/oper1.htm

Source: CEEW

Annexure 8: Distribution of liquid fuel consumption across industry sectors for 2012-13

Sum of Quantity Consumed	**NIC codes at 2-digit**																						
Fuel type	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**
Bituminous oil	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	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%	0%	0%	1%	0%	0%	0%	0%	11%	0%	0%	0%	0%
Diesel	17%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%
Fuel oils n.e.c.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%	0%	0%	31%	0%	100%	0%
Fuel, aviation turbine	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	16%	0%	28%	0%	0%	0%
Furnace oil	76%	0%	0%	99%	100%	0%	0%	0%	0%	2%	4%	6%	11%	88%	99%	99%	0%	2%	79%	7%	69%	0%	0%
Glancepitch	0%	0%	0%	0%	0%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
High speed diesel	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kerosene	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Kerosene n.e.c	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	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%	0%	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%	0%	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%	0%	1%	0%	0%	0%	0%	65%	0%	0%	0%	0%	5%

Medium petroleum oil, n.e.c.	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	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%	0%	0%	0%	0%	0%	72%	0%	0%	0%	0%	0%	9%
Oil, Coal tar	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	1%	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%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Paraffin incl wax	5%	0%	100%	0%	0%	2%	92%	100%	0%	1%	92%	66%	37%	0%	0%	1%	0%	7%	6%	0%	0%	0%	83%
Petroleum coke	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	3%	0%	0%	0%	0%	0%	0%	1%	0%	0%
Petroleum coke calcined	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	5%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Petroleum jelly	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	20%	0%	0%	0%	0%	0%	11%	0%	34%	0%	0%	0%
Petroleum oils and oils obtained from bituminous minerals, crude	0%	0%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	2%	0%	0%	0%	0%
Petroleum products obtained from bitumen n.e.c.	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	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%	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Shale Oil	0%	0%	0%	0%	0%	27%	0%	0%	0%	0%	0%	0%	18%	0%	1%	0%	27%	0%	0%	0%	28%	0%	0%
Spirit type (gasolene type) jet fuel	0%	96%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Superior kerosene	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	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%	1%	30%	1%	0%	0%	0%	0%	0%	0%	1%	0%	3%
Wax polythene	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: CEEW

Annexure 9: Uncertainty analysis of assumptions on assigning emission factors to the unspecified fuel reporting

	Emissions CO_2Eq (tonnes)			
Year	Median	Diesel	Furnace oil	Petroleum Coke
2004-05	238582040	229752913	245744660	254687889
2005-06	265756012	255380334	271048924	291375806
2006-07	306834889	300120612	305045927	348132406
2007-08	352647099	345468363	348286651	382969638
2008-09	380409738	374076281	383959891	393194294
2009-10	458734695	450924492	467380737	477666061
2010-11	442305930	453309415	456077623	506439171
2011-12	478852613	485481334	485209228	505391027
2012-13	508442737	506614401	502525050	539324516
2013-14	524768275	515521177	516381315	550240326
	Variation of emissions due to distribution of unspecified fuels			
	Observed trend	**All Diesel**	**All Furnace oil**	**All Petroleum Coke**
2004-05	0%	4%	-3%	-7%
2005-06	0%	4%	-2%	-10%
2006-07	0%	2%	1%	-13%
2007-08	0%	2%	1%	-9%
2008-09	0%	2%	-1%	-3%
2009-10	0%	2%	-2%	-4%
2010-11	0%	-2%	-3%	-14%
2011-12	0%	-1%	-1%	-6%
2012-13	0%	0%	1%	-6%
2013-14	0%	2%	2%	-5%

Source: CEEW