# $CO_2$ Baseline Database for the Indian Power Sector

# User Guide

**Version 9.0**

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**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 | - 4th October 2006 | - Draft for Stakeholder Consultation |
| 1.0 | November 2006 | - Added data on 10 stations which had been in exclusion worksheet of draft database<br>- 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<br>- 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<br>- 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<br>- Adjusted delineation of regional grids<br>- 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<br>- From FY 2011-12, scope of database is restricted to stations exceeding 25 MW<br>Retroactive changes to data for FY 2010-11:<br>- Three units in the NEWNE region identified as CDM units, leading to minor change in NEWNE build margin |
| 9.0 | January 2014 | - Added data for FY 2012-13, including new stations and units commissioned during 2012-13<br>Retroactive changes to data back to FY 2008-09:<br>- Nine units were identified as CDM units: retroactive changes to data back to FY 2009-10<br>- Updated GCVs of five stations back to FY 2008-09 |

## Expert Team Contributing to the Database

### Central Electricity Authority

Mr Ramesh  Kumar, Chief Engineer (C&E)

Mr. Praveen Gupta, Director (C&E)

Mr. Rajesh Kumar, Deputy Director (C&E)

Mr K.K.Sharma, Assistant Director (C&E)

### First Climate

Mr. Urs Brodmann, Managing Director

Mr. Subhendu Biswas, Managing Director

Mr. Dominik Englert, Senior Consultant

Mrs. Barla Vieli, Project Manager

# 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.

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

The Indian electricity system is divided into two grids, the Integrated Northern, Eastern, Western, and North-Eastern regional grids (NEWNE) and the Southern Grid. Each grid covers several states. As the grids are interconnected, there is inter-state and inter-regional exchange. A small power exchange also takes place with the neighbouring countries Bhutan and Nepal. For each of the two grids, 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.

The prevailing baseline emissions based on the data for the FY 2012-13 are shown in Table S-1. 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. Inter-Grid and cross-border electricity transfers were also taken into account for calculating the $CO_2$ emission baseline.

*Table S-1: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of all grids for FY 2012-13 (adjusted for inter-grid and cross-border electricity transfers), in t $CO_2$/MWh*

| | Average | OM | BM | CM |
|---|---|---|---|---|
| **NEWNE** | 0.82 | 0.99 | 0.97 | 0.98 |
| **South** | 0.85 | 1.00 | 0.95 | 0.97 |
| **India** | 0.82 | 0.99 | 0.96 | 0.98 |

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.

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 grids 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 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 4.0 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 223,343.60 MW as on 31.03.2013. Sector-wise details of installed capacity are shown in Table 1.

*Table 1: Sector- wise installed capacity (MW) as on 31.03.2013.*

| Sector | Hydro | Thermal | | | | Nuclear | Renew. | Total |
|---|---|---|---|---|---|---|---|---|
| | | Coal | Gas | Diesel | Total | | | |
| State | 27437.0 | 51660.50 | 5676.32 | 602.61 | 57939.43 | 0.00 | 3748.19 | 89124.62 |
| Central | 9459.40 | 44055.01 | 7065.53 | 0.00 | 51120.54 | 4780.00 | 0.00 | 65359.94 |
| Private | 2595.00 | 34505.38 | 7368.00 | 597.14 | 42470.52 | 0.00 | 23793.52 | 68859.04 |
| All India | 39491.40 | 130220.89 | 20109.85 | 1199.75 | 151530.49 | 4780.00 | 27541.71 | 223343.60 |

Note: These capacities are not identical with those listed in the Excel database, because the database excludes renewable, few small diesel and steam units.

It is evident from Table 1 that the installed capacity is predominantly coal based and therefore, is a major source of carbon dioxide emissions in India. Hence, there exists scope for reducing the $CO_2$ emissions in the country by way of fuel substitution, increased use of renewable energy sources, and also by improving the thermal efficiency of power generation.

[1] Tool to calculate the emission factor for an electricity system (Version 1.0), adopted by EB 35 (Annex 12) and subsequently revised to Version 4.0. See http://cdm.unfccc.int

## 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 have been integrated and are operating in synchronous mode, i.e. at same frequency. Consequently, the Northern, Eastern, Western and North-Eastern grids have been treated as a single grid named as NEWNE grid from FY 2007-08 onwards for the purpose of this $CO_2$ Baseline Database.

Power generation and supply within the regional grid is managed by Regional Load Dispatch Centre (RLDC). The Regional Power Committees (RPCs) provide a common platform for discussion and solution to the 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. Specific quotas are allocated to each state from the central sector power plants. Depending on the demand and generation, there are electricity exports and imports between states in the regional grid. Moreover, there are also electricity transfers between regional grids, and small exchanges in the form of cross-border imports and exports (e.g. from Bhutan).

*Table 2: Geographical scope of the two electricity grids.*

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

# 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 emission 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 "Data" provides the net generation and the absolute and specific $CO_2$ emissions of each grid-connected power station (see Section 4 for exceptions). It also indicates which stations and units were included in the operating margin and build margin, respectively.
- Worksheet "Results" provides the most commonly used aggregate emission factors. These are calculated from the station 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 "Data" worksheet.
- Worksheet "Assumptions" shows the assumptions that were used for the calculation of the $CO_2$ emissions at station and unit level, to the extent required.
- Worksheet "Transfers" shows the inter-Grid and 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 each regional 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 in the region by the region's total net generation. Net generation from so-called low-cost/must-run sources (hydro and nuclear) is included in the denominator.

[2] *Tool to calculate the emission factor for an electricity system* (Version 1.1), adopted by EB 35 (Annex 12) and subsequently revised to Version 4.0. See http://cdm.unfccc.int

**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 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 in the region *except* so-called low-cost or must-run sources. In India, hydro and nuclear stations qualify as low-cost/must-run sources and are excluded. The operating margin, therefore, can be calculated by dividing the region’s total $CO_2$ emissions by the net generation of all thermal stations. In other words, it represents the weighted average emissions rate of all thermal stations in the regional 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 in the grid based on net generation. Depending on the region, the build margin covers units commissioned in the last five to ten 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 chose 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]

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[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 4.0).

[5] See *Tool to calculate the emission factor for an electricity system* (Version 4.0), pp. 10 and 20f

## 3 Scope of Database

The database includes all grid-connected power stations having an installed capacity above 25 MW.[6] The data covers power stations of both public utilities and independent power producers (IPPs).

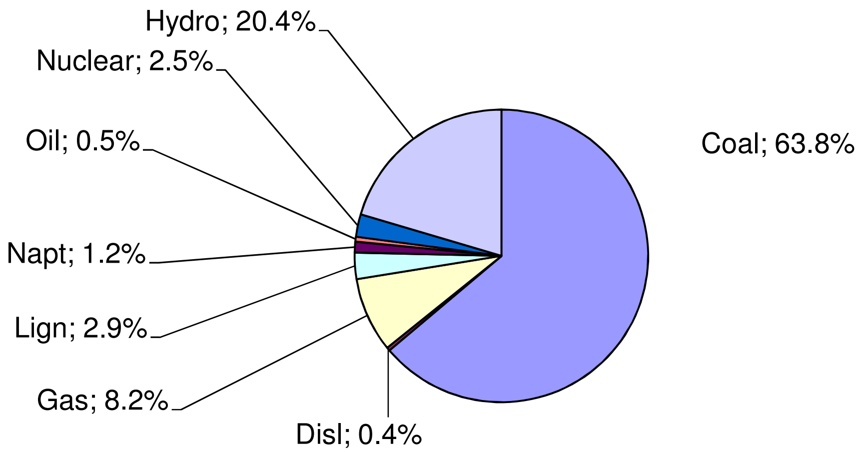


*Figure 1: Breakdown of generation capacity covered by the database. The total corresponds to 193169MW as on 31.03.2013.*

The following power stations are currently not accounted for in the database:

- Small decentralised generation sets;
- Stations or units installed in Andaman and Nicobar Islands and Lakshadweep;
- Captive power stations: As on 31 March 2013, the aggregate installed capacity of captive stations in industries having demand of 1 MW and above was 43,300.00 MW (provisional figure). The generation of these stations in 2012-13 was 148,000.00 GWh (provisional figure). **The data of captive plants could not be added in this database in absence of the data availability.**
- 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 27,541.71 MW as on 31.03.2013.[7] The generation from these non-conventional renewable energy sources in the FY 2012-13 was 57,448.86 GWh (provisional figures).

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[6] Previously, the database covered grid-connected power stations having an installed capacity above 3 MW in case of hydro and above 10 MW for all other plant types. Monitoring of stations up to 25 MW was discontinued from FY 2011-12. For archiving and consistency reasons, 70 of these small stations will remain in the database without new data entries.

[7] Ministry of New and Renewable Energy. The capacity figure may differ from CEA reported figure of installed capacity.

# 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:

- SNo:
  The Station Numbers start at 1 in each regional grid. The numbering has been introduced for unambiguous referral to each station and to allow for the insertion of additional stations in a region without having to change the numbers of other regions. All units of a station have the same station number. Numbers may change in future database versions.
- Station Name
  Name of the power station
- 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 2013.
- Grid:
  Grid to which the station is connected to. The table below gives the codes for the different grids used in the database:

*Table 3: Code for grids used in the database*

| Name of the Grid | Code |
|---|---|
| NEWNE Grid (covering former Northern, Eastern, Western and North-Eastern regions) | NEWNE |
| Southern Grid | SR |

- 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, 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 the five fiscal years 2008-09 to 2012-13. In addition, there are columns to indicate whether the station is included in the operating margin in the respective year, and an additional column indicating which units are included in the build margin. 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 of the gas- and diesel-fired 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 for those units falling into the build margin (i.e. the most recently built units comprising 20% of net generation):

**Gross generation**:
For some stations, gross generation data were not available at unit level. Therefore the plant

load factor of the respective station was used to derive the gross generation of the units. For units commissioned after the start of the relevant fiscal year, the gross generation was further adjusted pro rata the number of days since commissioning.

**Net generation:**
Net generation data is increasingly being reported at unit level by thermal stations. Two distinct approaches were applied to estimate net generation where unit level data was not available.

1. The auxiliary consumption (in % of gross generation) of the unit was assumed to be equal to that of the respective stations in the following cases:

   i. All units of a station fall into the build margin; or

   ii. All units of a station have the same installed capacity; or

   iii. The units in the station have different capacities but do not differ with respect to the applicable standard auxiliary consumption; or

   iv. If the default auxiliary power consumption for that type of generation unit is higher than the observed auxiliary power consumption of the station concerned, and the relevant unit is among the largest in that station.

2. In a few other cases, standard values for auxiliary consumption adopted by CEA were applied.

**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 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, default emission factors were derived from the IPCC 2006 Guidelines.[8] In line with the Grid Tool, the low end values of the 95% confidence intervals indicated by IPCC were used.[9] The IPCC default factors were converted to GCV basis using IEA default conversion factors.

The oxidation factor for 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.[10] For all other fuels, 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 ($NetGen(station)_y$).

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8 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 1.4

9 In accordance with the *Tool to calculate the emission factor for an electricity system, Version 4.0*

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

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

In FY 2012-13, fuel consumption was not available for five stations with very low gross generation (< 100 GWh). In these few cases, conservative standard values have been applied for the specific emissions of the respective station.

**Calculation Approach – Unit Level**

Unit-level $CO_2$ emissions were only calculated for units falling in the build margin.

Wherever reliable fuel consumption data was available at unit level, it was used for determining the emissions of units falling in the build margin, in the same way as for the station emissions. This applies for an increasing number of thermal units, especially new and large coal-fired stations.

In the remaining cases where unit-level fuel consumption was not available, the absolute $CO_2$ emissions of thermal units (*$AbsCO_2(unit)_y$*) were derived by multiplying the specific emissions (*$SpecCO_2(unit)_y$*) with the net generation of each unit (*$NetGen(unit)_y$*), where net generation was obtained as described in Section 4.2:

$$AbsCO_2(unit)_y = SpecCO_2(unit)_y \times NetGen\,(unit)_y \qquad (3)$$

Two distinct approaches were applied for determining the specific emissions of these units:

1. A unit was assumed to have the same specific emissions as the corresponding station in the following three cases:

i. If all units of a station fall into the build margin;

ii. If all units of a station have the same installed capacity;

iii. If the default specific emissions for the respective unit is higher than the corresponding station's specific emissions, and the concerned unit is capacity-wise among the largest of the station.

The large majority of units for which fuel consumption was not reported fall in one of the above-mentioned three categories.

2. In the remaining cases, the specific emissions of the units were derived from conservative standard heat rate values (see Appendix B). In FY 2012-13, this was required for nine units.

## 4.4 Adjustment for Inter-Grid and Cross-Border Electricity Transfers

The weighted average emission factors and operating margins of each grid were adjusted for inter-grid and 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.[11]

## 4.5 Conservativeness

The need to ensure conservativeness of calculations in situations of uncertainty is a fundamental principle in the CDM. Assumptions are conservative if they tend to reduce the number of emission reductions being credited to a CDM project activity. The following approaches and assumptions contribute to the conservativeness of the database:

- The quality of station-level data was ensured through extensive plausibility testing and interaction with the station operators.
- In cases of data gaps at station level, standard data from CEA were used. For example, standard auxiliary power consumption was assumed for a number of diesel-fired stations. Comparison with monitored values shows that these standard values are rather conservative, i.e. they lead to a somewhat lower heat rate and hence lower emissions than observed in many stations.
- The fuel emission factors and oxidation factors used are generally consistent with IPCC defaults and relevant EB guidance. For coal, the emission factor provided in India’s Initial National Communication was used (95.8 t $CO_2$/TJ on NCV basis), being somewhat lower than the IPCC default for sub-bituminous coal (96.1 t $CO_2$/TJ).[12] Also, the oxidation factor of 0.98 used for coal stations appears to be conservative in light of recent efficiency improvements in coal-fired generation. All other fuel emission factors represent the lower limits of the respective 95% confidence intervals indicated by IPCC, as required by the CDM Executive Board.[13]
- The scope of the database remains conservative because of the exclusion of captive power stations, which are generally thermal stations. As detailed in Section 3, generation from these captive stations remains far greater than the generation from non-conventional renewable energy stations, which are also excluded. The overall effect of these restrictions in scope is that the weighted average emission factor will tend to be slightly understated.

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[11] This corresponds to Options a)+b) listed in the Grid Tool, (Version 4.0), p. 8

[12] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 2.2

[13] See *Tool to calculate the emission factor for an electricity system* (Version 4.0), p.29

# 5 Results

Worksheet "Results" in the database provides the net generation and $CO_2$ emissions data and the resulting emission factors for the two grids in the fiscal years 2008-09 to 2012-13. 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 2012-13

Table 4 indicates the development of total emissions by grid over the last five years covered by the database.

*Table 4: Total emissions of the power sector by region for the FY 2008-09 to 2012-13, in million tonnes $CO_2$*

| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
|---|---|---|---|---|---|
| **NEWNE** | 430.7 | 453.2 | 468.6 | 491.9 | 539.5 |
| **South** | 117.9 | 126.8 | 129.1 | 145.4 | 156.8 |
| **India** | 548.6 | 580.1 | 597.7 | 637.3 | 696.3 |

Table 5 shows the emission factors for FY 2012-13 excluding inter-grid and cross-border power transfers, whereas Table 6 shows the emission factors for the same year including these power transfers.

*Table 5: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of grids for FY 2012-13 (not adjusted for inter-grid and cross-country electricity transfers), in t $CO_2$/MWh*

| | Average | OM | BM | CM |
|---|---|---|---|---|
| **NEWNE** | 0.83 | 1.00 | 0.97 | 0.98 |
| **South** | 0.85 | 1.00 | 0.95 | 0.97 |
| **India** | 0.83 | 1.00 | 0.96 | 0.98 |

*Table 6: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of grids for FY 2012-13 (adjusted for inter-grid and cross-country electricity transfers), in t $CO_2$/MWh*

| | Average | OM | BM | CM |
|---|---|---|---|---|
| **NEWNE** | 0.82 | 0.99 | 0.97 | 0.98 |
| **South** | 0.85 | 1.00 | 0.95 | 0.97 |
| **India** | 0.82 | 0.99 | 0.96 | 0.98 |

The observed variations in the emission factors between the different grids originate from the differing availability and use of coal, gas and hydro resources. Stations fired with other fossil fuels such as diesel as well as nuclear stations play a less significant role.

A comparison of Table 5 and Table 6 shows that electricity transfers between grids did not have a significant influence on the emission factors in 2012-13.

Table 7 shows the weighted average specific emissions for fossil fuel-fired power stations in the two grids. Inter-grid variations arise chiefly from differences in station age and build (installed capacity and conversion technology).

*Table 7: Weighted average specific emissions for fossil fuel-fired stations in FY 2012-13, in t $CO_2$/MWh.*

| | Coal | Disl | Gas | Lign | Napt | Oil |
|---|---|---|---|---|---|---|
| **NEWNE** | 1.05 | - | 0.47 | 1.36 | 0.40 | 0.63 |
| **South** | 1.01 | 0.59 | 0.46 | 1.41 | 0.56 | 0.61 |
| **India** | 1.04 | 0.59 | 0.47 | 1.40 | 0.40 | 0.62 |

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 capacity additions FY 2008-09 to FY 2012-13. The yearly additions of coal-based capacity increased significantly over this period, while the additions of other generation capacity remained more or less stable.

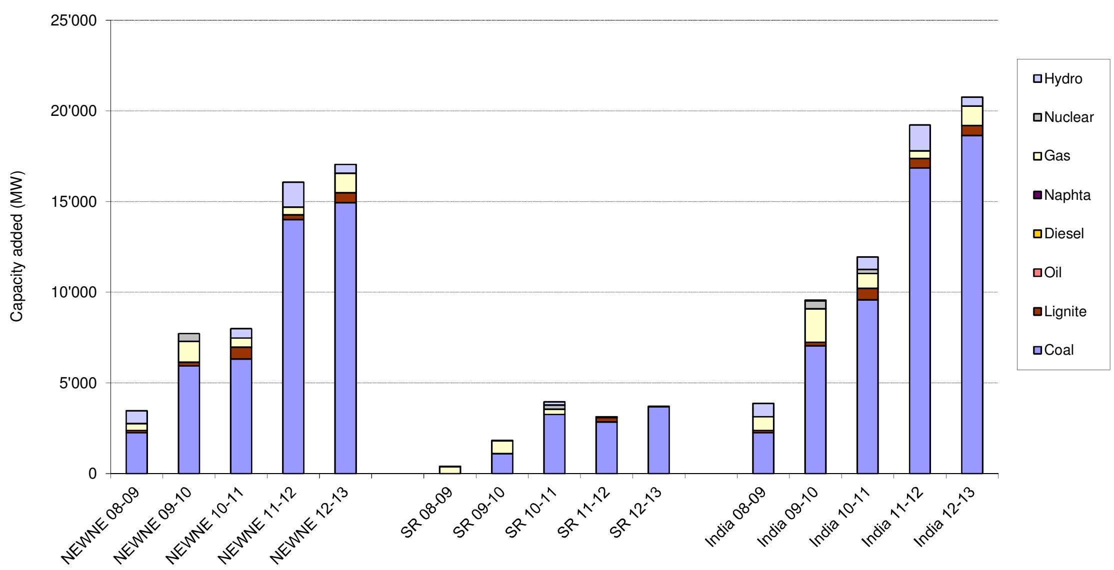


*Figure 2: Breakdown of new added capacity covered by the database over the period 2008-09 to 2012-13.*

Figure 3 shows the development of the weighted average emission factor over the period from FY 2008-09 to FY 2012-13 (see Appendix C for values before import adjustment). The weighted average for India has increased from 0.78 in the previous year to 0.82. This was mainly due to the above mentioned increase in coal-based capacity in FY 2012-13. In addition, there was a lower share of gas generation in FY 2012-13, due to scarcity of natural gas. The increasing coal generation together with a decrease in gas generation result in an increased weighted average emissions factor. In the Southern region, the increase of the weighted average emission is more pronounced than in the NEWNE region, mainly due to a lower share of hydro power related to less water availability in FY 2012-13.

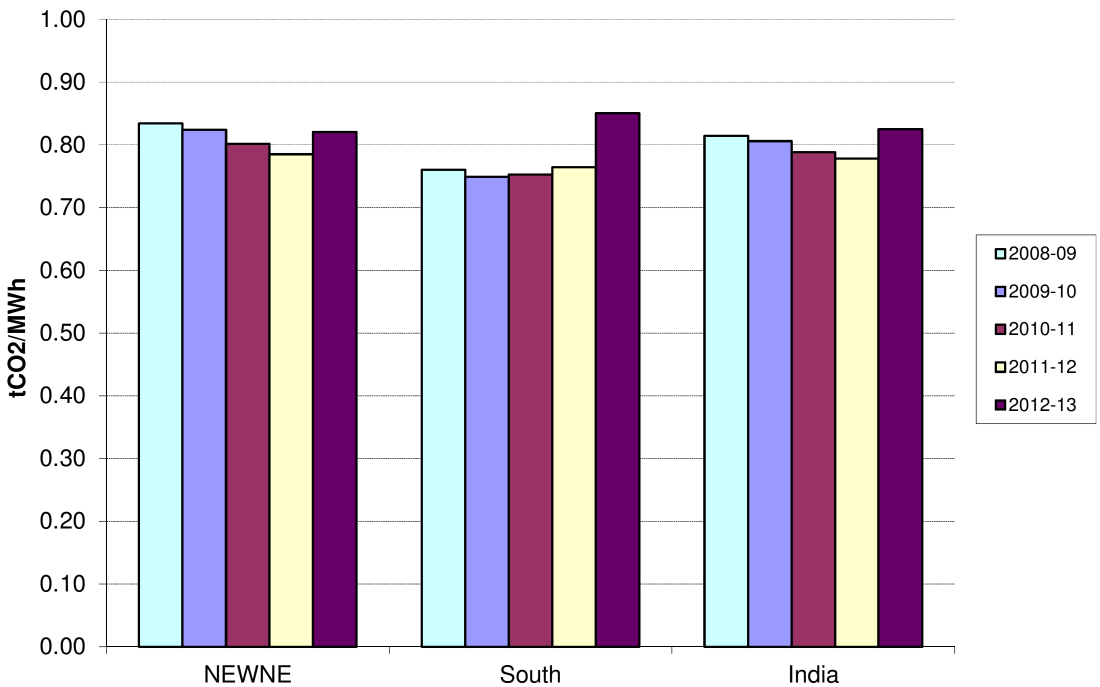


*Figure 3: Development of the weighted average emission factor (adjusted for electricity transfers) for India's grids over the period 2008-09 to 2012-13*

Figure 4 illustrates the development of the import-adjusted operating margins over the period from FY 2008-09 to FY 2012-13 (see Appendix C for values before import adjustment). The decreasing trend of the previous years has been reverted due to a higher share of coal-based generation relative to natural gas. In FY 2012-13 the operating margin increased in both regions.

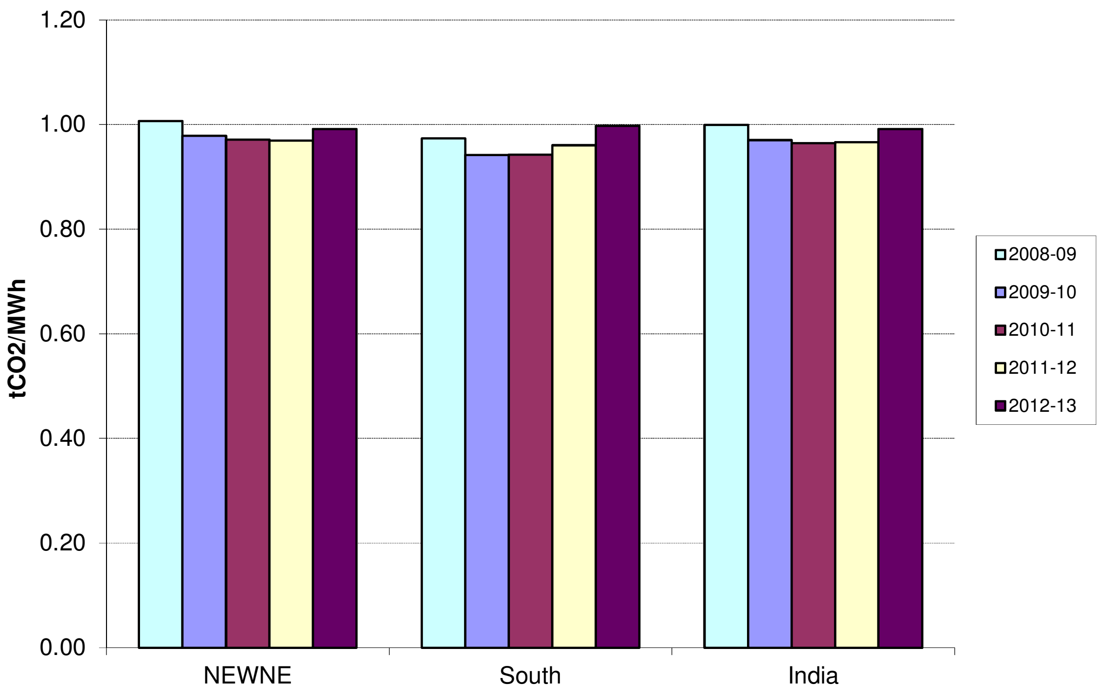


*Figure 4: Development of the operating margin (adjusted for electricity transfers) for India's grids over the period 2008-09 to 2012-13*

Figure 5 shows the build margins for the five fiscal years 2008-09 to 2012-13. The build margin in the NEWNE region increased again in FY 2012-13. As illustrated in Figure 6, this is due to an increased share of coal- and lignite-based generation in the build margin, with a corresponding decrease in the share of hydro power. As new coal-based units were commissioned, older units fell out of the build margin, among them many hydro units.

In the Southern region, the build margin had been decreasing from FY 2008-09 to FY 2010-11, mainly because new efficient coal based units displaced more carbon-intensive lignite based generation capacity from the build margin. This trend was reverted in FY 2011-12 when the build margin increased substantially. The reversion was even more pronounced in FY 2012-13. Figure 6 shows that the net generation in the BM formerly produced by gas-fired plants was largely replaced by more emissions-intensive coal-fired plants. Again, this was the result of new coal-based capacity additions, low availability of natural gas, and lower-than-normal plant load factors in hydro power stations.

It should be noted that due to the definition stipulated by the CDM rules, the build margin can react sensitively to a few large units being added to the grid in a given year. Consequently, the changes observed here need not necessarily point to longer-term trends.

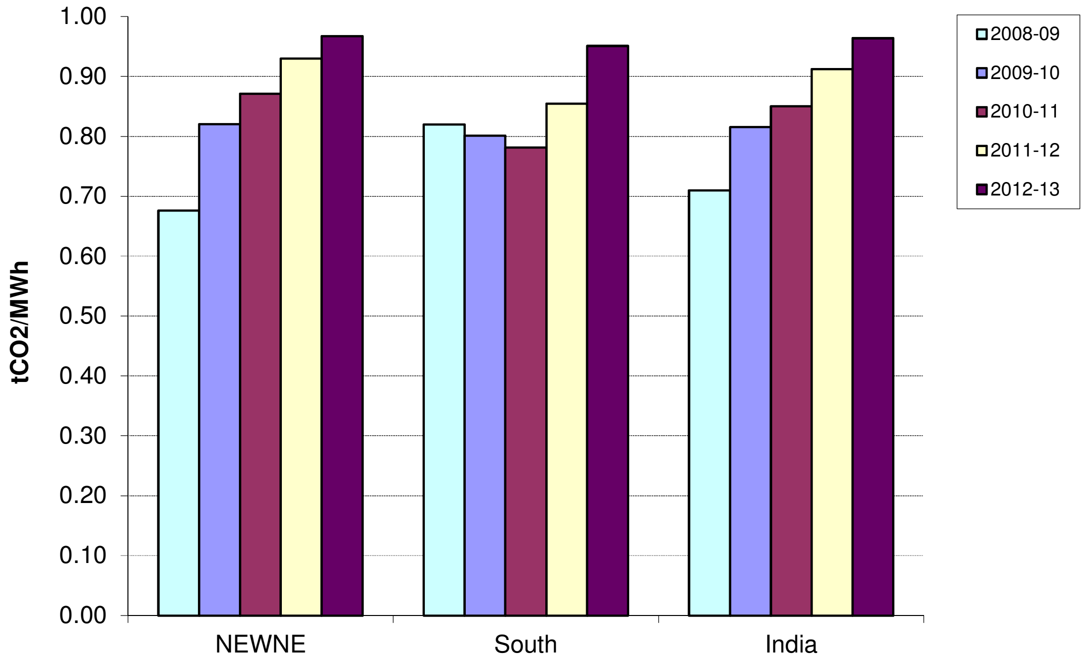


*Figure 5: Development of the build margins over the period 2007-08 to 2012-13*

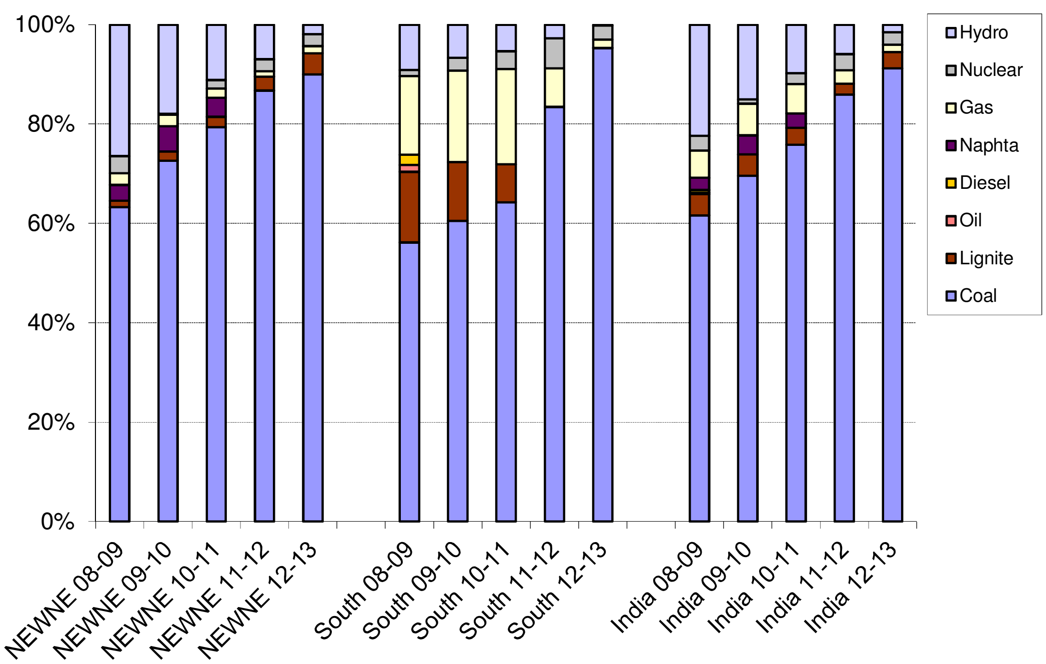


*Figure 6: Breakdown of the build margins by fuel type and grid (shares based on net generation)*

Figure 7 shows the trends in the import-adjusted combined margins in the period 2008-09 to 2012-13. Driven by the increases in both the operating and build margins, the combined margin increased in the NEWNE region as well as in the Southern region in comparison with last year.

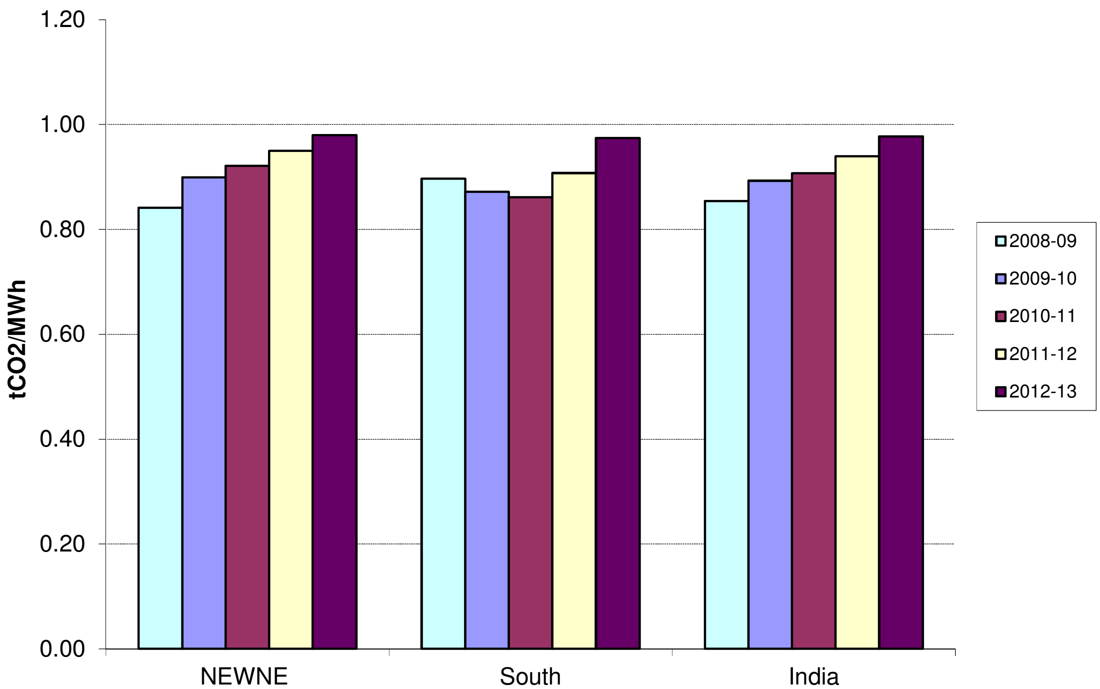


*Figure 7: Development of the combined margin (adjusted for electricity transfers) for India's grids over the period 2008-09 to 2012-13*

## 5.3 Changes compared to Previous Database Versions

In comparison with the previous version of the Database (Version 8.0), this updated Version 9.0 includes the following changes:

- Added data for FY 2012-13, including new stations and units commissioned during 2012-13.
- Seven units were retroactively identified as CDM units as from FY 2009-10 and 2 units as from FY 2011-12 after they were registered by the CDM Executive Board in FY 2012-13. This resulted in certain changes to the build margins of both regions for the corresponding fiscal years. The revised values are provided in Appendix C and in the Database file.
- For five thermal stations, the GCV was updated retroactively, leading to minor changes back to FY 2008-09.
- Consistency with the latest version of the Grid Tool (Version 4.0) was ascertained. No changes to the Database and calculation approach were required.

## 6 User Examples

This section provides two illustrative examples of how the $CO_2$ Database can be applied. The examples are based on hypothetical renewable energy projects that differ in size and supply different grids.

**Project A** is a grid-connected 5 MW small hydropower station located in the State of Assam which belongs to the NEWNE Region. The station will be commissioned in 2014. 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 power generation from renewable energy sources.
- 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, despite the fact that 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 NEWNE Grid in the most recent year for which data is available (2012-13). The corresponding value is 0.82 t $CO_2$/MWh. Hence the absolute emission reductions are projected at 0.82 * 17'500 = 14,350 t $CO_2$/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.[14] 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 (Southern Grid). The project will be commissioned in 2014. 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 addition, inter-grid power transfers (imports and exports) must be taken into account.

[14] The emission factor of the previous year may be used instead. See *Tool to calculate the emission factor for an electricity system* (Version 4.0), p.10

- 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 is calculated as the generation-weighted average of the three most recent years (here 2010-11 to 2012-13).[15] The operating margin to be applied thus works out to 0.968 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 is 0.964 t $CO_2$/MWh (75% x 0.968 + 25% x 0.95 for the FY 2012-13). This value is used for projecting the emission reductions in the PDD as well as for calculating the actual emission reductions.

[15] See *Tool to calculate the emission factor for an electricity system* (Version 4.0), p.10

The two CDM project activities are summarised in Table 8 below.

*Table 8: Illustration on how to use the $CO_2$ Database for calculating the emission reductions of CDM projects*

| | **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: | 2014 | 2014 |
| Year of CDM registration: | 2014 | 2014 |
| Grid : | NEWNE | Southern |
| CDM methodology: | AMS-I.D / Version 17 | ACM0002 / Version 14.0.0 |
| **Baseline Emission Factor Calculation** | | |
| Calculation method: | Weighted average | Combined margin |
| Data vintage for projection of emission reductions: | 2012-13 (most recent available at time of PDD validation) | For OM: 2010-11, 2011-12, 2012-13 (most recent 3 years available at time of PDD validation)<br><br>For BM: 2012-13 |
| Data vintage for verification of emission reductions: | Actual year of generation, i.e., 2014-15, 2015-16 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: | Operating margin: 50%<br>Build margin: 50% | Operating margin: 75%<br>Build margin: 25%<br>(default for intermittent sources) |
| **Emission Reduction Calculations** | | |
| Values in t $CO_2$/MWh: | 0.82 Weighted average | 0.968 Operating margin<br>0.95 Build margin<br>0.964 Combined margin |
| Projected emission reductions: | 14,350 t $CO_2$ per year | 301,250 t $CO_2$ per year |
| Actual emission reductions: | Monitored net generation x monitored weighted average | Monitored net generation x fixed combined margin |

# 7 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.

# 8 Further Information

For any further information, contact by email:

Chief Engineer (C&E)
Central Electricity Authority
Sewa Bhawan
R. K. Puram, New Delhi-110066
Email: cdmcea@yahoo.co.in

# Appendix A – Systems in India's Grids

*In alphabetical order*

| Abbreviation | Full name |
|---|---|
| ADHPL | AD Hydro Power Limited |
| APCPL | Aravali Power Company Limited |
| APGCL | Assam Power Generation Corporation Limited |
| APGENCO | Andhra Pradesh Power Generation Co Limited |
| ASEB | Assam State Electricity Board |
| BBMB | Bhakra Beas Management Board |
| BSEB | Bihar State Electricity Board |
| CESC | Calcutta Electric Supply Company Limited |
| CSEB | Chattisgarh State Electricity Board |
| DPL | Durgapur projects Limited |
| DVC | Damodar Valley Corporation |
| GIPCL | Gujarat Industries Power Company Ltd |
| GMDCL | Gujarat Mineral Development Corporation Limited |
| GMR Energ | GMR Energy |
| GPEC | Gujarat Paguthan Energy Corporation Pvt. Limited |
| GSECL | Gujarat State Electricity Corporation Limited |
| GTE Corp | GTE Corporation |
| GVK Ind. | GVK Power & Infrastructure Limited |
| HEGL | HEG Limited |
| HPGCL | Haryana Power Generation Corporation Limited |
| HPSEB | Himachal Pradesh State Electricity Board |
| INDSIL | Indsil Electrosmelt Ltd |
| IPPGCL | Indrapratha Power Generation Co Ltd |

*Continuation*

| Abbreviation | Full name |
|---|---|
| JINDAL | JSW Energy Limited |
| JKEB | Jammu & Kashmir Electricity Board |
| JPHPL | Jai Prakash Hydro Power Limited |
| JSEB | Jharkand State Electricity Board |
| JSW Energy | JSW Energy Limited |
| KPCL | Karnataka Power Corporation Limited |
| KSEB | Kerala State Electricity Board |
| LVS Power | LVS Power Limited |
| MaduraiP | Madurai Power Corporation Limited |
| MAHAGENCO | Maharastra State Power Generation Company Limited |
| MAPS | Madras Atomic Power Station |
| MALANA | Malana Power Corporation Limited |
| MPDC | Manipur Power Development Corporation |
| MEGEB | Meghalaya State Electricity Board |
| MPPCL | Madhya Pradesh Power Generating Co. Ltd. |
| NAPS | Narora Atomic Power Station |
| NCTPP | National Capital Thermal Power Plant |
| NEEPCO | North Eastern Electric Power Corporation Ltd |
| NHDC | Narmada Hydro Electric Development Corporation |
| NHPC | National Hydro Power Corporation Ltd |
| NLC | Neyvelli Lignite Corporation Ltd |
| NPC | Nuclear Power Corporation of India Ltd. |
| NTPC | NTPC Ltd |
| OHPC | Orissa Hydro Power Corporation |
| OPGC | Orissa Power Generation Corporation |
| PPCL | Pondichery Power Corporation Limited |

*Continuation*

| Abbreviation | Full name |
|---|---|
| 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 |
| RPG | RP Goenka Group |
| RRVUNL | Rajasthan Rajya Vidyut Utpadan Nigam |
| Samalpatti | Samalpatti Power Company Limited |
| SJVNL | Sutluj Jal Vidyut Nigam Ltd |
| SPECT. IND | Spectrum Power Generation Limited |
| 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 |
| TVNL | Tenughat Vidyut Nigam Limited |
| UPCL | Uttarakand 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: Coal/Lignite - Initial National Communication, Gas/Oil/Diesel/Naphta - IPCC 2006, Corex - own assumption)

| | Unit | Coal | Lignite | Gas | Oil | Diesel | Naphta | Corex |
|---|---|---|---|---|---|---|---|---|
| EF based on NCV | gCO2 /MJ | 95.8 | 106.2 | 54.3 | 75.5 | 72.6 | 69.3 | 0.0 |
| Delta GCV NCV | % | 3.6% | 3.6% | 10% | 5% | 5% | 5% | n/a |
| EF based on GCV | gCO2 /MJ | 92.5 | 102.5 | 49.4 | 71.9 | 69.1 | 66.0 | 0.0 |
| Oxidation Factor | - | 0.98 | 0.98 | 1.00 | 1.00 | 1.00 | 1.00 | n/a |
| Fuel Emission Factor | gCO2 /MJ | 90.6 | 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 | Naphta | 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 CO2 emissions | tCO2 /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 Type1 | 660 MW Type2 |
|---|---|---|---|---|---|---|---|---|---|---|
| Gross Heat Rate | kcal /kWh | 2,750 | 2,500 | 2,500 | 2,350 | 2,425 | 2,380 | 2,380 | 2,178 | 2,126 |
| Auxiliary Power Consumption | % | 12.0 | 9.0 | 9.0 | 9.0 | 7.5 | 6.5 | 6.5 | 6.5 | 6.5 |
| Net Heat Rate | kcal /kWh | 3,125 | 2,747 | 2,747 | 2,582 | 2,622 | 2,545 | 2,545 | 2,329 | 2,274 |
| Specific Oil Consumption | ml /kWh | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 | 2.0 |
| Specific CO2 Emissions | tCO2 /MWh | 1.19 | 1.05 | 1.05 | 0.99 | 1.00 | 0.97 | 0.97 | 0.89 | 0.87 |

| **Lignite** | Unit | 75 MW | 125 MW | 210/250 MW |
|---|---|---|---|---|
| Gross Heat Rate | kcal /kWh | 2,750 | 2,560 | 2,713 |
| Auxiliary Power Consumption | % | 12.0 | 12.0 | 10.0 |
| Net Heat Rate | kcal /kWh | 3,125 | 2,909 | 3,014 |
| Specific Oil Consumption | ml /kWh | 3.0 | 3.0 | 3.0 |
| Specific CO2 Emissions | tCO2 /MWh | 1.32 | 1.23 | 1.28 |

| **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 CO2 Emissions | tCO2 /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 CO2 Emissions | tCO2 /MWh | 0.70 | 0.67 | 0.63 | 0.59 |

| **Naphta** | 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 CO2 Emissions | tCO2 /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 | gCO2 /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 all grids for FY 2008-09 to 2012-13, excluding inter-grid and cross-border electricity transfers.***

| Weighted Average Emission Rate ($tCO_2/MWh$) (excl. Imports) | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 0.84 | 0.83 | 0.81 | 0.79 | 0.83 |
| South | 0.75 | 0.75 | 0.74 | 0.76 | 0.85 |
| India | 0.82 | 0.81 | 0.79 | 0.78 | 0.83 |

| Simple Operating Margin ($tCO_2/MWh$) (excl. Imports) (1) | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 1.02 | 0.99 | 0.98 | 0.98 | 1.00 |
| South | 0.97 | 0.94 | 0.94 | 0.96 | 1.00 |
| India | 1.01 | 0.98 | 0.97 | 0.97 | 1.00 |

| Build Margin ($tCO_2/MWh$) (excl. Imports) | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 0.68 | 0.82 | 0.87 | 0.93 | 0.97 |
| South | 0.82 | 0.80 | 0.78 | 0.85 | 0.95 |
| India | 0.71 | 0.82 | 0.85 | 0.92 | 0.96 |

| Combined Margin ($tCO_2/MWh$) (excl. Imports) (1) | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 0.85 | 0.91 | 0.93 | 0.96 | 0.98 |
| South | 0.90 | 0.87 | 0.86 | 0.91 | 0.97 |
| India | 0.86 | 0.90 | 0.91 | 0.95 | 0.98 |

(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. 4.0 (p.10)

***Table B: Values for all grids for FY 2008-09 to 2012-13, including inter-grid and cross-border electricity transfers.***

| **Weighted Average Emission Rate (tCO2/MWh) (incl. Imports) (2)** | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 0.83 | 0.82 | 0.80 | 0.78 | 0.82 |
| South | 0.76 | 0.75 | 0.75 | 0.76 | 0.85 |
| India | 0.81 | 0.81 | 0.79 | 0.78 | 0.82 |

| **Simple Operating Margin (tCO2/MWh) (incl. Imports) (1) (2)** | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 1.01 | 0.98 | 0.97 | 0.97 | 0.99 |
| South | 0.97 | 0.94 | 0.94 | 0.96 | 1.00 |
| India | 1.00 | 0.97 | 0.96 | 0.97 | 0.99 |

| **Build Margin (tCO2/MWh) (not adjusted for imports)** | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 0.68 | 0.82 | 0.87 | 0.93 | 0.97 |
| South | 0.82 | 0.80 | 0.78 | 0.85 | 0.95 |
| India | 0.71 | 0.82 | 0.85 | 0.92 | 0.96 |

| **Combined Margin in tCO2/MWh (incl. Imports) (1) (2)** | | | | | |
|---|---|---|---|---|---|
| | 2008-09 | 2009-10 | 2010-11 | 2011-12 | 2012-13 |
| NEWNE | 0.84 | 0.90 | 0.92 | 0.95 | 0.98 |
| South | 0.90 | 0.87 | 0.86 | 0.91 | 0.97 |
| India | 0.85 | 0.89 | 0.91 | 0.94 | 0.98 |

(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. 4.0 (p.10)

(2) Adjustments for imports from other Indian grids are based on operating margin of exporting grid. For imports from other countries, an emission factor of zero is used. See "Tool to Calculate the Emission Factor for an Electricity System", Ver. 4.0 (p.8), options a+b

## Appendix D – Summary of Methodology ACM0002 / Version 14.0.0

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 electricity capacity additions. Examples of eligible project types include run-of-river hydro power plants, and hydro power projects with existing reservoirs where the volume of the reservoir is not increased; 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*; 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

*In alphabetical order*

| 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 | Giga watt 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 |
| UNFCCC | United Nations Framework Convention on Climate Change |