# $CO_2$ Baseline Database for the Indian Power Sector

# User Guide

**Version 4.0**

**October 2008**

**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 for Stakeholder Consultation | 4th October 2006 | – |
| 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>Retroactive changes to data for FY 2000-01 to 2004-05:<br>- Introduced differentiated default heat rates for open- vs. combined-cycle stations (gas- and diesel-fired; only applicable where fuel consumption was not provided by station)<br>- Refined approximation of unit-level generation where not provided by station, by taking into account day of commissioning (for build margin)<br>- Revised fuel consumption for some stations where data became available |
| 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<br>- Baseline Emission Factor as per Methodology ACM0013 included as separate chapter |

## Expert Team Contributing to the Database

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# Foreword

The Clean Development Mechanism (CDM) gives an opportunity to developing countries in achieving their sustainable development objective, besides providing opportunity to introduce new and efficient technologies.

India has high potential for CDM projects, particularly in the Power Sector. With large resources of technical power we can develop innovative CDM projects in energy efficiency and conservation including R&M schemes for power generation and adopt new and renewable technologies.

The last version of $CO_2$ Baseline Database for the Indian Power Sector (Version 3.0) containing data for the year 2006-07 was published in December 2007. The Baseline Database has benefited all prospective CDM project developers to estimate the amount of Certified Emission Reduction (CERs).

Northern Regional Grid was synchronised with the integrated Eastern, North Eastern and Western Grid in August,2006 and the four regional grids have since been operating in synchronous mode. The emission factors have been worked out based on this new grid configuration. This publication is the **version 4.0** of the $CO_2$ Baseline Database for Indian Power Sector containing data for the year 2007-08. The emission factors have been calculated based on Tool approved and published by CDM Executive Board to calculate the emission factor for an electricity system version 1.1.

The average $CO_2$ emission rate has declined from 0.85 t $CO_2$/ MWh in the year 2002-03 to 0.79 t $CO_2$/MWh in the year 2007-08. All efforts are being made to improve the efficiency of power generation, transmission and distribution.

I am glad that Central Electricity Authority has also worked out $CO_2$ baseline emission factor as per CDM approved methodology ACM0013 for the new upcoming supercritical coal based power plants for availing CDM benefits. This has been included as a part of this book.

The team of CEA officers headed by Shri Amarjeet Singh, Chief Engineer (Conservation and Efficiency Division) has done a commendable job under the able guidance of Shri V.S. Verma, Member (Planning), CEA. We are thankful to Dr A. Kaupp, Mr Jens Burgtorf, Smt. Pamposh Bhat, , GTZ, Climate Change Unit, Mr Urs Brodmann and Dr Axel Michaelowa, GTZ-CDM-India consultants, who provided guidance and gave useful inputs to the team of CEA engineers.

New Delhi
October 2008

(Rakesh Nath)
Chairperson

## Preface

Developing countries like India do not fall in the Annex I category of the Kyoto Protocol but India has a strong commitment to reduce its emissions of greenhouse gases and mitigate climate change. Ministry of Power has accorded high priority to the CDM projects in the power sector. The number of Indian CDM projects registered with the CDM Executive Board is a good indication to India's commitment towards protection of the Global Environment. Till date, more than 358 Indian projects have been registered with the Executive Board. Host country approval to more than 1100 projects has already been accorded by National CDM Authority established under the Ministry of Environment and Forest.

CEA undertook the study relating to the baseline data for the Power sector in the country with a view to obtaining uniformity of approach in the country towards a common objective. Detailed information was collected from all power generating stations. The database has now been updated for the year 2007-08 with an endeavour to update on annual basis. The user guide has been prepared to enable project developers to use the baseline emission data effectively for CDM benefits. This version of the database has considered synchronous grid operation of Northern, Eastern, Western and North Eastern Grids (NEWNE) and therefore publishing Emission factors of NEWNE Grid and Southern Grid**. This version has also taken care of revised version 1.1 of the Tool to calculate the emission factor for an electricity system published by CDM Executive Board.**

The baseline emission database is useful not only to power sector projects but to all the industrial projects which are improving the efficiency of the process thus saving electricity. Indian industries have taken a lead in development of large number of CDM projects though of smaller size. The development of the baseline database would encourage project developers to pose large CDM projects in hydro power generation, Renovation and Modernisation of power stations, adoption of super critical technologies in power generation etc.

Based on recently CDM approved methodology for fossil fuel project using less GHG intensive technology, Central Electricity Authority has also worked out baseline emission factor for the new supercritical coal based power plants. This has been included as a part of this book.

I appreciate the efforts put in by all the officers of Central Electricity Authority, GTZ and Ms Pamposh Bhat of CDM India, in bringing out the updated version for the year 2007-08.

I am confident, that baseline carbon dioxide emissions, developed by CEA will continue to provide direction to help industry to come up with new CDM project concepts to further consolidate and reinforce our effort to save the global environment.

New Delhi (V.S. Verma)
October 2008 Member (Planning)

## Acknowledgement

India has the distinction of maximum number of registered CDM projects by the CDM Executive Board and I am confident that more and more CDM projects would be got registered in future. Various CDM projects had been facing the difficulties in establishing the baseline emissions for calculating authentic Certified Emission Reductions (CERs). Accordingly, Central Electricity Authority took the initiative to publish the Carbon di-oxide baseline database for the Indian Power Sector to assist CDM project developers for speedy approval of their CDM projects.

The present publication is the result of the trust Ministry of Power, Government of India, posed in Central Electricity Authority and entrusting us with the responsibility of establishing the Baseline Carbon dioxide emissions from the Indian power sector. I am thankful to Shri Anil Razdan, Secretary (Power) and Shri Anil Kumar, Additional Secretary and Shri Gireesh Pradhan, Additional Secretary, Ministry of Power who provided whole hearted support and encouragement in developing of Baseline database.

I am grateful to Shri Rakesh Nath, Chairperson, CEA and Shri V.S. Verma, Member(Planning), CEA for enlightening us with their valuable views and guidance all along in developing the Baseline carbon dioxide emissions.

I sincerely thank Dr A. Kaupp and Mr Jens Burgtorf of GTZ and its consultants Mr Urs Brodmann of First Climate , Dr Axel Michaelowa of Perspectives Climate Change and Ms Pamposh Bhat, GTZ- Climate Change Unit for providing their expert views in establishing the baseline emissions.

Central Electricity Authority extends its grateful thanks to all the power sector utilities/organizations and their officers for active co-operation and support rendered by them in timely furnishing the requisite data to bring out this updated document.

I acknowledge with deep appreciation, the hard work and efforts put in by Shri B.K.Sharma, Director and Shri Praveen Gupta, Deputy Director, CEA and other officers of Conservation and Efficiency Division, CEA in compilation of data and evolving the Baseline carbon dioxide emissions from the power sector. I also thank officers of Thermal, GO&D and Hydro wings of CEA for their contribution in compiling the database by providing necessary data and its validation.

All efforts have been made to project the latest data on energy generation to keep high integrity of the Baseline. Any omission in this could be due to oversight. Suggestions from the project developers and consultants are welcome to avoid such omissions in future.

New Delhi — (Amarjeet Singh)
October 2008 — Chief Engineer (C&E)

## Message

The Kyoto Protocol's Clean Development Mechanism is expected to result in emission reductions equivalent to over 2 to 3 billion tonnes of $CO_2$ to the end of 2012. CDM will bring in investments and technology transfer in developing projects that reduce Greenhouse Gases. CDM project implementers earn certified emission reduction units which are bought by countries with emission reduction commitments under the Kyoto protocol. CDM in India can lead the way to a low carbon economy.

Under Indo-German Bi-lateral Technical Cooperation between the Governments of India and Germany jointly implemented by GTZ together with partners Central Electricity Authority and the Bureau of Energy Efficiency under the Ministry of Power have undertaken the task of Carbon market development in India since 2003. We have together achieved many landmarks one among which is "Development of the Baseline Data for CDM Projects in the Power Sector". This valuable tool for CDM project developers reduces transaction costs and increases accuracy and consistency of emission reduction calculations. This latest version also includes $CO_2$ baseline emission factor for coal based power units as applicable to new coal fired power generating units with supercritical steam parameters.

India was the first nation to develop $CO_2$ baseline emission factor for power sector. It was presented to the public as an outstanding example of a national effort to support CDM project developers at the UNFCCC 12th Conference of Parties in Nairobi 2006. We congratulate our partner in the initiative and its regular updation by Central Electricity Authority Officials and Personnel as well as our international consultants for their tireless efforts and commitment to the cause.

Jens Burgtorf
Director
Indo German Energy Programme

Pamposh Bhat
Director
GTZ- Climate Change
Mitigation Programme

# 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), in cooperation with GTZ, has compiled a database containing the necessary data on $CO_2$ emissions for all grid-connected power stations in India.

Due to significant changes in the grid structure, the Indian electricity system is now divided into two grids, the new Integrated Northern, Eastern, Western, and North-Eastern regional grids (NEWNE) and the Southern Grid. This version of the database (2007-2008) therefore starts a new series of data. In addition, the emission factors for the preceding fiscal years (FY) 2005-06 and 2006-07 have also been back-calculated as per new definition of the grids. CEA will continue updating the database at the end of each fiscal year, according to the new grid structure.

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.

The prevailing baseline emissions based on the data for the FY 2007-08 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 2007-08 (inter-Grid and cross-border electricity transfers included), in $tCO_2/MWh$*

| Grid | Average | OM | BM | CM |
|---|---|---|---|---|
| **NEWNE** | 0.81 | 1.00 | 0.60 | 0.80 |
| **Southern** | 0.72 | 0.99 | 0.71 | 0.85 |
| **India** | 0.79 | 1.00 | 0.63 | 0.81 |

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).

The baseline emission factor which is to be used for calculating CDM Benefits by the supercritical technology based power projects has also been calculated by Central Electricity Authority as 0.941 $tCO_2/MWh$ for the year 2007-08 in accordance with CDM Executive Board approved methodology ACM0013.

# 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.

CDM appears to be a promising mechanism but many implementation issues were to be addressed like fixing of baseline etc. A need was, therefore, felt to work out an acceptable and realistic baseline of $CO_2$ emissions for the various regions of the country to enable the prospective project developers to pose their projects for approval by the CDM Executive Board. Central Electricity Authority (CEA) accordingly took up in cooperation with GTZ CDM-India, 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. India is the first country in the world to have ventured to take up the complex task of developing such an official baseline for the power sector as a whole.

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 October 2007, the CDM Executive Board 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, is set to become the main reference for CDM methodologies involving baseline emission factors for power grids. In particular, ACM0002 was subsequently revised and in its latest Version 07 refers to the Grid Tool with respect to the methodological details of the baseline emission factor calculation.

**This version is designed to be consistent with version 1.1 of the Tool to calculate the emission factor for an electricity system published by CDM Executive Board.** .. In comparison with the previous versions of the database, this required only minor modifications: one with respect to the IPCC default emission factors used (see Section 4.3) and the other in the calculation of $CO_2$ emissions from imported electricity (see Section 4.4).

### 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 144130.17 MW as on 31.03.2008, consisting of 91906.84 MW Thermal, 35908.76 MW Hydro and 4120 MW Nuclear. Sector-wise details of installed capacity are shown in Table 1.

*Table 1: Sector- wise installed capacity (MW) as on 31.03.2008.*

| Sector | Hydro | Thermal | | | | Nuclear | Renew. | Total |
|---|---|---|---|---|---|---|---|---|
| | | Coal | Gas | Diesel | Total | | | |
| **State** | **26086.76** | **42047.50** | **3834.22** | **604.61** | **46486.33** | **0.00** | **2200.04** | **74773.13** |
| **Central** | **8592.00** | **29010.00** | **6638.99** | **0.00** | **35648.99** | **4120.00** | **0.00** | **48360.99** |
| **Private** | **1230.00** | **4991.38** | **4183.00** | **597.14** | **9771.52** | **0.00** | **9994.53** | **20996.05** |
| **All India** | **35908.76** | **76048.88** | **14656.21** | **1201.75** | **91906.84** | **4120.00** | **12194.57** | **144130.17** |

Note: These capacities are not identical with those listed in the Excel database, because the database excludes renewable , small diesel and steam units but includes the units which are closed during recent years as database contain data from 2005-06..

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

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.

### 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 will be treated as a single grid and is being named as NEWNE grid in this document from FY 2007-08 onwards for the purpose of this $CO_2$ Baseline Database. The Southern grid has also been planned to be synchronously operated with rest of all Indian Grid by early 12th Plan (2012-2017). Presently Southern grid is connected with Western and Eastern grid through HVDC link and HVDC back to back systems.**

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 meet 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 | Pondicherry |
| 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 $tCO_2$/MWh) of the baseline and the project activity. The baseline emission factor reflects the carbon intensity of the displaced amount of 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 have been 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.

**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

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[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 1.1. See http://cdm.unfccc.int

listed in the Grid Tool for calculating the operating margin.[3] 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.

**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.[4]

[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 EB 35 (Annex 12), pp.5 and 13.

# 3 Scope of Database

The database includes all grid-connected power stations having an installed capacity above 3 MW in case of hydro and above 10 MW for other plant types. The data covers power stations of both public utilities and independent power producers (IPPs).

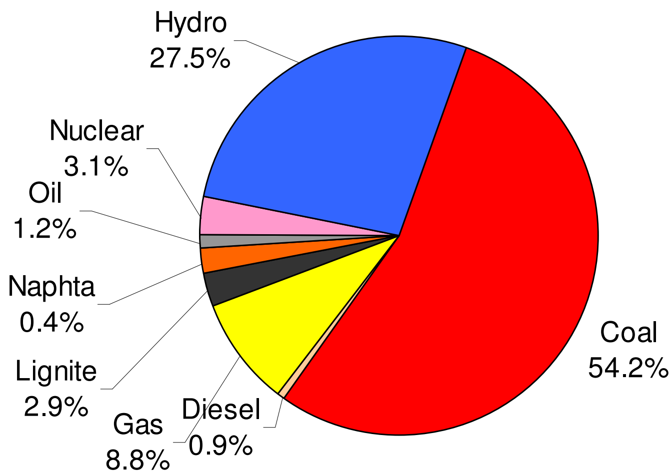


*Figure 1: Breakdown of generation capacity covered by the database. The total corresponds to 133,584 MW as on 31.03.2008.*

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

- Stations or units installed in Andaman and Nicobar Islands and Lakshadweep.
- Captive power stations:
  As on 31 March 2008, the installed capacity from captive stations was 24,680.70 MW. The generation of these stations in 2007-08 was 85431GWh, equalling 12.12% of total generation in India.
- Non-conventional renewable energy stations:
  These include power generation from wind, biomass, solar photovoltaic, and hydro below 3 MW capacity. The installed, grid-connected capacity of these sources was approx. 12194.57 MW as on 31. 03. 2008.[5]
- Small decentralised generation sets.

[5] Ministry of New and Renewable Energy

# 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 2008.
- 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 $tCO_2$/MWh, for the three FY 2005-06 to 2007-08. 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.

### 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.

### 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 generally not measured at unit level. Two distinct approaches were applied to estimate net generation.

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.

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

**Fuel consumption and GCV:**
Fuel consumption and GCV are generally not measured at unit level. Therefore, the specific $CO_2$ emissions of the relevant units were directly calculated based on heat rates. 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[6]. In line with the Grid Tool, the low end values of the 95% confidence intervals indicated by IPCC were used.[7] The IPCC default factors were converted to GCV basis using IEA default conversion factors.

The oxidation factor for coal and lignite were 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.[8] 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 ($NetGen(station)_y$).

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

**Calculation Approach – Unit Level**

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

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:

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

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;

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6 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 1.4

7 In accordance with the *Tool to calculate the emission factor for an electricity system, Version 1.1*

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

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

For over 90% of all thermal units in the build margin, one of these cases applied. In the remaining cases, the specific emissions of the units were derived from conservative standard heat rate values, defined as the design heat rate plus 5% (see Appendix B).

## 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.[9];

## 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 was used. For example, standard auxiliary power consumption was assumed for a number of gas-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.
- Where required, the emission factors of thermal units were also derived from standard CEA values (design heat rate plus 5%). Again, these values are conservative (i.e. relatively low) compared to the heat rates observed in practice. See Section 4.3 for details on the build margin calculation.
- 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).[10]

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9 This corresponds to Approach c) listed in the Grid Tool (Version 1.1).

10 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 2.2

# 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 2005-06 to 2007-08. 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 2007-08

Table 4 indicates the development of total emissions by grid over the last three years covered by the database (values for FY 2005-06 and 2006-2007 have been recalculated according to new grid configuration and takes care of adjusted IPCC-based fuel emission factors to account for uncertainty in line with EB 35 Annex 12 ).

*Table 4: Total emissions from the power sector by region for the FY 2005-06 to 2007-08*

**Absolute Emissions Total ( Million tCO2)**

| Grid | 2005-06 | 2006-07 | 2007-08 |
|---|---|---|---|
| NEWNE | 368.11 | 385.64 | 406.56 |
| Southern | 101.55 | 109.02 | 113.63 |
| India | 469.67 | 494.66 | 520.19 |

Table 5 shows the emission factors for FY 2007-08 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 2007-08 (not adjusted for inter-grid and cross-country electricity transfers), in $tCO_2/MWh$*

| Grid | Average | OM | BM | CM |
|---|---|---|---|---|
| NEWNE | 0.82 | 1.01 | 0.60 | 0.80 |
| Southern | 0.72 | 0.99 | 0.71 | 0.85 |
| India | 0.80 | 1.01 | 0.63 | 0.82 |

*Table 6: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of grids for FY 2007-08 (adjusted for inter-grid and cross-country electricity transfers), in $tCO_2/MWh$*

| Grid | Average | OM | BM | CM |
|---|---|---|---|---|
| NEWNE | 0.81 | 1.00 | 0.60 | 0.80 |
| Southern | 0.72 | 0.99 | 0.71 | 0.85 |
| India | 0.79 | 1.00 | 0.63 | 0.81 |

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 2007-08.

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 2007-08, in $tCO_2$/MWh..*

| **Weighted average specific emissions fuel wise in 2007-08 (tCO2/MWh)** | | | | | | |
|---|---|---|---|---|---|---|
| **Grid** | **Coal** | **Diesel** | **Gas** | **Lignite** | **Naphtha** | **Oil** |
| **NEWNE** | 1.10 | 0.63 | 0.47 | 1.37 | 0.44 | 0.77 |
| **Southern** | 1.01 | 0.62 | 0.47 | 1.41 | 0.60 | 0.64 |
| **India** | 1.08 | 0.62 | 0.47 | 1.40 | 0.45 | 0.74 |

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 illustrates the development of the import-adjusted operating margins over the period from FY 2005-06 to FY 2007-08. The variations between the years are generally quite small (see Appendix C for values before import adjustment).

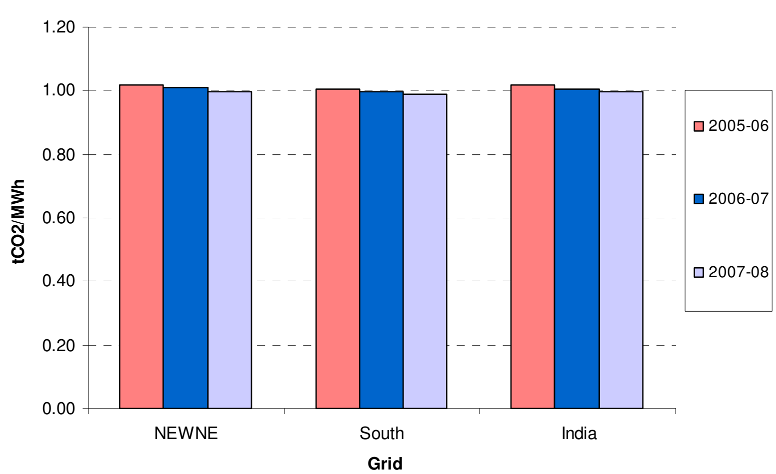


*Figure 2: Development of the operating margin (adjusted for electricity transfers) for India's grids over the period 2005-06 to 2007-08.*

Figure 3 shows the build margins for the three FY 2005-06 to 2007-08. Slight changes compared to the previous year are observed for the NEWNE Grid, which are reflected in the total values for India, while the Southern Grid is practically stable. Changes in the NEWNE Grid can be explained by variations in the shares of coal, hydro and other generation types among the units falling into the build margin, as shown in Figure 4. 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.

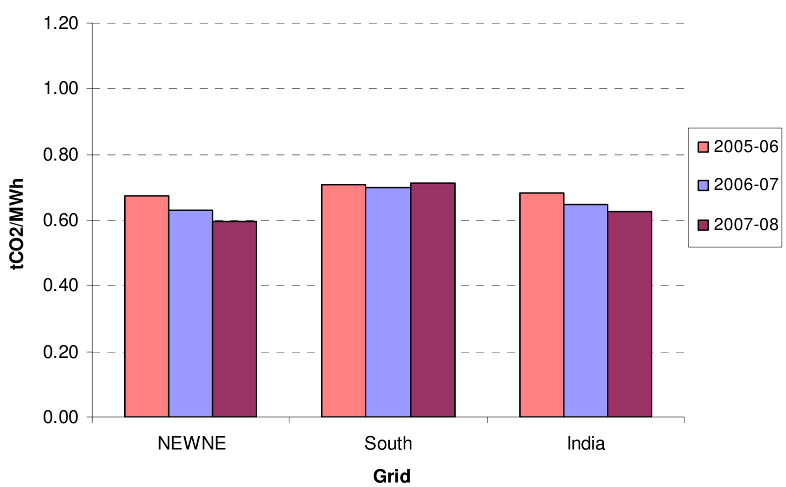


*Figure 3:* *Development of the build margins for India's grids over the period 2005-06 to 2007-08*

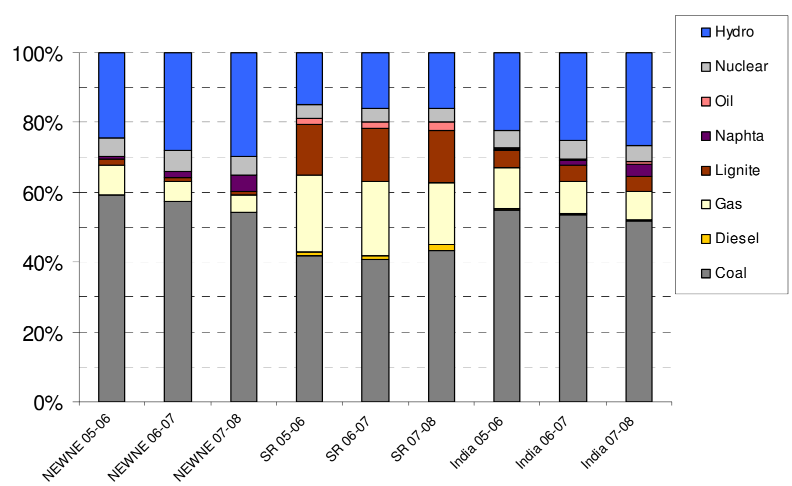


*Figure 4:* *Breakdown of the build margin (comparison of FY 2005-06 to 2007-08) by station and fuel type for grids (shares based on net generation)*

Figure 5 shows the trends in the import-adjusted combined margins in the period 2005-06 to 2007-08. As a result of the recent decrease in the build margin of the NEWNE Grid, a decreasing trend is observed also for the combined margin at the level of the NEWNE Grid and nation-wide.

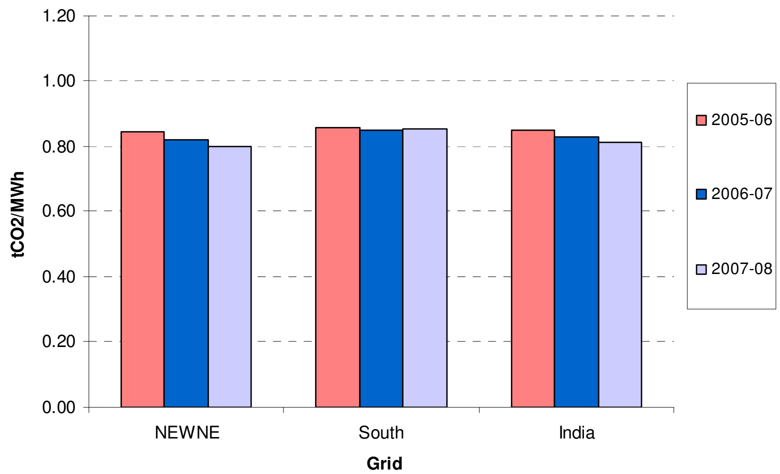


*Figure 5: Development of the combined margin (adjusted for electricity transfers) for India's grids over the period 2005-06 to 2007-08.*

## 5.3 Changes compared to Previous Database Versions

In comparison with the previous version of the Database (Version 3.0), this version includes the following methodological changes:

- Change from five to two grids, as described in Section 1;
- Accounting for uncertainty in IPCC default emission factors for fuels, by using low end of 95% confidence intervals (see Section 4.3).
- Baseline Emission Factor as per Methodology ACM0013 included as separate chapter

# 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 (formerly North-Eastern Region, since FY 2007-2008 NEWNE Grid). The station will be commissioned in 2009. 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 (2007-08). The corresponding value is 0.81 t $CO_2$/MWh. Hence the absolute emission reductions are projected at 0.81 * 17’500 = 14’175 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.[11] 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 2009. 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.

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[11] The emission factor of the previous year may be used instead. See request for clarification AM_CLA_0038 (http://cdm.unfccc.int/methodologies/PAmethodologies/Clarifications/index.html).

- 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[12] requires that the operating margin is calculated as the average of the three most recent years (here 2005-06 to 2007-08). The operating margin to be applied thus works out to 1.00 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 0.93 t $CO_2$/MWh (75% x 1.00 + 25% x 0.71 for the FY 2007-08). 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 8 below.

[12] Tool to calculate the emission factor for an electricity system (Version 01.1), adopted by EB 35 (Annex 12). and subsequently revised to Version 1.1. See http://cdm.unfccc.int

*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: | 2009 | 2009 |
| Year of CDM registration: | 2008 | 2008 |
| Grid : | NEWNE | Southern |
| CDM methodology: | AMS-I.D / Version 13 | ACM0002 / Version 07 |
| **Baseline Emission Factor Calculation** | | |
| Calculation method: | Weighted average | Combined margin |
| Data vintage for projection of emission reductions: | 2007-08 (most recent available at time of PDD validation) | For OM: 2005-06, 2006-07, 2007-08 (most recent 3 years available at time of PDD validation)<br><br>For BM: 2007-08 |
| Data vintage for verification of emission reductions: | Actual year of generation, i.e. 2008-09, 2009-10 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 $tCO_2$/MWh: | 0.81 Weighted average | 1.00 Operating margin<br>0.71 Build margin<br>0.93 Combined margin |
| Projected emission reductions: | 14’125 t $CO_2$ per year | 290’625 t $CO_2$ per year |
| Actual emission reductions: | Monitored net generation x monitored weighted average | Monitored net generation x fixed combined margin |

# 7 Baseline Emission Factor as per Methodology ACM0013

**(To be used by new coal based power plants with supercritical parameters)**

CDM Executive Board has approved the consolidated methodology **ACM0013 ver 1.0** for new grid connected fossil fuel fired power plants using a less GHG intensive technology.

The project activity is the construction and operation of a new fossil fuel fired grid-connected electricity generation plant that uses a more efficient power generation technology than what would otherwise be used with the given fossil fuel. This methodology can be used by project proponent installing supercritical units in India for claiming CDM benefits.

Central Electricity Authority has calculated the baseline emission factor for the year 2007-08 which can be used by the power utilities installing coal based generating units based on supercritical parameters. The baseline emission factor can be multiplied by electricity generated in the power plant to calculate the baseline emissions. The emission factors is applicable to the new Supercritical unit size ranging from 600MW to 1000MW

The relevant methodological steps as described in ACM0013 are given below:

**Baseline Emissions**

Baseline emissions are calculated by multiplying the electricity generated in the project plant ($EG_{PJ,y}$) with a baseline CO2 emission factor ($EF_{BL,CO2,y}$), as follows:

$$BE_y = EG_{PJ,y} * EF_{BL,CO2}$$

Where:

$BE_y$ Baseline emissions in year $y$ ($tCO_2$)

$EG_{PJ,y}$ Quantity of electricity generated in the project plant in year $y$ (MWh)

$EF_{BL,CO2}$ Baseline emission factor in year $y$ ($tCO_2$/MWh)

$EF_{BL,CO2}$ is determined using the lower value between the emission factor of the technology and fuel type that has been identified as the most likely baseline scenario and a benchmark emission factor determined based on the performance of the top 15% power plants that use the same fuel as the project plant and any technology available in the geographical area.

To calculate $EF_{BL,CO2,}y$ the lowest value among the following two options will be used.

***Option 1:*** The emission factor of the technology and fuel identified as the most likely baseline scenario under "Identification of the baseline scenario" section above, and calculated as follows:

$$EF_{BL,CO2,y} = \frac{MIN(EF_{FF,CO2,y}, EF_{FF,PJ,CO2,y})}{\eta_{BL}} * 3.6\ GJ/MWh$$

Where:

$EF_{BL,CO2,y}$ Baseline emission factor in year *y* ($tCO_2$/MWh)

$EF_{FF,CO2,y}$ baseline emission factor of the baseline fossil fuel type that has been identified as the most likely baseline scenario ($tCO_2$ / Mass or volume unit)

$EF_{FF,PJ,CO2,y}$ Average $CO_2$ emission factor of the fossil fuel type used in the project plant in year *y* ($tCO_2$ / Mass or volume unit)

$\eta_{BL}$ is the Energy efficiency of the power generation technology that has been identified as the most likely baseline scenario

**Calculation of baseline efficiency $\eta_{BL}$**

For the proposed project activity, the baseline fossil fuel type that has been identified as the most likely baseline scenario is coal and the fossil fuel to be used in the proposed project activity is also coal. To calculate $\eta_{BL}$ , it is assumed that baseline plant would be 500 MW sub critical power plant based on sub Bituminous coal or imported coal.

Taking normative Gross Heat Rate ( CERC norms) = 2450 kcal/kWh

Auxiliary Power Consumption as per CERC = 7%

i.e. Net Heat rate $= \frac{2450}{0.93}$ = 2635 kcal/kWh

**Net** $\eta_{BL} = \frac{860}{2635}$ = 32.63%

**Case (i)** Project is using the same coal as baseline coal i.e. (sub Bituminous coal)

Emission factor as per Initial National Communication

$EF_{FF,BL,CO2,y}$ = 90.6 g $CO_2$/MJ

(Emission factor as per Initial National Communication based on GCV basis with oxidation factor of 0.98)

$EF_{FF,PJ,CO2,Y}$ = 90.6 g $CO_2$/MJ (project is using the same coal as baseline coal)

Using the formula for option 1 above

$$= \text{Min } \frac{(90.6,\ 90.6)}{32.63\%} \text{ X } 3.6 \frac{GJ}{MWh}$$

= **0.99 t $CO_2$ / MWh**

**Case (ii)** Project is using the same coal as baseline coal i.e. (sub Bituminous coal)

Emission factor as per IPCC

$EF_{FF,BL,CO2,y}$ = 90.9 g $CO_2$/MJ

(Emission factors i.e. 96.1 g$CO_2$/MJ on NCV or 90.9 g $CO_2$/MJ on GCV basis with oxidation factor of 0.98)

$EF_{FF,PJ,CO2,Y}$ = 90.9 g $CO_2$/MJ (project is using the same coal as baseline coal)

Using the formula for option 1 above

$$= \text{Min } \frac{(90.9,90.9)}{32.63} \text{ X } 3.6 \text{ g } CO_2/\text{MWh}$$

= **1.02 t $CO_2$/MWh**

**Case (iii)** Project is using other bituminous coal i.e. imported coal and baseline coal is sub bituminous.

Considering Project emission factor based on IPCC for other bituminous coal ie imported coal as 94.6 g $CO_2$/MJ on NCV basis or 89.5 g$CO_2$/MJ on GCV basis with oxidation factor of 0.98

Considering National communication emission factor of 90.6 gCO2/MJ on GCV basis for sub bituminous baseline coal.

$EF_{FF,BL,CO2,y}$ = 90.6 g $CO_2$/MJ

$EF_{FF,PJ,CO2,Y}$ = 89.5 g $CO_2$/MJ

$$= \frac{\text{Min } (90.6,89.5)}{32.63} \text{ X } 3.6 \text{ g } CO_2/\text{MWh}$$

**= 0.987 t$CO_2$/MWh**

**Case (iv)** Project is using other bituminous coal i.e. imported coal and baseline coal is sub bituminous coal

Considering both Emission factor ie for imported coal and baseline coal from IPCC default values

$EF_{FF,BL,CO2,y}$ = 90.9 g $CO_2$/MJ

$EF_{FF,PJ,CO2,Y}$ = 89.5 g $CO_2$/MJ

$$= \frac{\text{Min ( 90.9, 89.5)}}{32.63} \text{ g } CO_2 \text{ /MWh}$$

**= 0.987 t $CO_2$ / MWh**

**So Minimum emission factor ( Case i to iv) calculated for option 1 is 0.987 t $CO_2$/MWh**

***Option 2:*** The average emissions intensity of all power plants *j*, corresponding to the power plants whose performance is among the top 15 % of their category, as follows:

$$EF_{BL,CO2,y} = \frac{FC_{j,x} * NCV_{j,x} * EF_{CO2,j,x}}{EG_{j,x}}$$

Where:

$EF_{BL,CO2,y}$ Baseline emission factor in year *y* ($tCO_2$/MWh)

$FC_{j,x}$ Amount of fuel consumed by power plant *j* in year *x* (Mass or volume unit)

$NCV_{j,x}$ Net calorific value of the fossil fuel type consumed by power plant j in year *x* (GJ / Mass or volume unit)

$EF_{CO2,j,x}$ $CO_2$ emission factor of the fossil fuel type consumed by power plant *j* in year *x* ($tCO_2$ / Mass or volume unit)

$EG_{j,x}$ Net electricity generated and delivered to the grid by power plant *j* in year *x*

*X* *M*ost recent year prior to the start of the project activity for which data is available

*J* Top 15% performing power plants (excluding cogeneration plants and including

Power plants registered as CDM project activities), as identified below, among all power plants in a defined geographical area (India) that have a similar size, are operated at similar load (*i.e.* at base load) and use the same fuel type (coal) as the project activity

For determination of the top 15% performer power plants *j*, the following step-wise approach is used:

***Step 1: Definition of similar plants to the project activity***

The sample group of similar power plants should consist of all power plants (except for

cogeneration power plants):

• Those use the same fossil fuel type as the project activity, where fuel types are defined in the following categories:

-Coal

-Oils (e.g. diesel, kerosene, residual oil)

-Natural gas

• Those have been constructed in the previous five years;

• Those have a comparable size to the project activity, defined as the range from 50% to 150% of the rated capacity of the project plant;

• Those are operated in the same load category, *i.e.* at peak load (defined as a load factor of less than 3,000 hours per year) or base load (defined as a load factor of more than 3,000 hours per year) as the project activity; and

• Those have operated (supplied electricity to the grid) in the year prior to the start of the project activity.

The sample group of plants identified consists of coal based sub-critical power plants that have a capacity between 330MW to 990MW, have been constructed in last 5 years, operate at base load and have supplied electricity to the grid before start of the proposed project activity.

***Step 2: Definition of the geographical area***

As per the methodology ACM0013, Version 01, the geographical area to identify similar power plants is chosen in a manner that the total number of power plants "N" in the sample group comprises at least 10 plants. As a default, the grid to which the project plant will be connected should be used. As the number of similar plants, as defined in Step 1, within the Western regional grid boundary is less than 10, the geographical area is extended to India. The number of similar plants is now greater than 10.

***Step 3: Identification of the sample group***

Identify all power plants *n* that are to be included in the sample group. Determine the total number "N" of all identified power plants that use the same fuel as the project plant and any technology available within the geographical area, as defined in Step 2 above.

The sample group should also include all power plants within the geographical area registered as CDM project activities, which meet the criteria defined in Step 1 above.

The proposed supercritical units that are proposed to be installed are of the range 660 MW to 800 MW. Therefore according to conditions for selection of sample group given in step 1 above ( 50% to 150% criteria), unit sizes above 330 MW upto 990 MW are selected. The sample group of plants satisfying the above mentioned criteria are 14 units of 500MW. The list of the units in sample group are given below:

*Table 9: Details of the thermal units selected under sample Group*

| SNo | NAME | UNIT_NO | SIZE in MW |
|---|---|---|---|
| 1 | TALCHER STPS | 3 | 500 |
| 2 | TALCHER STPS | 4 | 500 |
| 3 | TALCHER STPS | 5 | 500 |
| 4 | TALCHER STPS | 6 | 500 |
| 5 | R_GUNDEM STPS | 7 | 500 |
| 6 | VINDH_CHAL STPS | 10 | 500 |
| 7 | VINDH_CHAL STPS | 9 | 500 |
| 8 | RIHAND | 3 | 500 |
| 9 | RIHAND | 4 | 500 |
| 10 | KAHALGAON | 6 | 500 |
| 11 | BELLARY TPS | 1 | 500 |
| 12 | SANJAY GANDHI | 5 | 500 |
| 13 | SIPAT STPS | 1 | 500 |
| 14 | KAHALGAON | 5 | 500 |

***Step 4: Determination of the plant efficiencies***

Calculate the operational efficiency of each power plant *n* identified in the previous step. The most recent one-year data available is used. Hence the data for the year 2007-08 was used in calculations of plant efficiencies.

The operational efficiency of each power plant *n* in the sample group is calculated as follows:

$$\eta_{n,x} = \frac{EG_{n,x} * 860}{FC_{n,x} * GCV_{n,x}}$$

Where:

*EGn,x* :Net electricity generated and delivered to the grid by the power plant *n* in the year *x*

*(MWh)*

*FCn,x :* Quantity of fuel consumed in the power plant *n* in year *x* (Mass or volume unit)

*GCVn,x :* Gross calorific value of the fuel type fired in power plant *n* in year x (kcal / mass or volume unit). Calorific value of coal is reported as Gross Calorific Value in kcal/kg by the power plants in India.

860 : is a conversion factor ( 1 kwh = 860 kcal)

n : are all power plants in the defined geographical area that have a similar size, are operated at similar load and use the same fuel types as the project activity

*x :* Most recent year prior to the start of the project activity for which data are available

***Step 5: Identification of the top 15% performer plants j***

Sort the sample group of *N* plants from the power plants with the highest to the lowest operational efficiency. Identify the top 15% performer plants *j* as the plants with the 1st to $J^{th}$ highest operational efficiency, where the *J* (the total number of plants *j*) is calculated as the product of N (the total number of plants *n* identified in step 3) and 15%, rounded down if it is decimal.4 If the generation of all identified plants *j* (the top 15% performers) is less than 15% of the total generation of all plants n (the whole sample group), then the number of plants *j* included in the top 15% performer group should be enlarged until the group represents at least 15% of total generation of all plants *n*.

Accordingly, two units of 500MW i.e. Talchar STPS unit 3 and 4 are identified as 15% top performing units. These units also cover more than the 15% of the total net generation of all plants selected in the sample Group. The operating data has been obtained from all the identified unit from the respective power utility.

**The emission factor calculated in accordance with option 2 works out to be 0.941 $tCO_2$/MWh.**

As per the methodology ACM0013, minimum of option 1 and option 2 is to be taken as baseline emission factor

i.e Minimum ( 0.987, 0.941)

**Therefore, the baseline emission factor which is to be used for calculating CDM Benefits for supercritical projects has been calculated as 0.941 $tCO_2$/MWh for the year 2007-08.**

# 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:

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# Appendix A – Systems in India's Grids

*In alphabetical order*

| Abbreviation | Full name |
|---|---|
| ABAN | ABAN Power Company |
| 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 |
| JINDAL | JSW Energy Limited |
| JKEB | Jammu & Kashmir Electricity Board |

*Continuation*

| Abbreviation | Full name |
|---|---|
| JPHPL | Jai Prakash Hydro Power Limited |
| JSEB | Jharkand State Electricity Board |
| 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 Electric Corporation |
| 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 |
| 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 | 500 MW |
|---|---|---|---|---|---|
| Gross Heat Rate | kcal /kWh | 2'750 | 2'500 | 2'500 | 2'425 |
| Auxiliary Power Consumption | % | 12.0 | 9.0 | 9.0 | 7.5 |
| Net Heat Rate | kcal /kWh | 3'125 | 2'747 | 2'747 | 2'622 |
| Net Efficiency | % | 28% | 31% | 31% | 33% |
| Specific Oil Consumption | ml /kWh | 2.0 | 2.0 | 2.0 | 2.0 |
| Specific CO2 Emissions | tCO2 /MWh | 1.19 | 1.05 | 1.05 | 1.00 |

| **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 |
| Net Efficiency | % | 28% | 30% | 29% |
| 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 |
| Net Efficiency | % | 43% | 44% | 42% |
| 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 2005-06 to 2007-08, excluding inter-grid and cross-border electricity transfers.***

**Weighted Average Emission Rate (tCO2/MWh) (excl. Imports)**

| **Grid** | **2005-06** | **2006-07** | **2007-08** |
|---|---|---|---|
| **NEWNE** | 0.84 | 0.83 | 0.82 |
| **Southern** | 0.73 | 0.72 | 0.72 |
| **India** | 0.82 | 0.80 | 0.80 |

**Simple Operating Margin (tCO2/MWh) (excl. Imports)**

| **Grid** | **2005-06** | **2006-07** | **2007-08** |
|---|---|---|---|
| **NEWNE** | 1.02 | 1.02 | 1.01 |
| **Southern** | 1.01 | 1.00 | 0.99 |
| **India** | 1.02 | 1.01 | 1.01 |

**Build Margin (tCO2/MWh) (excl. Imports)**

| **Grid** | **2005-06** | **2006-07** | **2007-08** |
|---|---|---|---|
| **NEWNE** | 0.67 | 0.63 | 0.60 |
| **Southern** | 0.71 | 0.70 | 0.71 |
| **India** | 0.68 | 0.65 | 0.63 |

**Combined Margin (tCO2/MWh) (excl. Imports)**

| **Grid** | **2005-06** | **2006-07** | **2007-08** |
|---|---|---|---|
| **NEWNE** | 0.85 | 0.82 | 0.80 |
| **Southern** | 0.86 | 0.85 | 0.85 |
| **India** | 0.85 | 0.83 | 0.82 |

***Table B: Values for all grids for FY 2007-08, including inter-grid and cross-border electricity transfers.***

**Weighted Average Emission Rate (tCO2/MWh) (incl. Imports)**

| Grid | 2005-06 | 2006-07 | 2007-08 | |
|---|---|---|---|---|
| **NEWNE** | 0.84 | 0.82 | 0.81 | * |
| **Southern** | 0.73 | 0.72 | 0.72 | * |
| **India** | 0.81 | 0.80 | 0.79 | |

**Simple Operating Margin (tCO2/MWh) (incl. Imports)**

| Grid | 2005-06 | 2006-07 | 2007-08 | |
|---|---|---|---|---|
| **NEWNE** | 1.02 | 1.01 | 1.00 | * |
| **Southern** | 1.01 | 1.00 | 0.99 | * |
| **India** | 1.02 | 1.01 | 1.00 | |

**Build Margin (tCO2/MWh) (not adjusted for imports)**

| Grid | 2005-06 | 2006-07 | 2007-08 |
|---|---|---|---|
| **NEWNE** | 0.67 | 0.63 | 0.60 |
| **Southern** | 0.71 | 0.70 | 0.71 |
| **India** | 0.68 | 0.65 | 0.63 |

**Combined Margin in tCO2/MWh (incl. Imports)**

| Grid | 2005-06 | 2006-07 | 2007-08 |
|---|---|---|---|
| **NEWNE** | 0.85 | 0.82 | 0.80 |
| **Southern** | 0.86 | 0.85 | 0.85 |
| **India** | 0.85 | 0.83 | 0.81 |

* = Using approach (c) on p. 4 of "Tool to Calculate the Emission Factor for an Electricity System", Ver. 1.1

## Appendix D – Summary of Methodology ACM0002 / Version 07

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 |