CO_2 Baseline Database for the Indian Power Sector

User Guide

Version 20.0

December 2024

Government of India

Ministry of Power

Central Electricity Authority

Sewa Bhawan, R.K.Puram,
New Delhi-66

Revision History of the Database

Version No.	Date of Publication	Main Revisions Compared to Previous Version
1.0 Draft	October 2006	- Draft for Stakeholder Consultation
1.0	November 2006	- Added data on 10 stations which had been in exclusion worksheet of draft database - Adjusted values to latest IPCC Guidance (IPCC 2006 Guidelines for National Greenhouse Gas Inventories) where IPCC defaults are used
1.1	December 2006	- Adjusted fuel emission factor of lignite to be in line with Initial National Communication figures
2.0	June 2007	- Added data for FY 2005-06, including new stations and units commissioned during 2005-06 - Some retroactive changes to data for FY 2000-01 to 2004-05
3.0	December 2007	- Added data for FY 2006-07, including new stations and units commissioned during 2006-07 - Adapted calculations and User Guide to ensure consistency with new CDM methodologies: ACM0002 Version 07, and Tool to Calculate the Emission Factor for an Electricity System (Version 01.1, EB 35 Annex 12)
4.0	October 2008	- Added data for FY 2007-08, including new stations and units commissioned during 2007-08 - Adjusted delineation of regional grids - Adjusted IPCC-based fuel emission factors to account for uncertainty in line with EB 35 Annex 12
5.0	November 2009	- Added data for FY 2008-09, including new stations and units commissioned during 2008-09
6.0	March 2011	- Added data for FY 2009-10, including new stations and units commissioned during 2009-10
7.0	January 2012	- Added data for FY 2010-11, including new stations and units commissioned during 2010-11
8.0	January 2013	- Added data for FY 2011-12, including new stations and units commissioned during 2011-12 - From FY 2011-12, scope of database is restricted to stations exceeding 25 MW - Retroactive changes: Three units in NEWNE region identified as CDM units, leading to minor change in build margin for FY 2010-11
9.0	December 2013	- Added data for FY 2012-13, including new stations and units commissioned during 2012-13 - Retroactive changes: Nine units identified as CDM units, leading to changes in build margins back to FY 2009-10 - Updated GCVs of five stations back to FY 2008-09
10.0	December 2014	- Added data for FY 2013-14, including new stations and units commissioned during 2013-14 - Introduced distinction between Indian and imported coal as from FY 2013-14 - Retroactive changes to previous FY due to: identification of CDM units, identification of waste heat recovery steam turbines, harmonization of GCV for oil used as secondary fuel - One station was reclassified from SR to NEWNE region
11.0	April 2016	- Added data for FY 2014-15, including new stations and units commissioned during 2014-15 - Introduced integrated Single Indian Grid (NEWNE and Southern are now synchronized) - Export of power to Bangladesh also considered in the Import/Export data.
12.0	May 2017	- Added data for FY 2015-16, including new stations and units commissioned during 2015-16
13.0	June 2018	- Added data for FY 2016-17, including new stations and units commissioned during 2016-17 - Export of power to Myanmar also considered in the Import/Export data.
14.0	December 2018	- Added data for FY 2017-18, including new stations and units commissioned during 2017-18
15.0	December 2019	- Added data for FY 2018-19, including new stations and units commissioned during 2018-19
16.0	March 2021	- Added data for FY 2019-20, including new stations and units commissioned during 2019-20 - Some retroactive changes to data for FY 2018-19
17.0	October 2021	- Added data for FY 2020-21, including new stations and units commissioned during 2020-21
18.0	September 2022	- Added data for FY 2021-22, including new stations and units commissioned during 2021-22
19.0	December 2023	- Added data for FY 2022-23, including new stations and units commissioned during 2022-23 - Unit wise emission factor calculated for 2022-23 - Captive Power Injection into the grid incorporated for calculating grid emission factor - Renewable Energy transactions through Open access adjusted to avoid double accounting
20.0	December 2024	- Added data for FY 2023-24, including new stations and units commissioned during 2023-24 - Build Margin and Combined Margin calculated for year accounting for renewable energy generation into the grid.

Expert Team Contributing to the Database

Central Electricity Authority:

Shri. Vijay Menghani, Chief Engineer (CE&ET)

Shri. Sachin K. Bhise, Director (CE&ET)

Shri. Manoj Kumar, Dy. Director (CE&ET)

Shri. Harkaran Singh, Asst. Director (CE&ET)

Contents

Summary

Since the emergence of the Kyoto Protocol and its Clean Development Mechanism (CDM), energy projects lowering the carbon intensity of the electricity grid can generate additional revenues from carbon credits. Methodologies approved by the CDM Executive Board have to be applied to determine the resulting emission reductions, using the “baseline” CO_2 emission factor of the relevant geographical area.

The Paris agreement in 2015 called for the establishment of a ‘Sustainable Development Mechanism (SDM)’. SDM is the direct successor to the Clean Development Mechanism (CDM) under the Kyoto Protocol. The goals of the SDM are to promote higher ambition that contributes to emission reductions and sustainable development, and deliver an overall mitigation of greenhouse gas emissions. In the Paris Agreement, all countries have made mitigation pledges in the form of their NDCs (Nationally Determined Contributions). To facilitate the achievement of India’s enhanced NDC targets, India is on the pathway to develop a robust framework for the Indian Carbon Market (ICM) with an objective to decarbonize the Indian economy by pricing the GHG emission through trading of the carbon credit certificates.

In order to facilitate adoption of authentic baseline emissions data and also to ensure uniformity in the calculations of CO_2 emission reductions, Central Electricity Authority (CEA) has compiled a database containing the necessary data on CO_2 emissions for all grid-connected power stations in India.

All regional grids have been integrated as a single Indian Grid covering all the states in December 2013. Small power exchanges also take place with the neighbouring countries Bhutan, Nepal, Bangladesh and Myanmar. For the unified grid, the main emission factors are calculated in accordance with the relevant CDM methodologies. CEA will continue updating the database at the end of each fiscal year.

To show the impact of Renewable energy in reducing the CO_2 emission intensity of Indian Electricity Generation, weighted average emission factor is also calculated by including Renewable energy. The calculations are based on generation, fuel consumption and fuel quality data obtained from the power stations. Typical standard data were used only for a few stations where information was not available from the station. The prevailing baseline emissions based on the data for the FY 2023-24 are shown in Table S.

Table S: *Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of the Indian Grid for FY 2023-24 (adjusted for cross-border electricity transfers)* ***(including RES & Captive power injection into grid)****, in* tCO_2/MWh

Average	OM	BM	CM
0.727	**0.962**	**0.552**	**0.757**

Average is the average emission of all stations in the grid, weighted by net generation.

OM is the average emission from all stations excluding the low cost/must run sources.

BM is the average emission of the 20% (by net generation) most recent capacity addition in the grid (including RE).

CM is a weighted average of the OM and BM (here weighted 50: 50).

1 Background and Objective

Purpose of the CO_2 Database

The Clean Development Mechanism (CDM) under the Kyoto Protocol to United Nations Framework Convention on Climate Change (UNFCCC) provides an opportunity for the Indian power sector to earn revenue through the reduction of greenhouse gas emissions (GHG), particularly carbon dioxide (CO_2). India has tremendous potential for CDM projects. Power generation based on higher efficiency technologies such as supercritical technology, integrated gasification combined cycle, and renovation and modernisation of old thermal power plants, co-generation along with renewable energy sources are some of potential candidates for CDM in the power sector. Energy efficiency and conservation projects also present themselves as eligible CDM projects, as these would also result in energy savings and displace associated CO_2 emissions which otherwise would be produced by grid-connected power stations.

The CDM has by now become an established mechanism for crediting climate friendly projects. Projects involving displacement or saving of grid electricity must calculate their emission reductions based on a grid emission factor, which needs to be determined in accordance with the rules set by the CDM Executive Board. Central Electricity Authority (CEA) accordingly took up to compile a database for all grid-connected power stations in India. The purpose of the database is to establish authentic and consistent quantification of the CO_2 emission baseline, which can be readily used by CDM project developers in the Indian power sector. This would enhance the acceptability of Indian projects and would also expedite the clearance/approval process. The baseline emissions for the Indian Grid are given in Section 5 (Results) of this User Guide. The complete updated CO_2 Database (Microsoft Excel File) and this User Guide along with all previous versions is available on the website of Central Electricity Authority: www.cea.nic.in.

The purpose of this User Guide is to provide a ready reference to the underlying calculations and assumptions used in the CO_2 database and to summarise the key results.

Official Status of the Database

The database is an official publication of the Government of India for the purpose of CDM baselines. It is based on the most recent data available with the Central Electricity Authority.

Consistency of the Database with CDM Methodologies

Under the CDM, emission reductions must be quantified using an approved methodology. Key examples of such methodologies include AMS-I.D and ACM0002 for grid-connected power generation from renewable sources in small- and large-scale projects, respectively. The latest versions of all approved CDM methodologies are available at the official CDM website, http://cdm.unfccc.int.

In addition, the CDM Executive Board has adopted a methodological tool to facilitate the calculation of baseline emission factors for electricity grids.[1] This tool, which is referred to as the

[1] Tool to calculate the emission factor for an electricity system (Version 7.0). See http://cdm.unfccc.int

Grid Tool in this user guide, has become the main reference for CDM methodologies involving baseline emission factors for power grids, such as ACM0002.

This version of the database is designed to be consistent with version 7.0 of the Tool to calculate the emission factor for an electricity system published by the CDM Executive Board.

Installed Capacity

As a result of the impressive growth attained by the Indian Power Sector, the installed capacity has grown from mere 1,713 MW in 1950 to 441969.60 MW as on 31.03.2024. Sector-wise details of installed capacity are shown in Table 1.

Table 1: Sector- wise installed capacity (MW) as on 31.03.2024

Sector	Thermal					Nuclear	Hydro	RES	Total
	Coal	Lignite	Gas	Diesel	Total				
State	69437.50	1150.00	7012.05	280.31	77879.86	0.00	27254.45	2535.11	107669.43
Central	68019.96	3640.00	7237.91	0.00	78897.91	8180.00	15742.72	1632.30	104452.93
Private	73512.00	1830.00	10788.24	308.89	86439.15	0.00	3931.00	139477.09	229847.24
All India	210969.46	6620.00	25038.21	589.20	243216.87	8180.00	46928.17	143644.51	441969.55

Source: Installed Capacity Report by CEA for FY2023-24 (https://cea.nic.in/wp-content/uploads/installed/2024/03/IC_Mar_2024_allocation_wise.pdf).

Indian Grids

Historically, the Indian power system was divided into five independent regional grids, namely Northern, Eastern, Western, Southern, and North-Eastern. Each grid covered several states (see Table 2). Since August 2006, however, all regional grids except the Southern Grid had been integrated and were operating in synchronous mode, i.e. at same frequency. Consequently, the Northern, Eastern, Western and North-Eastern grids were treated as a single grid named as NEWNE grid from FY 2007-08 onwards for the purpose of this CO_2 Baseline Database. As of 31 December 2013, the Southern grid has also been synchronised with the NEWNE grid, hence forming one unified Indian Grid.

Power generation and supply within the Indian Grid is managed by Regional Load Dispatch Centres (RLDC). The National Power Committee (NPC) and Regional Power Committees (RPCs) provide a common platform for discussion and solution to the national and regional problems relating to the grid. Each state meets their demand with their own generation facilities and also with allocation from power plants owned by the central sector such as NTPC and NHPC etc. and IPP's being operated by private sector. Specific quotas are allocated to each state from the central sector power plants. Depending on the demand and generation, there are cross-border electricity exports and imports (e.g., from Bhutan, Nepal, Bangladesh and Myanmar).

Table 2: Geographical scope of the Indian electricity grid

INDIAN GRID				
Northern	**Eastern**	**Western**	**North-Eastern**	**Southern**
Chandigarh	Bihar	Chhattisgarh	Arunachal Pradesh	Andhra Pradesh
Delhi	Jharkhand	Gujarat	Assam	Karnataka
Haryana	Orissa	Dadar & Nagar Haveli and Daman & Diu	Manipur	Kerala
Himachal Pradesh	West Bengal	Madhya Pradesh	Meghalaya	Tamil Nadu
Jammu & Kashmir	Sikkim	Maharashtra	Mizoram	Puducherry
Ladakh	Andaman-Nicobar*	Goa	Nagaland	Lakshadweep*
Punjab			Tripura	Telengana
Rajasthan				
Uttar Pradesh				
Uttarakhand				

**The union territories Andaman and Nicobar Islands and Lakshadweep islands are not connected to the National grid. The power generation and distribution systems of these territories is served by standalone systems.*

2 How to Use the Database

Structure of the Database

Emission reductions from CDM projects in the power sector are calculated based on the net electricity generated by the project and the difference between the emissions factors (in t CO_2/MWh) of the baseline and the project activity. The baseline emission factor reflects the carbon intensity of the displaced grid electricity. This baseline emission factor can be derived from the data provided in the CO_2 Database.

Specifically, the database contains the following elements:

- Worksheet "Database" provides the net generation and the absolute and specific CO_2 emissions of each grid-connected power station and individual units (see Section 4 for calculation approach). It also indicates stations and units which were included in the build margin
- Worksheet "Results" provides the most commonly used aggregate emission factors. These are calculated from the station unit data in accordance with the most recent Grid Tool.[2] The emission factors are explained in more detail in the next section.
- Worksheet "Abbreviations" explains the abbreviations used in the "Datasheet" worksheet.
- Worksheet "Assumptions" shows the assumptions that were used for the calculation of the CO_2 emissions at station and unit level, where the information was not provided by the station.
- Worksheet "Transfers" shows the cross-border power transfers.

Different Types of Emission Factors:

The CDM methodologies which have been approved to date by the CDM Executive Board distinguish a range of different emission factors. In the Indian context, the following four are most relevant, and were therefore calculated for the Indian Grid based on the underlying station data:

Weighted average:
The weighted average emission factor describes the average CO_2 emitted per unit of electricity generated in the grid. It is calculated by dividing the absolute CO_2 emissions of all power stations by the total net generation. Net generation from so-called low-cost/must-run sources is included in the denominator. In India, hydro and nuclear stations qualify as low-cost/must-run sources. The weighted average emission factor also includes generation from Renewable sources and grid connected captive stations.

Simple operating margin (OM):
The operating margin describes the average CO_2 intensity of the existing stations in the grid which are most likely to reduce their output if a CDM project supplies electricity to the grid (or reduces consumption of grid electricity). "Simple" denotes one out of four possible variants

[2] *Tool to calculate the emission factor for an electricity system* (Version 7.0). See http://cdm.unfccc.int

listed in the Grid Tool for calculating the operating margin.[3] Furthermore, option A has been selected as the required disaggregated data is available in India.

The simple operating margin is the weighted average emissions rate of all generation sources *except* so-called low-cost or must-run sources (hydro, nuclear and other renewable stations) and are excluded. The operating margin, therefore, can be calculated by dividing the grid's total CO_2 emissions by the net generation of all thermal stations (including Captive). In other words, it represents the weighted average emissions rate of all thermal stations connected to grid.

Values for operating margins given in this User Guide and the Database are always based on the "ex post" option as set out in the Grid Tool.[4]

Build margin (BM):

The build margin reflects the average CO_2 intensity of newly built power stations that will be (partially) replaced by a CDM project. In accordance with the Grid Tool, the build margin is calculated in this database as the average emissions intensity of the 20% most recent capacity additions including renewable energy generation. The build margin generally covers units commissioned in the last five years.

Combined margin (CM):

The combined margin is a weighted average of the simple operating margin and the build margin. By default, both margins have equal weights (50%). However, CDM project developers may choose to argue for different weights. In particular, for intermittent and non-dispatchable generation types such as wind and solar photovoltaic, the Grid Tool allows to weigh the operating margin and build margin at 75% and 25%, respectively. However, the combined margins shown in the database are calculated based on equal weights.

In line with the Grid Tool, if a station is registered as a CDM activity, it is excluded from the build margin but not from the operating margin.[5]

---

3 The two variants "Simple adjusted operating margin" and "Dispatch data analysis operating margin" cannot currently be applied in India due to lack of necessary data.

4 See *Tool to calculate the emission factor for an electricity system* (Version 7.0).

5 See *Tool to calculate the emission factor for an electricity system* (Version 7.0), pp. 16 and pp 25 point (f)

3 Scope of Database

The database used for CO_2 emission calculation includes all grid-connected power stations[6] which covers power stations of both public utilities and independent power producers (IPPs).

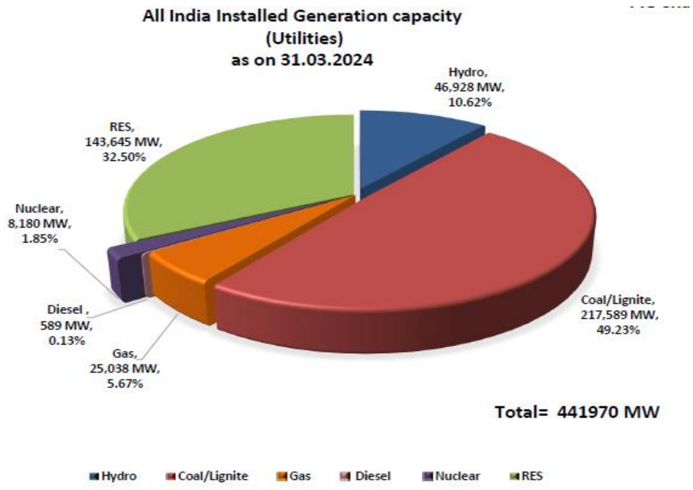

Figure 1: Breakdown of the total I/C corresponds to 441970 MW as on 31.03.2024

The following power stations are currently not included in the database:

- Small decentralised generation sets;
- Stations or units installed in Andaman and Nicobar Islands and Lakshadweep ; as they are not connected to the Indian Grid;

Renewable energy generation into the grid is accounted for calculating the average emission factor of the Indian grid. However, the detail of these plants are not included in the database due to non-availability plant wise RE data.

Captive power stations: As on 31 March-2024, the aggregate installed capacity of captive stations in industries having demand of 0.5 MW and above was 79,340 MW inclusive of 7500 MW approx. of non-conventional renewable energy capacity**.** The generation of these stations in FY 2022-23 was 211,931 MUs and estimated generation in FY 2023-24 is 214,581 MUs (provisional figure) [7].The estimated Energy injection into the grid by captive plants is 17560 MUs (provisional figure) in FY 2023-24. The details of captive plants could not be added in this database due to non-availability of plant wise data, but energy injection into the grid is accounted for calculation of Weighted Average emission factor of the Indian Grid (Table S).

Non-conventional renewable energy stations: These include hydro stations up to 25 MW, as well as all wind, biomass and solar photovoltaic stations. The installed, grid-connected capacity of these sources was 1,43,645 MW as on 31.03.2024.[8] The generation from these non-conventional renewable energy sources in FY 2023-24 was 225,830 MUs. The detail of these plants is not included in data base but used for calculation of Weighted Average emission factor of the Indian Grid (Table S).

---

6 Captive Power Injection into the grid for FY 2023-24 is calculated based on progressive analysis of 2022-23 published Data and estimated installed capacity in 2023-24.

7 Growth of Electricity Sector in India From 1947-2024 by CEA (https://cea.nic.in/wp-content/uploads/pdm/2024/08/Growth_Book_2024.pdf ; Pages-60/64).

8 The installed capacity for FY 2023-24 as reported by CEA (https://cea.nic.in/wp-content/uploads/installed/2024/03/IC_Mar_2024_allocation_wise.pdf).

4 Data and Calculation Approach

This section gives an overview on the base data, annual data as well as the approaches used to calculate station-level and unit-level CO_2 emissions.

4.1 Base Data

The following base data parameters were collected for all the stations listed in the CO_2 database:

- **S No:**
  The Station Numbers start at 1 and proceed alphabetically for all stations. All units of a station have the same station number. Numbers may change in future database versions due to insertion of new stations. Few Stations Numbers are not included in the list for either they are de-commissioned or not relevant in the database category.

- **Station Name:**
  Name of the power station. The station names have been arranged in alphabetical order.

- **Unit Number:**
  The units of a station are numbered serially starting with 1. Stations are attributed with unit number 0 for the purpose of calculations.

- **Commissioning Date:**
  The commissioning date is provided for each unit. Commissioning dates are important for the determination of the build margin.

- **Capacity:**
  Capacity data is based on declared rated capacities in MW for each unit as of 31st March 2024.

- **State:**
  State where the power station is located.

- **Sector:**
  This denotes whether the station is operated by the central sector, the state authorities, or the private sector.

- **System:**
  A list of the systems including abbreviations and full names is provided in Appendix A.

- **Type:**
  Indicates the type of the station, viz. thermal, nuclear, and hydro.

- **Fuel:**
  Fuel 1 and Fuel 2 indicates the main fuels used for power generation at each station. For example, in coal-based stations, Coal is indicated as Fuel 1 and Oil as Fuel 2.

4.2 Annual Data

The annual data columns in the database provide the following: net generation in GWh of the station, absolute carbon dioxide emissions in metric tonnes, and specific carbon dioxide emissions in t CO_2/MWh, for 2023-24. In addition, there are columns to indicate whether the station is included in the build margin in the respective year. If a unit is part of a registered CDM activity, it is excluded from the build margin, and the CDM registration number is indicated in the respective column.

CEA has compiled the CO_2 Database based upon generation, fuel consumption and fuel gross calorific value (GCV) data furnished by each power station. In cases where the station could not provide reliable data for all the relevant parameters, assumptions were made as described below. Further details on the assumptions made are provided in Appendix B.

a) Assumptions at Station Level

At the station level, the following assumptions were made where the relevant data could not be provided by a station:

Net generation:
For hydro stations, only gross generation was available, but not net generation data. Therefore, the CEA standard value for auxiliary power consumption in hydro units (0.5%) was applied to derive the net generation from the gross generation data reported by the stations. Likewise, CEA standard values for auxiliary power consumption had to be applied for some thermal stations.

Gross Calorific Value (GCV):
Default values were used for some thermal stations where station-specific GCVs were not available.

If the station consists just of one unit, the assumptions at unit level were applied to the station level.

b) Assumptions at Unit Level

At unit level, the following assumptions were made-

Gross generation:
For some stations, gross generation data were not shared by generating stations at Unit level. Hence, the gross generation figures were taken from the CEA publication by OPM Division for Annual Generation Data for fiscal year 2023-24.

Net generation:
Net generation data is being reported at unit level by thermal stations. However, for the stations where unit wise net generation data was not made available assuming that Unit level Auxiliary Power Consumption (APC) is in same proportion of station level APC.

Fuel consumption and GCV:
In case fuel consumption and GCV are not reported at unit level by thermal stations, the specific CO_2 emissions of the units coming in the build margin could usually be assumed to be equal to the values of the respective station. See Section 4.3 for details.

4.3 Calculation of CO_2 Emissions

Calculation Approach – Station Level

CO_2 emissions of thermal stations were calculated using the formula below:

$$AbsCO_2(station)_y = \sum_{i=1}^{2} FuelCon_{i,y} \times GCV_{i,y} \times EF_i \times Oxid_i \qquad (1)$$

Where:

$AbsCO_{2,y}$	Absolute CO_2 emission of the station in the given fiscal year 'y'
$FuelCon_{i,y}$	Amount of fuel of type i consumed in the fiscal year 'y'
$GCV_{i,y}$	Gross calorific value of the fuel i in the fiscal year 'y'
EF_i	CO_2 emission factor of the fuel i based on GCV
$Oxid_i$	Oxidation factor of the fuel i

The emission and oxidation factors used in the CO_2 Database are provided in Appendix B.

The emission factors for Indian coal and lignite were based on the values provided in India's Initial National Communication under the UNFCCC (Ministry of Environment & Forests, 2004). The emission factor for coal is supported by the results of an analysis of approx. 120 coal samples collected from different Indian coal fields. Since the values in the National Communication are based on the NCV (Net Calorific Value), they were converted to GCV basis using a formula also furnished in the National Communication. For all other fuels as well as for imported coal, default emission factors were derived from the IPCC 2006 Guidelines.[9] In line with the Grid Tool, the low-end values of the 95% confidence intervals indicated by IPCC were used.[10] The IPCC default factors were converted to GCV basis using IEA default conversion factors.

The oxidation factor for Indian coal and lignite was derived from an analysis performed with data on the unburnt carbon content in the ash from various Indian coal-fired power stations. The value of 98% is consistent with the default value provided in the IPCC 1996 Guidelines.[11] For all other fuels as well as imported coal, default values provided in the more recent IPCC 2006 Guidelines were used.

Specific CO_2 emissions of stations ($SpecCO_2\ (station)_y$) were computed by dividing the absolute emissions ($AbsCO_2\ (station)_y$) estimated above by the station's net generation ($NetGen\ (station)_y$).

$$SpecCO_2(station)_y = \frac{AbsCO_2(station)_y}{NetGen\,(station)_y} \qquad (2)$$

---

9 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 1.4

10 In accordance with the *Tool to calculate the emission factor for an electricity system*, *Version 7.0*

11 IPCC 1996 Revised Guidelines for National Greenhouse Gas Inventories, Volume 3 (Reference Manual), p.1.13

Calculation Approach – Unit Level

Unit-level CO_2 emissions were calculated for all the units in the database.

For determining the emissions of units, fuel consumption data at unit level was used wherever available in the same way as used for calculating the station emissions.

In the units where unit-level fuel consumption was not available, the fuel consumption of each unit was calculated on pro-rata basis of total fuel consumption of the station based on unit wise gross generation. The absolute CO_2 emission was then calculated individually for each unit.

4.4 Adjustment for Cross-Border Electricity Transfers

The weighted average emission factors and operating margins of the Indian Grid were adjusted for cross-border electricity imports and exports, in line with the Grid Tool:

- The relevant amounts of electricity imported and exported are listed in the database worksheet "Transfers";
- The CO_2 emissions associated with these imports were quantified based on the simple operating margin of the exporting grid.[12]

4.5 Generation from Renewable Energy Sources (RES)

During the review of the process of the computation it was noticed that since the declaration of 175 GW Renewable Energy Capacity in 2015, the Generation from Renewable Energy Sources (including Hydro) has increased gradually and its contribution in the Indian Power during 2023-24 was about 20.7 **%.** So the average carbon emission of electricity generation in India has been decreasing and this should be captured in computation. Hence in the computation of the weighted Average emission factor with RES, the total CO_2 emission has been divided by total electricity generated.

In this version of the report for the FY 2023-24, renewable energy generation is accounted for to calculate Build Margin (BM) and Combined Margin (CM) emission factors of the country. This gives improved results than the previous approach where renewable generation was not included to calculate BM and CM due to lack of available data.

To capture the role played by RES in decreasing the carbon emission intensity of the Indian electricity generation, the weighted average emission factor with RES has been computed for last ten years and is enclosed as Annexure- I.

12 This corresponds to Options a)+b) listed in the Grid Tool, (Version 7.0), p. 10 & 11

Methodology with examples:

For the ease of understanding, the methodology for computation of various emission factors is explained below:

1. **Weighted Average Emission factor**: It is computed by dividing the total CO_2 emission by net electricity generation.

$$\text{Weighted Average Emission factor (tCo2/MWh)} = \frac{\text{Total } CO_2 \text{ emission}}{\text{Net Electricity generation}}$$

   Total CO_2 emission from grid connected stations in 2023-24 = 1204.51 Million Tonne

   Net Electricity Generation into grid including import, RES and Captive = 1655.7 BU

   Weighted Average factor (Grid Emission Factor) = 1204.51 MT / 1655.7 BU
   = 0.727 tCO_2/MWh (Table S)

2. **Simple Operating Margin:** The operating margin is calculated by dividing the grid's total CO_2 emissions by the net generation of all sources except so-called low-cost or must-run sources. In other words, it represents the weighted average emissions rate of all thermal stations (including captive).

   Total CO_2 emission for the 2023-24 = 1204.51 Million Tonne

   Net Electricity Generation (Thermal) + Imports = 1248.86 + 3.86= 1252.72 BU

   Operating Margin =1204.51 /1252.72
   = 0.962 tCO_2/MWh (Table S)

3. **Build Margin**: The build margin reflects the average CO_2 intensity of newly built power stations that will be (partially) replaced by a CDM project. First 20 % of the net energy is computed and then it is attributed to newly commissioned units in reverse order in bucket fill mode. Then generation of all these units (which may be slightly higher than 20% of net generation) and their emission is used for computation of BM in accordance with the Grid Tool, the build margin is calculated in this database as the average emissions intensity of the 20% most recent capacity (including renewable capacity) in the grid based net generation.

   The net generation by **most recent capacity (including RES)** = 327.60 BU

   Total CO_2 emission from these units for the 2023-24 = 180.88 Million Tonne

   Build Margin = 180.88/327.6
   = 0.552 tCO_2/MWh

4. **Combined margin (CM):** The combined margin is a weighted average of the simple operating margin and the build margin. By default, both margins have equal weights (50%).

   Combined Margin = 0.5*OM + 0.5*BM
   = 0.5*0.962 + 0.5*0.552
   = 0.757 tCO_2/MWh

5 Results

Worksheet "Results" in the database provides the net generation and CO_2 emissions data and the resulting emission factors for the Indian Grid in the fiscal years 2019-20 to 2023-24. The emission factors are also reproduced in Appendix C. The values are rounded off at two decimals. See database file for additional decimals.

5.1 Results for Fiscal Year 2023-24

Table 3 indicates the development of total emissions over the last five years covered by the database.

Table 3: Total emissions of the power sector for the FY 2019-20 to 2023-24, in million tonnes CO_2

2019-20	2020-21	2021-22	2022-23	2023-24
960.90	928.14	910.02	1108.139*	1204.51*

*Corresponding to electricity injected into grid (including grid connected captive)

Table 4 shows the emission factors for FY 2023-24 both excluding and including cross-border power transfers.

Table 4: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of the Indian Grid for FY 2023-24 (not adjusted and adjusted for cross-country electricity transfers), in tCO_2/MWh

	Average	OM	BM	CM
Excluding cross-border power transfers	0.729	0.964	0.552	0.758
Including cross-border power transfers	0.727	0.962	0.552	0.757

A comparison of both cases in Table 4 shows that cross border electricity transfers did not have a significant influence on the emission factors in 2023-24.

Table 5 shows the weighted average specific emissions for fossil fuel-fired power stations in the Indian Grid.

Table 5: Weighted average specific emissions (on net generation) for fossil fuel-fired stations in FY 2023-24, in tCO_2/MWh

Coal	Diesel	Gas**	Lignite	Oil
0.969	-	0.451	1.30	-

Note: Stations for which assumptions had to be made are included in this analysis (see Section 4 for details).

5.2 Developments over Time

Figure 2 shows the Total Installed Capacity from 2014 to 2024 for the country. Out of the total installed Capacity, the share of Coal and Hydro based capacities has remained steady over a large period and in recent years the share of RES has significantly increased in the total installed capacity.

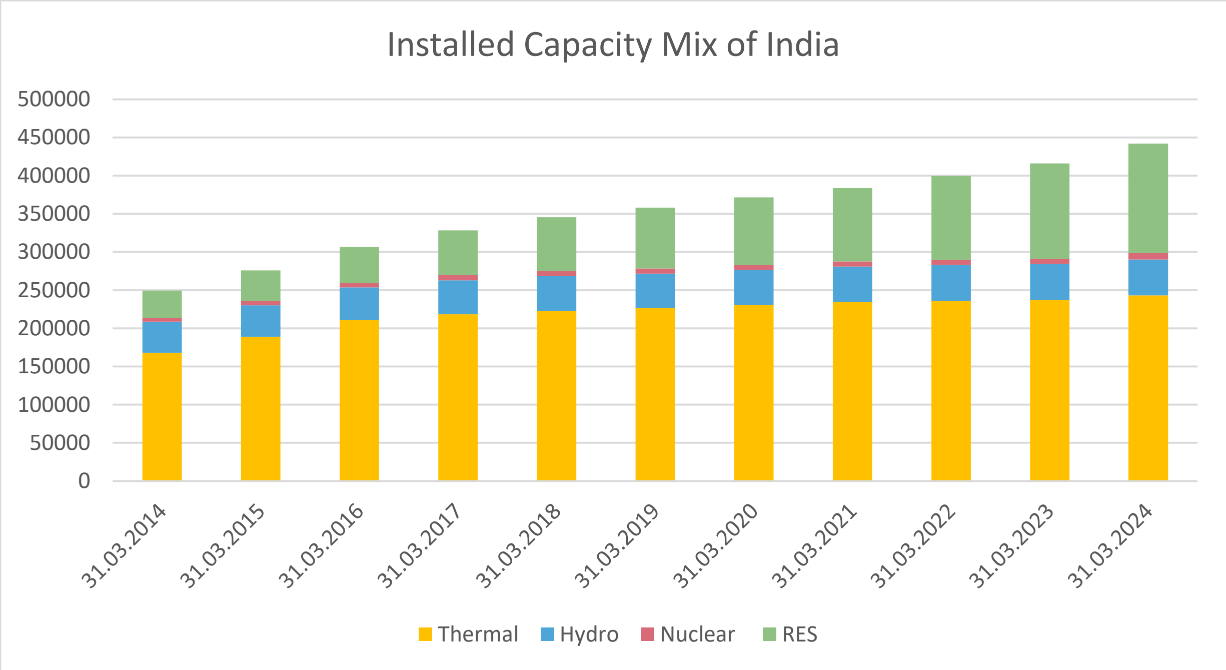

Figure 2: The Installed Capacity Mix of India

Figure 3 shows the development of the weighted average emission factor (including RES) over the period from FY 2019-20 to FY 2023-24. The weighted average emission factor has increased marginally in FY 2023-24 mainly due to the increase in total thermal generation. The thermal generation increased by 10% (approx.) in 2023-24 compared to 2022-23.

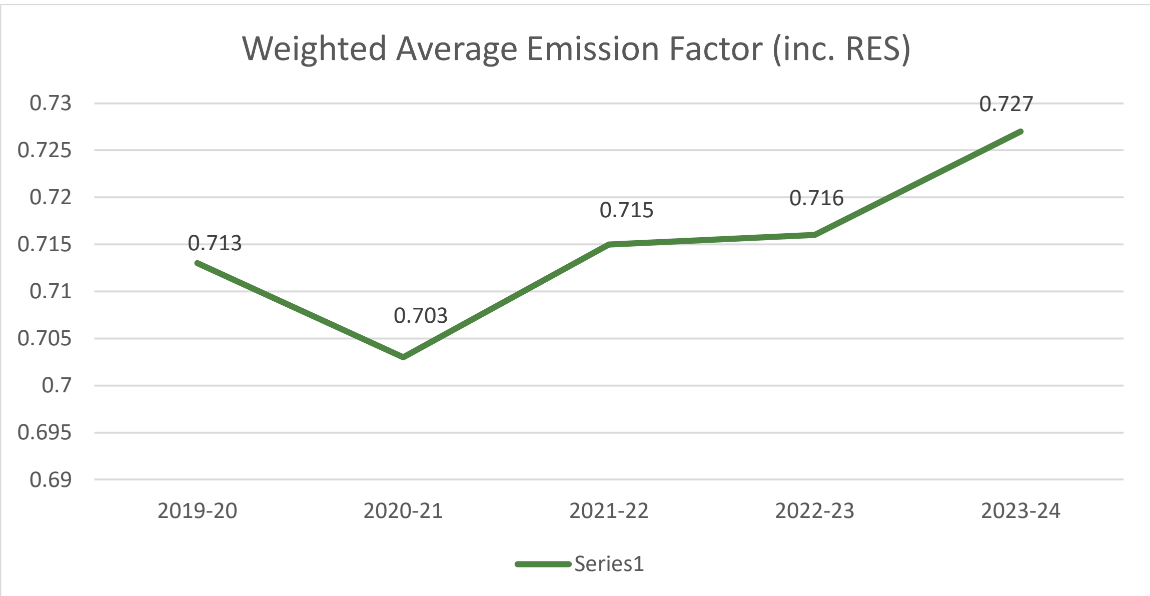

Figure 3 Development of the weighted average emission factor (adjusted for electricity transfers & inclusive of renewable generation) for the Indian Grid for the period 2019-20 to 2023-24

Figure 4 illustrates the development of the import-adjusted operating margins over the period from FY 2019-20 to FY 2023-24. In 2023-24, the import-adjusted operating margin has decreased marginally mainly due to increase in PLF of Coal+Lignite based plants from 64.15 in 2022-23 to 69.09 in 2023-24.

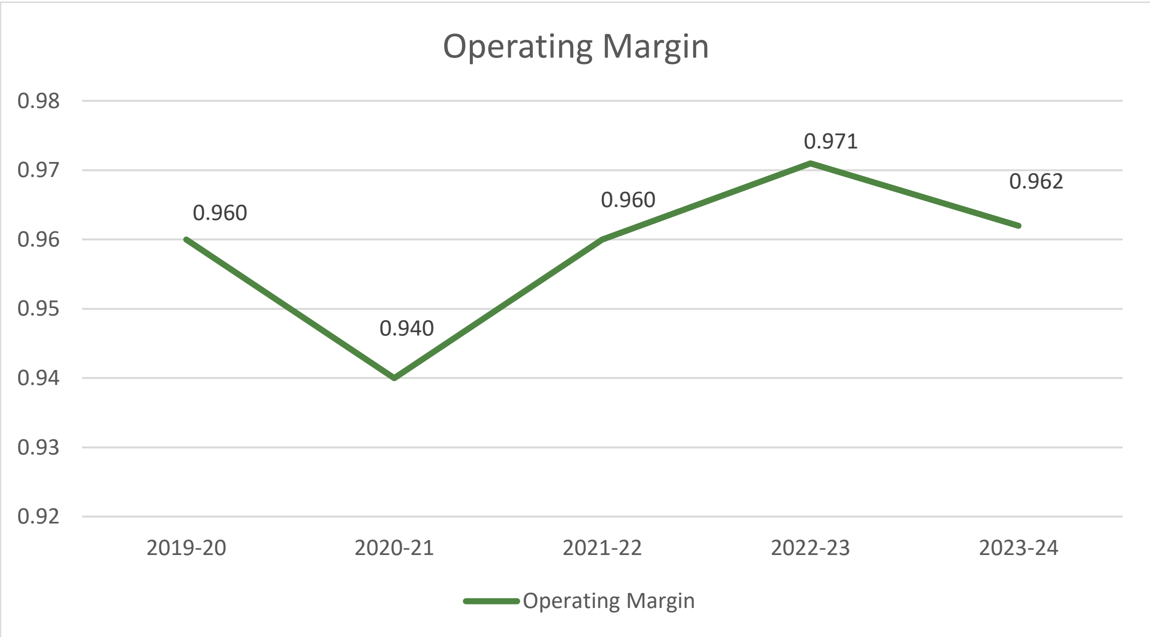

Figure 4: Development of the operating margin (adjusted for electricity transfers) for the Indian Grid over the period 2019-20 to 2023-24.

Figure 5 shows the build margins for the five fiscal years 2019-20 to 2023-24. With adoption of more efficient generation technologies such as Supercritical and Ultra-Supercritical Units accounted in the latest Installed capacity, a declining trend has been observed for the Build Margin. From 2023-24 year onwards, RE generation is also accounted to calculate the Build Margin. Therefore, there a decline is observed in the graph in 2023-24.

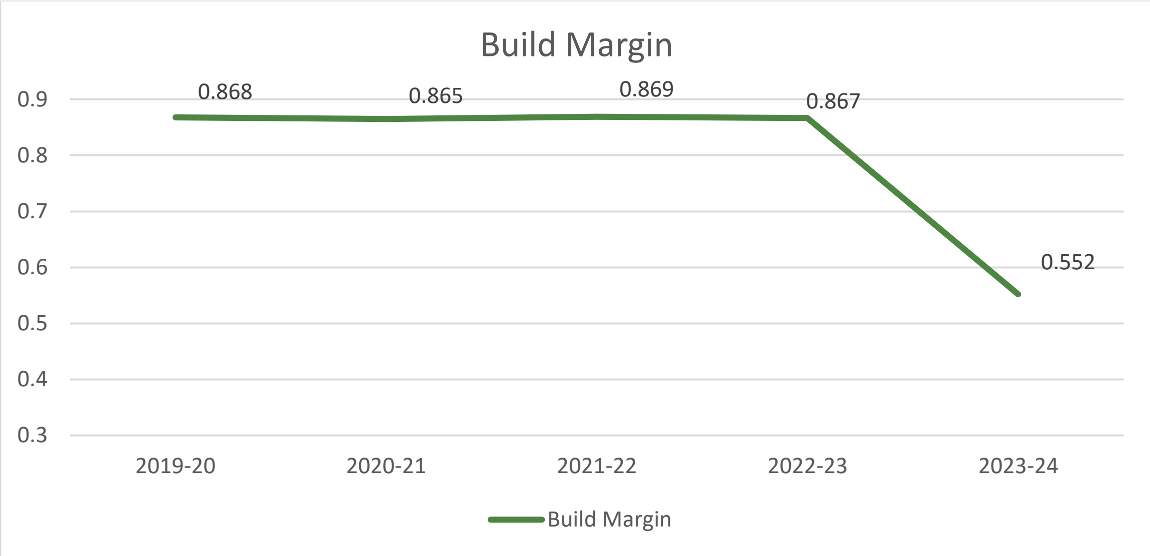

Figure 5: Development of the build margins over the period 2019-20 to 2023-24.

Figure 6 shows the trends in the import-adjusted combined margins in the period 2019-20 to 2023-24. In 2023-24, a decline is observed in the graph due to fall in combined margin after taking into account RE generation for calculating the build margin from this financial year on-wards.

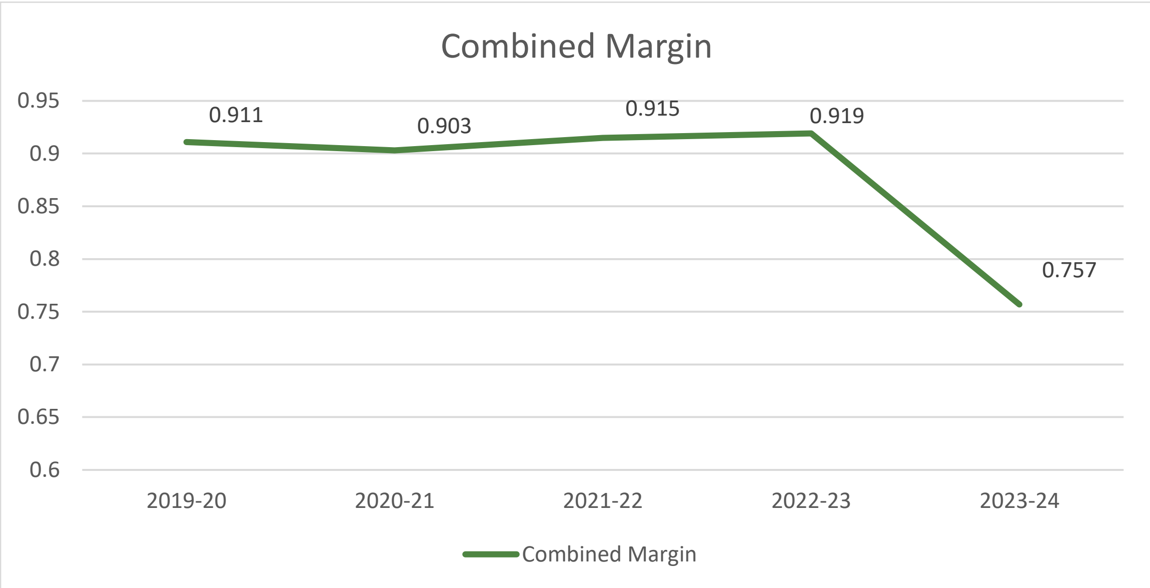

Figure 6: Development of the combined margin (adjusted for electricity transfers) for the Indian Grid over the period 2019-20 to 2023-24

5.3 Changes compared to Previous Database Versions

In comparison with the previous version of the Database (Version 19.0), this updated Version 20.0 includes the following changes:

- Added data for FY 2023-24, including new stations and units commissioned during 2023-24. De-commissioned units and plant have been removed from database.
- Made minor correction in data for the year 2022-23 in Annexure-I.
- The revised emission factors are provided in Appendix C and in the Database file.
- In 2023-24, RE generation is accounted to calculate Build Margin and Combined Margin emission factors. This gives improved emission intensity of the Indian grid.
- Due to inclusion of RE generation in BM and CM, only Table S is published in the year 2023-24 compared to two tables (S-1 and S-2) in the previous year.
- The four emission factors which are published for year namely weighted average emission factor, operating margin emission factor, build margin emission factor and combined margin emission factor. All these factors are inherently accounted for RE generation, captive generation and imports.
- All the data and graphs corresponding to average emission factor (without RE) has been excluded in this version of database and User Guide.

Installed capacity and Generation comparison for 2022-23 and 2023-24 as mentioned in Excel Database:

Year	Installed Capacity (in MW)				Gross Generation (in MU)			
	Thermal	Hydro	Nuclear	RES	Thermal	Hydro	Nuclear	RES
2022-23	237349	46850	6780	125160	1205894	162098	45861	203552
2023-24	243048	46928	8180	143645	1328084	134054	47937	225830

Table 6: Comparison between installed capacity and generation in 2022-23 and 2023-24

6 User Examples

6.1 This section provides two illustrative examples of how the CO_2 Database can be applied. The examples are based on hypothetical renewable energy projects

Project A is a grid-connected 5 MW small hydropower station located in the State of Assam. The station will be commissioned in 2025. Annual net generation is projected at approx. 17,500 MWh.

- The project qualifies as a small-scale CDM activity since its capacity is below the 15 MW threshold. Hence it will use the latest version of CDM methodology AMS-I.D for grid-connected renewable electricity generation.
- Methodology AMS-I.D gives two options for determining the baseline emission factor: Either the weighted average emissions, or the combined margin of the grid. In this example, it is assumed that the promoters choose the weighted average option. In addition, it is assumed that the promoters choose to adjust the weighted average emission factor for electricity imports, even though this is not mandatory under AMS-I.D.
- In the PDD, the expected emission reductions achieved by the hydro station are projected based on the expected annual generation, and the import-adjusted weighted average emission factor for the Indian Grid in the most recent year for which data is available (2023-24). The corresponding value is 0.727 tCO_2/MWh. Hence the absolute emission reductions are projected at 0.727 * 17,500 = 12,722.5 tCO_2/yr. The emission reductions are equal to the baseline emissions, since the project does not result in greenhouse gas emissions of its own.
- In accordance with AMS-I. D, the promoters will determine the *actual* baseline emission factor *ex post.* The actual emission reductions will then be calculated in each year of the crediting period based on the observed net generation and the weighted average emission factor for the respective year.[13] The latter would be published annually by CEA.

Project B is a 100 MW grid-connected wind farm located in the State of Tamil Nadu. The project will be commissioned in 2025. Average net supplies to the grid are projected at 312,500 MWh per year.

- The project exceeds the 15 MW threshold and thus qualifies as a large-scale CDM activity. Hence it is eligible to use the latest version of methodology ACM0002 for grid-connected power generation from renewable energy sources.
- Under ACM0002, the combined margin approach is mandatory.
- In contrast to the first example, the promoters decide to fix the baseline emission factor *ex ante.* That is, the baseline emission factor is determined based on the most recent data available, and remains fixed for the duration of the crediting period. The actual emission reductions will be calculated in each year based on the observed net generation and the pre-defined baseline emission factor.
- For this *ex ante*-option, the Grid Tool referred to in the methodology ACM0002 requires that the operating margin be calculated as the generation-weighted average of the three most recent years (here 2021-22 to 2023-24).[14] The operating margin to be applied thus works out to 0.964 t CO_2/MWh.
- Since wind is an intermittent energy source, the promoter is allowed to assign a weight of 75% to the operating margin, and 25% to the build margin. The resulting combined margin

[13] The emission factor of the previous year may be used instead. See *Tool to calculate the emission factor for an electricity system* (Version 7.0), p.16

[14] See *Tool to calculate the emission factor for an electricity system* (Version 7.0), p.16

is 0.861 t CO_2/MWh (75% x 0.964 + 25% x 0.552) for the FY (2023-24). This value is used for projecting the emission reductions in the PDD as well as for calculating the actual emission reductions.

The two CDM project activities are summarised in Table 7 below.

	Project A	Project B
Project Info		
Type:	Hydro station	Wind park
Size:	5 MW (small-scale according to CDM criteria)	100 MW (large-scale according to CDM criteria)
Projected Generation (net):	17,500 MWh /yr	312,500 MWh/yr
Commissioning year:	2025	2025
Year of CDM registration:	2025	2025
Grid :	Indian	Indian
CDM methodology:	AMS-I.D / Version 19	ACM0002 / Version 19.0
Baseline Emission Factor Calculation		
Calculation method:	Weighted average	Combined margin
Data vintage for projection of emission reductions:	2023-24 (most recent available at time of PDD validation)	For OM: 2021-22,2022-23,2023-24(most recent 3 years available at time of PDD validation) For BM: 2023-24
Data vintage for verification of emission reductions:	Actual year of generation, i.e., 2025-26, 2026-27 etc. (emission factor fixed *ex post*)	Same as for projection (emission factor fixed *ex ante*)
Accounting of imports:	Not mandatory, but done	Mandatory
Weights for combined margin:	Not applicable	Operating margin: 75% Build margin: 25% (default for intermittent sources)
Emission Reduction Calculations		
Values in t CO_2/MWh:	0.727 Weighted average	0.964 Operating margin 0.552 Build margin 0.861 Combined margin
Projected emission reductions:	12740 t CO_2 per year	269062.5 t CO_2 per year
Actual emission reductions:	Monitored net generation x monitored weighted average	Monitored net generation x fixed combined margin

Table 7: Illustration on how to use the CO_2 Database for calculating the emission reductions of CDM projects

6.2 Suggestive example to compute the emissions for electricity use for individual industrial consumers:

Case: An industry consuming 100 MUs of power from the grid, of which 70 MUs is taken from the grid through an STU/CTU connection without any specific requisite for RE power, 20 MUs of RE power taken through Open Access and remaining 10 MUs of RE power taken from state utility though a green tariff mechanism.

Total CO_2 emissions footprint of the industry from electricity consumption in this case will be calculated as:
Total CO_2 Emissions = (70 MU x Grid's Average Emission factor) + (20 MU x 0) + (10 MU x 0)
= 70,000 MWh x 0.727 tCO_2/MWh
= 50890 tCO_2= 50.89 $ktCO_2$.

Note: The emission factor for electricity procured through green open access and green tariff mechanism may be considered as zero.

7. Biomass Co-Firing in Thermal Power Plants (FY 2023-24)

Capacity (MW)	No. of TPPs started Co-firing	Biomass usage (MT) in FY 2023-24 (01.04.23 -31.03.2024)	Cumulative Biomass usage (MT) till date 31.03.2024
82412	**65**	**374857**	**493369**

Table 8: Biomass co-fired in Thermal Power Plants

Biomass Co-Firing results in reduction in amount of coal used for power generation resulting in corresponding savings in CO_2 emissions. This would also reduce the sector's dependence on coal.

8 Updating Procedure

The CO_2 Database will be updated annually by CEA and made available on its website: www.cea.nic.in. Previous versions will be archived by CEA and the main changes relative to previous database versions will be documented.

9 Further Information

For any further information, contact by email:

Chief Engineer (CE&ET)
Central Electricity Authority
Sewa Bhawan
R. K. Puram, New Delhi-110066
Email: ceet-cea@gov.in

Annexure –I

Weighted Average Emission Factor (Considering Renewable Energy Generation) of Indian Grid

FY	Total CO_2 Emissions (Million Tonnes)	Net Generation (BU) Conventional	RE generation (BU)	Total Net Electricity Generation (BU)	Weighted Average Emission factor of Grid Electricity (including RE) (tCO_2/MWh)
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)=(2)/(5)**
2013-14	727.4	886.77	53.06	939.83	**0.774**
2014-15	805.4	972.04	61.72	1033.76	**0.779**
2015-16	846.3	1027.03	65.78	1092.81	**0.774**
2016-17	888.34	1072.84	81.55	1154.39	**0.770**
2017-18	922.18	1121.57	101.84	1223.41	**0.754**
2018-19	960.9	1165.16	126.76	1291.92	**0.744**
2019-20	928.14	1162.97	138.34	1301.31	**0.713**
2020-21	910.02	1147.52	147.25	1294.77	**0.703**
2021-22	1002.01	1230.09	170.91	1401.01	**0.715**
2022-23*	1108.14	1320.18	203.55	1546.27	**0.716**
2023-24*	1204.51	1408.45	225.83	1655.70	**0.727**

**For the years 2022-23 and 2023-24, total CO_2 emissions are inclusive of electricity injected into the grid by grid connected captive power plants and total net electricity generation is also inclusive of electricity injected into the grid by grid connected captive power plants.*

Appendix A – Systems in India's Grids

	Full name
ABAN	ABAN Power Company
ADHPL	AD Hydro Power Limited
APCPL	Aravali Power Company Limited
APGCL	Assam Power Generation Corporation Limited
APGENCO	Andhra Pradesh Power Generation Co Limited
APPDCL	Andhra Pradesh Power Development Corporation Ltd.
ASEB	Assam State Electricity Board
BBMB	Bhakra Beas Management Board
BECL	Bhavnagar Energy Co. Ltd.
BSEB	Bihar State Electricity Board
BALCO	Bharat Aluminum Co. India Pvt. Ltd.
CESC	Calcutta Electric Supply Company Limited
CSEB	Chattisgarh State Electricity Board
CSPGCL	Chattisgarh State Power Generation Co Ltd
D.B. Power Ltd	Diligent Power Limited
DANS EPL	DANS Energy Pvt. Ltd.
DPL	Durgapur projects Limited
DVC	Damodar Valley Corporation
DVC Tata JV	Damodar Valley Corporation-Tata Joint Venture
GAMA	Gama Infraprop
GIPCL	Gujarat Industries Power Company Ltd
GMDCL	Gujarat Mineral Development Corporation Limited
GMR Chattisgarh	GMR Chattisgarh
GMR Energy	GMR Energy
GMR K Ltd	GMR Kamlanga Energy Ltd.
GMR Bajoli Holi	GMR Bajoli Holi Hydro Power Pvt. Ltd.
GPEC	Gujarat Paguthan Energy Corporation Pvt. Limited
GSECL	Gujarat State Electricity Corporation Limited
GSEGL	Gujarat State Energy Generation Limited
GTE Corp	GTE Corporation
GVK Ind.	GVK Power & Infrastructure Limited
GVK	GVK Group

	Full name
HEGL	HEG Limited
HIRANMAYE	Hiranmaye Energy Ltd.
HNPCL	Hinduja National Power Corp. Ltd.
HPGCL	Haryana Power Generation Corporation Limited
HPPCL	Himachal Pradesh Power Corporation Ltd.
HPSEB	Himachal Pradesh State Electricity Board
HSPPL	Himachal Sorang Power Pvt. Ltd.
IEPL	Ideal Energy Pvt. Ltd.
IL&FS TN PC Ltd.	IL&FS Tamil Nadu Power Co. Ltd.
INDSIL	Indsil Electrosmelt Ltd
IPPGCL	Indraprastha Power Generation Co Ltd
JINDAL	JSW Energy Limited
JIPL	Jas Infrastructure and Power Ltd.
JKEB	Jammu & Kashmir Electricity Board
JKPDC	Jammu & Kashmir Power Development Corp. Ltd.
JPHPL	Jai Prakash Hydro Power Limited
JPL	Jhabua Power Ltd.
JSEB	Jharkhand State Electricity Board
JSW Energy	JSW Energy Limited
JV NTPC & BSEB	Joint Venture NTPC & Bihar State Electricity Board
KPCL	Karnataka Power Corporation Limited
KSEB	Kerala State Electricity Board
KSK Ventures	KSK Energy Ventures Ltd.
LPG CO	Lalitpur Power Generation Co. Ltd.
LVS Power	LVS Power Limited
M B Power (M P)	M B Power Madhya Pradesh
MBPC	Madhya Bharat Power Corpn.
Madurai P	Madurai Power Corporation Limited
MAHAGENCO	Maharashtra State Power Generation Company Limited
MAPS	Madras Atomic Power Station
MEECL	Meghalaya Energy Generation Corporation Ltd.
MEGEB	Meghalaya State Electricity Board
MPDC	Manipur Power Development Corporation
MEECL	Meghalaya Energy Corporation Ltd.
MPDC	Manipur Power Development Corporation

	Full name
MPGPCL	Madhya Pradesh Power Generating Co. Ltd.
NAPS	Narora Atomic Power Station
NCTPP	National Capital Thermal Power Plant
NDPL	North Delhi Power Ltd.
NEEPCO	North Eastern Electric Power Corporation Ltd
NHDC	Narmada Hydro Electric Development Corporation
NHPC	National Hydro Electric Corporation
NLC	Neyvelli Lignite Corporation Ltd
NPC	Nuclear Power Corporation of India Ltd.
NTPC	NTPC Ltd
NTPC/NTECL	NTPC Tamilnadu Energy Company Limited
OHPC	Orissa Hydro Power Corporation
OPGC	Orissa Power Generation Corporation
PPCL	Puducherry Power Corporation Limited
PPGCL	Prayagraj Generation Co. Ltd.
PPNPG	PPN Power Generating Company Pvt. Limited
PSEB	Punjab State Electricity Board
RAPS	Rajasthan Atomic Power Station
RATANAGIRI	Ratnagiri Gas & power Pvt Ltd
REL	Reliance Energy Ltd
RKM PPL	RKM Powergen Pvt. Ltd.
RPG	RP Goenka Group
RRVUNL	Rajasthan Rajya Vidyut Utpadan Nigam
Samalpatti	Samalpatti Power Company Limited
SHIRPUR	Shirpur Power Pvt. Ltd.
SCPL Ltd.	Spectrum Power Limited
SEPC	Sepc Power Pvt. Ltd.
SJVNL	Sutluj Jal Vidyut Nigam Ltd
SKS Power	SKS Power Generation
SKPL	Sneha Kinetic Power Projects Pvt. Ltd.
SPECT. IND	Spectrum Power Generation Limited
SP&ML	Subhash Projects and Marketing Co. Ltd.

	Full name
SSVNL	Sardar Sorovar Vidyut Nigam Limited
STPS	Super Thermal Power Station
Tata MAH	Tata Power Company Limited
Tata PCL	Tata Power Company Limited
THDC	Tehri Hydroelectric Development Corporation
TNEB	Tamilnadu Electricity Board
Torr. Power	Torrent Power Limited
TSECL	Tripura State Electricity Corporation Limited
TSGENCO	Telangana Power Generation Corp. Ltd.
TVNL	Tenughat Vidyut Nigam Limited
UJVNL	Uttarakhand Jal Vidyut Nigam Limited
UPCL	Uttarakhand Power Corporation Limited
UPHPC	Uttar Pradesh Hydro Power Corporation Limited
UPRVUNL	Uttar Pradesh Rajya Vidyut Utpadan Nigam
VVNL	Visvesarya Vidyut Nigam Ltd
WBPDC	West Bengal Power Development Corporation Ltd
WBSEB	West Bengal State Electricity Board

Appendix B – Assumptions for CO_2 Emission Calculations

Fuel Emission Factors (EF) (Source: for Indian Coal/Lignite - Initial National Communication; for Imported Coal Gas/Oil/Diesel/Naphtha - IPCC 2006; for Corex - own assumption)

	Unit	Coal	Imported Coal	Lignite	Gas	Oil	Diesel	Naphtha	Corex
EF based on NCV	gCO_2 /MJ	95.8	89.5	106.2	54.3	75.5	72.6	69.3	0.0
Delta GCV NCV	%	3.6%	5.0%	3.6%	10%	5%	5%	5%	n/a
EF based on GCV	gCO_2 /MJ	92.5	85.2	102.5	49.4	71.9	69.1	66.0	0.0
Oxidation Factor	-	0.98	1.00	0.98	1.00	1.00	1.00	1.00	n/a
Fuel Emission Factor	gCO_2 /MJ	90.6	85.2	100.5	49.4	71.9	69.1	66.0	0.0

n/a = not applicable (i.e. no assumptions were needed)

Assumptions at Station Level (only where data was not provided by station)

	Unit	Coal	Lignite	Gas-CC	Gas-OC	Oil	Diesel-Eng	Diesel-OC	Naphtha	Hydro	Nuclear
Auxiliary Power Consumption	%	8.0	10.0	3.0	1.0	3.5	3.5	1.0	3.5	0.5	10.5
Gross Heat Rate	kcal /kWh (gross)	2,500	2,713	2,013	3150	2,117	1,975	3,213	2,117	n/a	n/a
Net Heat Rate	kcal /kWh (net)	2,717	3,014	2,075	3,182	2,193	2,047	3,330	2,193	n/a	n/a
Specific Oil Consumption	ml /kWh (gross)	2.0	3.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
GCV	kcal /kg (or m3)	3,755	n/a	8,800	n/a	10,100	10,500	10,500	11,300	n/a	n/a
Density	t /1,000 lt	n/a	n/a	n/a	n/a	0.95	0.83	0.83	0.70	n/a	n/a
Specific CO_2 emissions	tCO_2 /MWh	1.04	1.28	0.43	0.66	0.66	0.59	0.96	0.61	n/a	n/a

n/a = not applicable (i.e. no assumptions were needed)

Assumptions at Unit Level (by capacity; only for units in the BM, where data was not provided by station)

Coal	Unit	67.5 MW	120 MW	200-250 MW	300 MW	500 MW Type 1	500 MW Type 2	600 MW	660 MW Type 1	660 MW Type 2	800 MW
Gross Heat Rate	kcal /kWh	2,750	2,500	2,500	2,350	2,425	2,380	2,380	2,178	2,126	2126
Auxiliary Power Consumption	%	12.0	9.0	9.0	9.0	7.5	6.5	6.5	6.5	6.5	5.25
Net Heat Rate	kcal /kWh	3,125	2,747	2,747	2,582	2,622	2,545	2,545	2,329	2,274	2,244
Specific Oil Consumption	ml /kWh	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	0.5
Specific CO_2 Emissions	tCO_2 /MWh	1.19	1.05	1.05	0.99	1.00	0.97	0.97	0.89	0.87	0.85

Lignite	Unit	75 MW	125 MW	210/250 MW	500 MW
Gross Heat Rate	kcal /kWh	2,750	2,560	2,713	2713
Auxiliary Power Consumption	%	12.0	12.0	10.0	8.5
Net Heat Rate	kcal /kWh	3,125	2,909	3,014	2965
Specific Oil Consumption	ml /kWh	3.0	3.0	3.0	3.0
Specific CO_2 Emissions	tCO_2 /MWh	1.32	1.23	1.28	1.25

Gas	Unit	0-49.9 MW	50-99.9 MW	>100 MW
Gross Heat Rate	kcal /kWh	1,950	1,910	1,970
Auxiliary Power Consumption	%	3.0	3.0	3.0
Net Heat Rate	kcal /kWh	2,010	1,969	2,031
Specific CO_2 Emissions	tCO_2 /MWh	0.42	0.41	0.42

Diesel	Unit	0.1-1 MW	1-3 MW	3-10 MW	>10 MW
Gross Heat Rate	kcal /kWh	2,350	2,250	2,100	1,975
Auxiliary Power Consumption	%	3.5	3.5	3.5	3.5
Net Heat Rate	kcal /kWh	2,435	2,332	2,176	2,047
Specific CO_2 Emissions	tCO_2 /MWh	0.70	0.67	0.63	0.59

Naphtha	Unit	All sizes
Increment to Gas Heat Rate	%	2%
Gross Heat Rate	kcal /kWh	2,117
Auxiliary Power Consumption	%	3.5
Net Heat Rate	kcal /kWh	2,193
Specific CO_2 Emissions	tCO_2 /MWh	0.61

Combined Margin	Unit	
Weight OM	%	50%
Weight BM	%	50%

Conversion Factors	Unit	
Energy	kJ /kcal	4.1868
	MJ /kWh	3.6

Oil		
Specific Emission	gCO_2 /ml	2.89

Appendix C – Grid Emission Factors

Note: Values are rounded off at two decimals here. See Database (Excel File, Worksheet "Results") for additional decimals.

Table A: Values for FY 2019-20 to 2023-24, excluding cross-border electricity transfers.

Emission Factors (tCO$_2$/MWh) (excl. Imports)	2019-20	2020-21	2021-22	2022-23	2023-24*
Weighted Average Emission Rate (Incl RES)	0.713	0.703	0.715	0.719	0.729
Simple Operating Margin (1)	0.96	0.95	0.97	0.976	0.964
Build Margin	0.87	0.87	0.87	0.867	0.552
Combined Margin (1)	0.92	0.91	0.92	0.921	0.758

*BM and CM calculation for 2023-24 is accounted for RE generation into the grid

(1) Operating margin is based on the data for the same year. This corresponds to the *ex post option* given in "Tool to Calculate the Emission Factor for an Electricity System", Ver. 7.0 (p.16)

Table B: Values for FY 2019-20 to 2023-24, including cross-border electricity transfers.

Emission Factors (tCO$_2$/MWh) (incl. Imports)	2019-20	2020-21	2021-22	2022-23	2023-24*
Weighted Average Emission Rate Incl RES (2)	0.71	0.70	0.71	0.716	0.727
Simple Operating Margin (1) (2)	0.96	0.94	0.96	0.971	0.962
Build Margin (not adjusted for imports)	0.87	0.87	0.87	0.867	0.552
Combined Margin (1) (2)	0.91	0.90	0.91	0.919	0.757

*BM and CM calculation for 2023-24 is accounted for RE generation into the grid

(1) Operating margin is based on the data for the same year. This corresponds to the *ex post option* given in "Tool to Calculate the Emission Factor for an Electricity System", Ver. 7.0 (p.16)

(2) For Adjustments of imports from other countries, an emission factor of zero is used. See "Tool to Calculate the Emission Factor for an Electricity System", Ver. 7.0 (p.10 & 11), options a+b

Appendix D – Summary of Methodology ACM0002 / Version 22.0

Download ACM0002 at: http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html

ACM0002 is a consolidated CDM methodology for grid-connected power generation from renewable energy sources. It covers grid-connected renewable power generation project activities that involve retrofitting, rehabilitation (or refurbishment), replacement or capacity addition of an existing power plant or construction and operation of a Greenfield power plant. Examples of eligible project types include hydro power plants with or without reservoir; wind energy; geothermal energy; solar energy; and wave and tidal energy.

The methodology requires the calculation of the baseline emission factor following the combined margin (CM) approach. The combined margin consists of a weighted average of:

- Operating margin (OM);
- Build margin (BM).

The relative weights used to determine the combined margin are by default the same, i.e. 50%. Alternative weights can be used for intermittent power sources.

There are four options to calculate the operating margin, depending on local conditions:

- *Simple operating margin*. This is the preferred approach for India.
- The other three approaches are: (i) *simple adjusted operating margin*; (ii) *dispatch data analysis operating margin*; and (iii) *average operating margin*.

The build margin is the generation-weighted average emission factor of the most recent power plants, consisting of the larger of (i) the five power plants that have been built most recently; or (ii) the capacity additions that represent 20% of the system generation that have been built most recently. In India, the latter approach generally yields the larger sample and hence must be followed. CDM projects must be excluded from the build margin, as long as the build margin does not contain generation units older than 10 years.

The operating margin must be adjusted for electricity transfers (imports) from connected electricity systems (other states/regions, other countries) to the project electricity system. Generally, no such adjustments are required for the build margin.

The actual emission reductions achieved by a CDM project are calculated based on the monitored electricity production in each year, and the combined margin (baseline emission factor). The combined margin is initially calculated from the most recent data available at the time of PDD submission. It can then either remain fixed for the duration of the project's crediting period *(ex-ante approach)*, or be updated annually *(ex-post approach)*. The two approaches have different requirements in terms of data vintage.

Appendix E – Abbreviations

Abbreviation	Full Name
ACM0002	Approved Consolidated Methodology by CDM Executive Board for grid connected large scale renewable project
ACM0013	Approved Consolidated Methodology by CDM Executive Board for new grid connected fossil fuel fired power plants using a less GHG intensive technology.
AMS-I.D	Approved Methodology for small scale grid connected renewable projects
BM	Build margin
CDM	Clean Development Mechanism
CEA	Central Electricity Authority
CER	Certified Emission Reduction
CM	Combined margin
CO_2	Carbon Dioxide
FY	Fiscal year
GCV	Gross Calorific Value
GHG	Greenhouse Gases
GWh	Gigawatt hour
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
IPP	Independent Power Producer
MW	Megawatt
NEWNE	Integrated Northern, Eastern, Western and North Eastern Grid
OM	Operating margin
PDD	Project Design Document
RLDC	Regional Load Dispatch Centre
RPC	Regional Power Committee
SDM	Sustainable Development Mechanism
SR	Southern Grid
UNFCCC	United Nations Framework Convention on Climate Change