

CO₂ Baseline Database for the Indian Power Sector

User Guide

Version 5.0

November 2009

**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	4 th October 2006	–
1.0	November 2006	<ul style="list-style-type: none"> - Added data on 10 stations which had been in exclusion worksheet of draft database - Adjusted values to latest IPCC Guidance (IPCC 2006 Guidelines for National Greenhouse Gas Inventories) where IPCC defaults are used
1.1	December 2006	<ul style="list-style-type: none"> - Adjusted fuel emission factor of lignite to be in line with Initial National Communication figures
2.0	June 2007	<ul style="list-style-type: none"> - Added data for FY 2005-06, including new stations and units commissioned during 2005-06 <p>Retroactive changes to data for FY 2000-01 to 2004-05:</p> <ul style="list-style-type: none"> - 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) - Refined approximation of unit-level generation where not provided by station, by taking into account day of commissioning (for build margin) - Revised fuel consumption for some stations where data became available
3.0	December 2007	<ul style="list-style-type: none"> - Added data for FY 2006-07, including new stations and units commissioned during 2006-07 - Adapted calculations and User Guide to ensure consistency with new CDM methodologies: ACM0002 Version 07, and Tool to Calculate the Emission Factor for an Electricity System (Version 01.1, EB 35 Annex 12)
4.0	October 2008	<ul style="list-style-type: none"> - Added data for FY 2007-08, including new stations and units commissioned during 2007-08 - Adjusted delineation of regional grids - Adjusted IPCC-based fuel emission factors to account for uncertainty in line with EB 35 Annex 12 - Baseline Emission Factor as per Methodology ACM0013 included as separate chapter
5.0	November 2009	<ul style="list-style-type: none"> - Added data for FY 2008-09, including new stations and units commissioned during 2008-09

Expert Team Contributing to the Database

Central Electricity Authority

Mr. S.M. Dhiman, Member (Planning)
 Mr. Amarjeet Singh, Chief Engineer (C&E)
 Mr. Praveen Gupta, Director (C&E)
 Mr. Rajesh Kumar, Assistant Director (C&E)

First Climate (Switzerland) AG

Mr. Urs Brodmann, Executive Director
 Mr. Till Danckwardt, Project Manager
 Mr. Mathias Sacher, Project Assistant
 Mr. Luca Morganti, Project Manager

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 CO₂ Baseline Database for the Indian Power Sector (Version 4.0) containing data for the year 2007-08 was published in October 2008. The Baseline Database has benefited all prospective CDM project developers to estimate the amount of Certified Emission Reduction (CERs). India has 452 registered projects out of 1862 of world total. Host country approval to more than 1100 projects has already been accorded by National CDM Authority established under the Ministry of Environment and Forest.

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 CO₂ emission rate has increased marginally to 0.82 t CO₂/MWh in the year 2008-09 from 0.79 t CO₂/MWh in the year 2007-08 due to the fact that generation from hydro and nuclear plants have declined.

I am glad that Central Electricity Authority has also worked out CO₂ 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 S.M. Dhiman, Member (Planning), CEA. We are thankful to Mr Juergen Bischoff, Director ,GTZ-ASEM and Mr Jens Burgtorf, Director, IGEN-GTZ, Mr Urs Brodmann GTZ consultants, who provided guidance and gave useful inputs to the team of CEA engineers.

New Delhi
November 2009

(Rakesh Nath)
Chairperson

Preface

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. Hon able Prime Minister of India has released the **National Action Plan on Climate Change (NAPCC)** in June 2008.. The National Action Plan on Climate Change (NAPCC) outlines a national strategy that aims to enable the country adapt to climate change and enhances the ecological sustainability of India's development path

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. The database has now been updated for the year 2008-09 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.

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 CDM approved methodology (ACM0013) 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.

I appreciate the efforts put in by all the officers of Central Electricity Authority, in bringing out the updated version for the year 2008-09.

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
November 2009

(S.M. Dhiman)
Member (Planning)

Acknowledgement

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 H.S.Brahma, 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 CO₂ Baseline database.

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

I sincerely thank Mr Juergen Bischoff, Director ,GTZ-ASEM and Mr Jens Burgtorf, Director, IGEN- GTZ and its consultants Mr Urs Brodmann 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 Praveen Gupta, Director, CEA and Shri Rajesh Kumar, Assistant Director, CEA in compilation of data and evolving the Baseline carbon dioxide emissions for 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. Suggestions from the project developers and consultants are welcome to avoid such omissions in future.

New Delhi
November 2009

(Amarjeet Singh)
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 CO₂ to the end of 2012. CDM has brought investments and technology transfer in 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.

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 version also includes CO₂ baseline emission factor for coal based power units, applicable to new coal fired power generating units with supercritical steam parameters.

We congratulate our partners 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.

Mr Juergen Bischoff
Director
GTZ-ASEM

Jens Burgtorf
Director
GTZ-IGEN

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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” CO₂ 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 CO₂ emission reductions by CDM project developers, Central Electricity Authority (CEA), in cooperation with GTZ, has compiled a database containing the necessary data on CO₂ 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 2008-09 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 CO₂ 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 2008-09 (adjusted for inter-grid and cross-border electricity transfers), in tCO₂/MWh

	Average	OM	BM	CM
NEWNE	0.83	1.01	0.68	0.84
South	0.76	0.97	0.82	0.90
India	0.82	1.01	0.71	0.86

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 super-critical technology based power projects has also been calculated by Central Electricity Authority as 0.944 tCO₂/MWh for the year 2008-09 in accordance with CDM Executive Board approved methodology ACM0013 ver 2.1.

1 Background and Objective

Purpose of the CO₂ 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 (CO₂). 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 CO₂ 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 in cooperation with GTZ, 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 CO₂ 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 CO₂ 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 CO₂ 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 10 refers to the Grid Tool with respect to the methodological details of the baseline emission factor calculation.

This version of the Database 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.

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 147,965.41 MW as on 31.03.2009, consisting of 93,725.24 MW Thermal, 36,877.76 MW Hydro and 4,120 MW Nuclear. Sector-wise details of installed capacity are shown in Table 1.

Table 1: Sector- wise installed capacity (MW) as on 31.03.2009.

Sector	Hydro	Thermal				Nuclear	Renew.	Total
		Coal	Gas	Diesel	Total			
State	27055.76	42537.50	3672.12	602.61	46812.23	0.00	2247.68	76115.67
Central	8592.00	29620.00	6638.99	0.00	36258.99	4120.00	0.00	48970.99
Private	1230.00	5491.38	4565.50	597.14	10654.02	0.00	10994.73	22878.75
All India	36877.76	77648.88	14876.61	1199.75	93725.24	4120.00	13242.41	147965.41

Note: These capacities are not identical with those listed in the Excel database, because the database excludes renewable , 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 CO₂ 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 1.1. 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 are treated as a single grid named as NEWNE grid in this document from FY 2007-08 onwards for the purpose of this CO₂ 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 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	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 tCO₂/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 CO₂ Database.

Specifically, the database contains the following elements:

- Worksheet “Data” provides the net generation and the absolute and specific CO₂ 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 CO₂ 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 CO₂ emitted per unit of electricity generated in the grid. It is calculated by dividing the absolute CO₂ 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 CO₂ intensity of the existing stations in the grid which are most likely to reduce their output if a CDM project supplies electricity to the grid (or reduces consumption of grid electricity). “Simple” denotes one out of four possible variants

² Tool to calculate the emission factor for an electricity system (Version 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 CO₂ 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 CO₂ 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 choose to argue for different weights. In particular, for intermittent and non-dispatchable generation types such as wind and solar photovoltaic, the Grid Tool allows to weigh the operating margin and build margin at 75% and 25%, respectively. However, the combined margins shown in the database are calculated based on equal weights.

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

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

⁴ See *Tool to calculate the emission factor for an electricity system* (Version 1.1), Page 4.

⁵ 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).

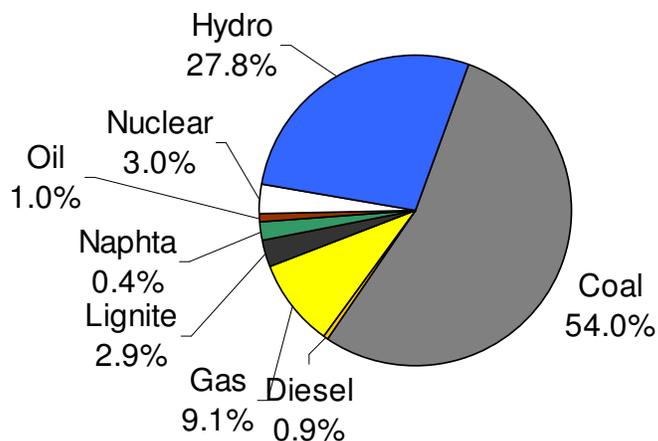


Figure 1: Breakdown of generation capacity covered by the database. The total corresponds to 134,941 MW as on 31.03.2009.

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. 13242.41 MW as on 31. 03. 2009.⁶
- Small decentralised generation sets.

⁶ 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 CO₂ emissions.

4.1 Base Data

The following base data parameters were collected for all the stations listed in the CO₂ 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 2009.
- **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 tCO₂/MWh, for the four fiscal years 2005-06 to 2008-09. 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 CO₂ 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, except in some units. Therefore, the specific CO₂ emissions of the relevant units were mostly calculated from heat rates. See Section 4.3 for details.

4.3 Calculation of CO₂ Emissions**Calculation Approach – Station Level**

CO₂ emissions of thermal stations were calculated using the formula below:

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

Where:

$AbsCO_{2,y}$ Absolute CO₂ 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 CO₂ 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 CO₂ 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 Guidelines⁷. In line with the Grid Tool, the low end values of the 95% confidence intervals indicated by IPCC were used.⁸ 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.⁹ For all other fuels, default values provided in the more recent IPCC 2006 Guidelines were used.

Specific CO₂ 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 ($NetGen(station)_y$).

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

Calculation Approach – Unit Level

Unit-level CO₂ emissions were only calculated for units falling in the build margin.

The absolute CO₂ 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:

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

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;
- 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 85% 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).

⁷ 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 1.4

⁸ In accordance with the *Tool to calculate the emission factor for an electricity system, Version 1.1*

⁹ IPCC 1996 Revised Guidelines for National Greenhouse Gas Inventories, Volume 3 (Reference Manual), p.1.13

Where ever reliable fuel consumption data are available at unit level., it has been used for determining the emissions of units falling into the build margin.

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 CO₂ emissions associated with these imports were quantified based on the simple operating margin of the exporting grid.¹⁰;

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 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 CO₂/TJ on NCV basis), being somewhat lower than the IPCC default for sub-bituminous coal (96.1 t CO₂/TJ).¹¹

¹⁰ This corresponds to Approach c) listed in the Grid Tool (Version 1.1).

¹¹ 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 CO₂ emissions data and the resulting emission factors for the two grids in the fiscal years 2005-06 to 2008-09. 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 2008-09

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

Table 4: Total emissions from the power sector by region for the FY 2006-07 to 2008-09, in million tonnes CO₂

	2005-06	2006-07	2007-08	2008-09
NEWNE	368.2	385.7	406.9	430.4
South	101.6	109.0	113.6	117.9
India	469.7	494.7	520.5	548.3

Table 5 shows the emission factors for FY 2008-09 excluding inter-grid and cross-border power transfers, whereas Table 6 shows the emission factors for the same year including these power transfers. The weighted average emission factor for India has increased from 0.79 in the previous year to 0.82, mainly due to below-average nuclear and hydro-based generation in FY 2008-09.

Table 5: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of grids for FY 2008-09 (not adjusted for inter-grid and cross-country electricity transfers), in tCO₂/MWh

	Average	OM	BM	CM
NEWNE	0.84	1.02	0.68	0.85
South	0.75	0.97	0.82	0.89
India	0.82	1.01	0.71	0.86

Table 6: Weighted average emission factor, simple operating margin (OM), build margin (BM) and combined margin (CM) of grids for FY 2008-09 (adjusted for inter-grid and cross-country electricity transfers), in tCO₂/MWh

	Average	OM	BM	CM
NEWNE	0.83	1.01	0.68	0.84
South	0.76	0.97	0.82	0.90
India	0.82	1.01	0.71	0.86

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 2008-09.

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 2008-09, in tCO₂/MWh..*

	Coal	Disl	Gas	Lign	Napt	Oil
NEWNE	1.11	0.00	0.46	1.43	0.41	0.78
South	1.00	0.63	0.47	1.44	0.60	0.64
India	1.09	0.63	0.47	1.44	0.44	0.73

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 2008-09. The variations between the years are generally quite small (see Appendix C for values before import adjustment).

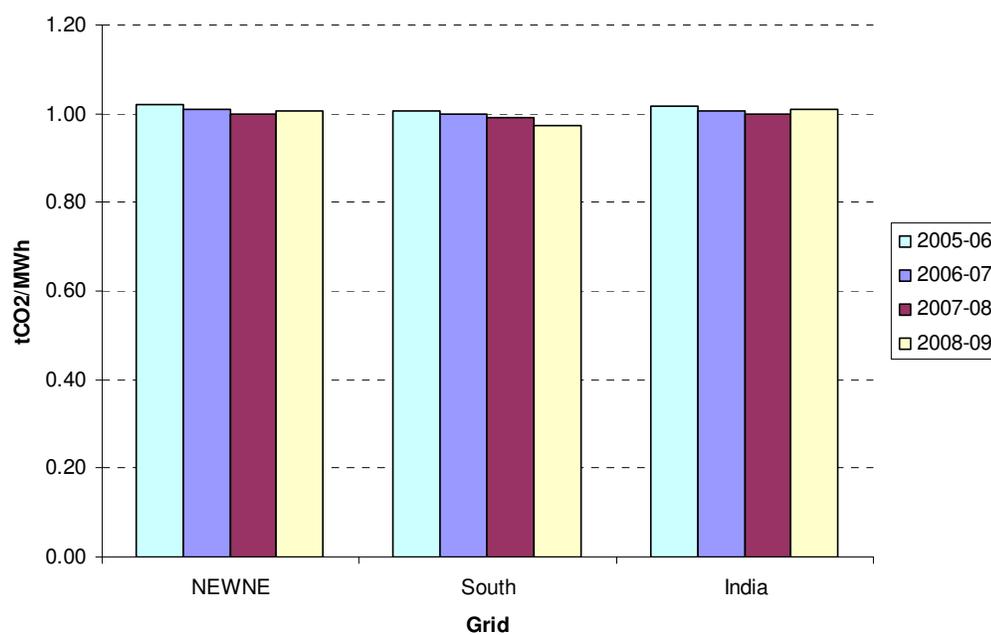


Figure 2: *Development of the operating margin (adjusted for electricity transfers) for India's grids over the period 2005-06 to 2008-09.*

Figure 3 shows the build margins for the four fiscal years 2005-06 to 2008-09. A significant increase is observed in both regions. As illustrated in Figure 4, this is due to an increased share of coal-based generation in the build margin, with a corresponding decrease in the

shares of hydro-, nuclear- and (in the case of the NEWNE region) gas-based generation. In the NEWNE Region, the increased weight of coal-fired generation relative to other generation modes can be primarily explained by a higher average plant load factor for the coal-fired stations, as several coal-based units commissioned in the previous year took up commercial operation. In addition, the plant load factors observed in those nuclear units falling into the build margin were lower than in previous years. In the Southern region, the relative increase in coal-based generation is due to several factors, including a decrease in the nuclear and hydro capacity in the build margin, an increased plant load factor in coal-based units, as well as exceptionally low plant load factors for the nuclear and hydro units in the build margin.

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.

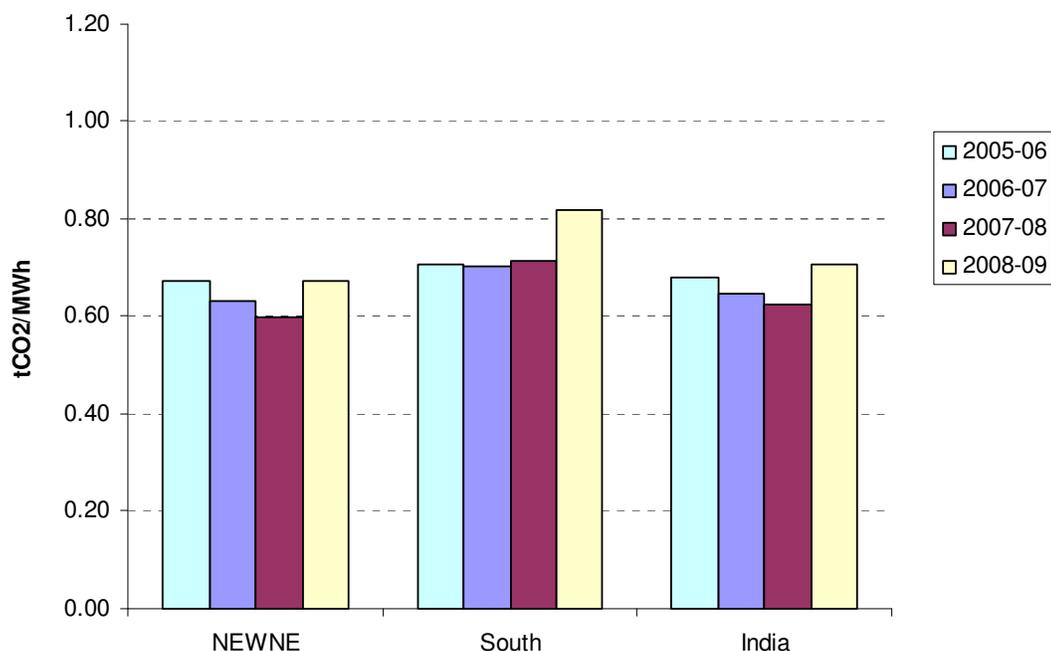


Figure 3: *Development of the build margins for India's grids over the period 2006-07 to 2008-09*

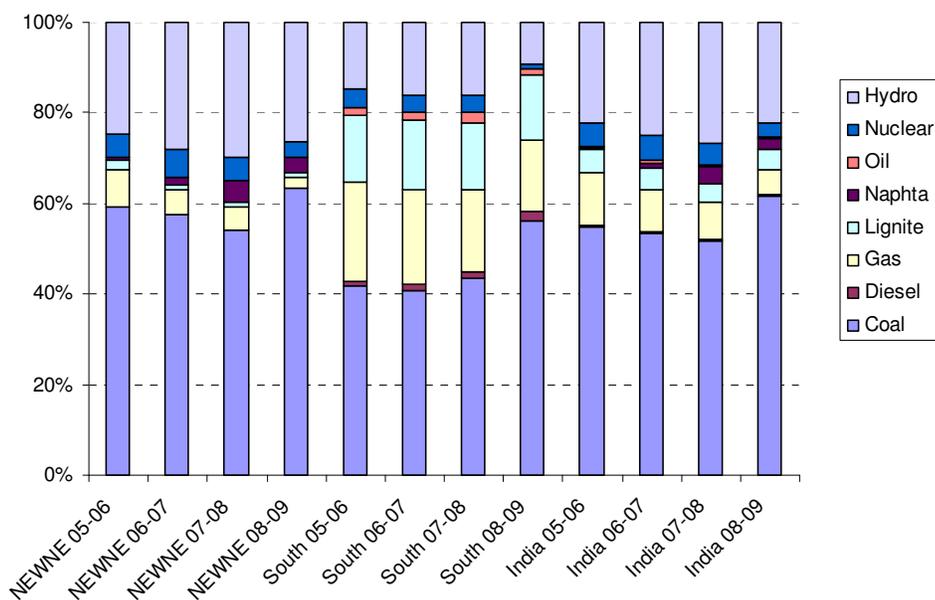


Figure 4: Breakdown of the build margin (comparison of FY 2006-07 to 2008-09) by station and fuel type for grids (shares based on net generation)

Figure 5 shows the trends in the import-adjusted combined margins in the period 2005-06 to 2008-09. As a result of the increase in the build margin of both grids, an increasing trend is observed also at the level of the combined margins of both grids and nation-wide.

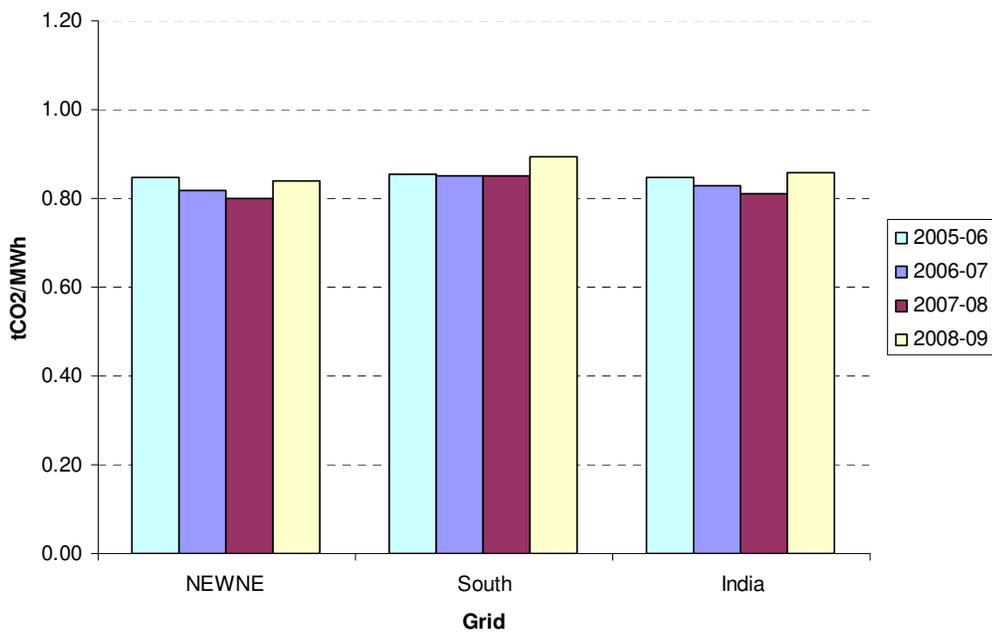


Figure 5: Development of the combined margin (adjusted for electricity transfers) for India's grids over the period 2005-06 to 2008-09.

5.3 Changes compared to Previous Database Versions

In comparison with the previous version of the Database (Version 4.0), this version includes the following methodological changes:

- For the first time, fuel consumption data measured at unit level was used for determining the emissions of some units of 500 MW falling into the build margin (see Section 4.3 for details).

6 User Examples

This section provides two illustrative examples of how the CO₂ 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 (belongs to the NEWNE Region). The station will be commissioned in 2010. 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 (2008-09). The corresponding value is 0.83 t CO₂/MWh. Hence the absolute emission reductions are projected at $0.83 * 17'500 = 14'525$ t CO₂/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.¹² 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 2010. 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.

¹² 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 ACM0002¹³ requires that the operating margin is calculated as the generation-weighted average of the three most recent years (here 2006-07 to 2008-09). The operating margin to be applied thus works out to 0.99 t CO₂/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 0.94 t CO₂/MWh (75% x 0.99 + 25% x 0.82 for the FY 2008-09). 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.

¹³ 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 CO₂ 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:	2010	2010
Year of CDM registration:	2009	2009
Grid :	NEWNE	Southern
CDM methodology:	AMS-I.D / Version 14	ACM0002 / Version 10
Baseline Emission Factor Calculation		
Calculation method:	Weighted average	Combined margin
Data vintage for projection of emission reductions:	2008-09 (most recent available at time of PDD validation)	For OM: 2006-07, 2007-08, 2008-09 (most recent 3 years available at time of PDD validation) For BM: 2008-09
Data vintage for verification of emission reductions:	Actual year of generation, i.e. 2009-10, 2010-11 etc. (emission factor fixed <i>ex post</i>)	Same as for projection (emission factor fixed <i>ex ante</i>)
Accounting of imports:	Not mandatory, but done	Mandatory
Weights for combined margin:	Operating margin: 50% Build margin: 50%	Operating margin: 75% Build margin: 25% (default for intermittent sources)
Emission Reduction Calculations		
Values in tCO ₂ /MWh:	0.83 Weighted average	0.99 Operating margin 0.82 Build margin 0.94 Combined margin
Projected emission reductions:	14'525 t CO ₂ per year	293'750 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 2.1** 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 2008-09 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 ver 2.1 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 ($EF_{BL,CO_2,y}$), as follows:

$$BE_y = EG_{PJ,y} * EF_{BL,CO_2}$$

Where:

BE_y Baseline emissions in year y (tCO₂)

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

EF_{BL,CO_2} Baseline emission factor in year y (tCO₂/MWh)

EF_{BL,CO_2} 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 $EF_{BL,CO_2,y}$ 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:

$$EF_{BL,CO_2,y} = 3.6 \cdot \frac{MIN(EF_{FF,BL,CO_2,y}, EF_{FF,PJ,CO_2,y})}{\eta_{BL}}$$

Where:

$EF_{BL,CO_2,y}$ Baseline emission factor in year y (tCO₂/MWh)

$EF_{FF,BL,CO_2,y}$ CO₂ emission factor of the fossil fuel type that has been identified as the most likely baseline scenario (tCO₂/GJ)

$EF_{FF,PJ,CO_2,y}$ Average CO₂ emission factor of the fossil fuel type used in the project plant in year y (tCO₂/GJ)

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

3.6 is the unit conversion factor from GJ to MWh

Calculation of baseline efficiency η_{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 η_{BL} , it is assumed that baseline plant would be 500 MW sub critical power plant based on Indigenous 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 η_{BL} = $\frac{860}{2635}$ = 32.63%

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

Emission factor as per Initial National Communication

$EF_{FF,BL,CO_2,y} = 90.6 \text{ g CO}_2/\text{MJ}$

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

$EF_{FF,PJ,CO_2,y} = 90.6 \text{ g CO}_2/\text{MJ}$ (project is using the same coal as baseline coal)

Using the formula for option 1 above

= $\frac{\text{Min}(90.6, 90.6)}{32.63\%} \times 3.6$

$$= 1.00 \text{ t CO}_2 / \text{MWh}$$

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

Emission factor as per IPCC

$$EF_{FF,BL,CO_2,Y} = 90.9 \text{ g CO}_2/\text{MJ}$$

(Emission factors i.e. 96.1 gCO₂/MJ on NCV or 90.9 g CO₂/MJ on GCV basis with oxidation factor of 0.98)

$$EF_{FF,PJ,CO_2,Y} = 90.9 \text{ g CO}_2/\text{MJ} \text{ (project is using the same coal as baseline coal)}$$

Using the formula for option 1 above

$$= \frac{\text{Min}(90.9, 90.9)}{32.63} \times 3.6$$

$$= 1.00 \text{ t CO}_2/\text{MWh}$$

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

Considering Project emission factor based on IPCC for other bituminous coal ie imported coal as 94.6 g CO₂/MJ on NCV basis or 89.5 gCO₂/MJ on GCV basis with oxidation factor of 0.98.

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

$$EF_{FF,BL,CO_2,Y} = 90.6 \text{ g CO}_2/\text{MJ}$$

$$EF_{FF,PJ,CO_2,Y} = 89.5 \text{ g CO}_2/\text{MJ}$$

$$= \frac{\text{Min}(90.6, 89.5)}{32.63} \times 3.6$$

$$= 0.987 \text{ tCO}_2/\text{MWh}$$

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

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

$$EF_{FF,BL,CO_2,y} = 90.9 \text{ g CO}_2/\text{MJ}$$

$$EF_{FF,PJ,CO_2,Y} = 89.5 \text{ g CO}_2/\text{MJ}$$

$$= \frac{\text{Min} (90.9, 89.5)}{32.63}$$

$$= 0.987 \text{ t CO}_2 / \text{MWh}$$

So Minimum emission factor (Case i to iv) calculated for option 1 is 0.987 t CO₂/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:

$$EF_{BL,CO_2,y} = \frac{FC_{j,x} * NCV_{j,x} * EF_{CO_2,j,x}}{EG_{j,x}}$$

Where:

$EF_{BL,CO_2,y}$ Baseline emission factor in year y (tCO₂/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)

$EF_{CO_2,j,x}$ CO₂ emission factor of the fossil fuel type consumed by power plant j in year x (tCO₂/GJ)

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

X Most 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 2.1, 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 any 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 13 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	VINDH_CHAL STPS	9	500
2	VINDH_CHAL STPS	10	500
3	KAHALGAON	5	500
4	KAHALGAON	6	500
5	TALCHER STPS	6	500
6	RIHAND	4	500
7	RIHAND	3	500
8	SIPAT STPS	2	500
9	SIPAT STPS	1	500
10	SANJAY GANDHI	5	500
11	BELLARY TPS	1	500
12	R_GUNDEM STPS	7	500
13	TALCHER STPS	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:

$EG_{n,x}$:Net electricity generated and delivered to the grid by the power plant n in the year x (MWh)

$FC_{n,x}$: Quantity of fuel consumed in the power plant n in year x (Mass or volume unit)

$GCV_{n,x}$: 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 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. 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. Vindhyachal STPS unit 9 and 10 are identified 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 0.944 tCO₂/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, 0.944)

Therefore, the baseline emission factor which is to be used for calculating CDM Benefits for supercritical projects has been calculated as 0.944 tCO₂/MWh for the year 2008-09.

8 Updating Procedure

The CO₂ Database will be updated annually by CEA and made available on its website: www.cea.nic.in . Previous versions will be archived by CEA and the main changes relative to previous database versions will be documented.

9 Further Information

For any further information, contact by email:

Chief Engineer(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
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 Electros melt 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	Maharashtra 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 CO₂ 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	gCO ₂ /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	gCO ₂ /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	gCO ₂ /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	3'150	2'117	1'975	3'213	2'117	n/a	n/a
Net Heat Rate	kcal /kWh (net)	2'717	3'014	2'075	3'182	2'193	2'047	3'330	2'193	n/a	n/a
Specific Oil Consumption	ml /kWh (gross)	2.0	3.0	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
GCV	kcal /kg (or m3)	3'755	n/a	8'800	n/a	10'100	10'500	10'500	11'300	n/a	n/a
Density	t /1,000 lt	n/a	n/a	n/a	n/a	0.95	0.83	0.83	0.70	n/a	n/a
Specific CO ₂ emissions	tCO ₂ /MWh	1.04	1.28	0.43	0.66	0.66	0.59	0.96	0.61	n/a	n/a

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

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

Coal	Unit	67.5 MW	120 MW	200-250 MW	300 MW	500 MW
Gross Heat Rate	kcal /kWh	2'750	2'500	2'500	2'350	2'425
Auxiliary Power Consumption	%	12.0	9.0	9.0	9.0	7.5
Net Heat Rate	kcal /kWh	3'125	2'747	2'747	2'582	2'622
Specific Oil Consumption	ml /kWh	2.0	2.0	2.0	2.0	2.0
Specific CO ₂ Emissions	tCO ₂ /MWh	1.19	1.05	1.05	0.98	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		
Specific Oil Consumption	ml /kWh	3.0	3.0	3.0		
Specific CO ₂ Emissions	tCO ₂ /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 CO ₂ Emissions	tCO ₂ /MWh	0.42	0.41	0.42		
Diesel	Unit	0.1-1 MW	1-3 MW	3-10 MW	>10 MW	
Gross Heat Rate	kcal /kWh	2'350	2'250	2'100	1'975	
Auxiliary Power Consumption	%	3.5	3.5	3.5	3.5	
Net Heat Rate	kcal /kWh	2'435	2'332	2'176	2'047	
Specific CO ₂ Emissions	tCO ₂ /MWh	0.70	0.67	0.63	0.59	
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 CO ₂ Emissions	tCO ₂ /MWh	0.61				
Combined Margin	Unit					
Weight OM	%	50%				
Weight BM	%	50%				
Conversion Factors	Unit					
Energy	kJ /kcal	4.1868				
	MJ /kWh	3.6				
Oil	Unit					
Specific Emission	gCO ₂ /ml	2.89				

Appendix C – Grid Emission Factors

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

Table A: Values for all grids for FY 2005-06 to 2008-09, excluding inter-grid and cross-border electricity transfers.

Weighted Average Emission Rate (tCO₂/MWh) (excl. Imports)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	0.84	0.83	0.82	0.84
South	0.73	0.72	0.72	0.75
India	0.82	0.80	0.80	0.82

Simple Operating Margin (tCO₂/MWh) (excl. Imports) (1)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	1.02	1.02	1.01	1.02
South	1.01	1.00	0.99	0.97
India	1.02	1.01	1.01	1.01

Build Margin (tCO₂/MWh) (excl. Imports)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	0.67	0.63	0.60	0.68
South	0.71	0.70	0.71	0.82
India	0.68	0.65	0.63	0.71

Combined Margin (tCO₂/MWh) (excl. Imports) (1)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	0.85	0.82	0.81	0.85
South	0.86	0.85	0.85	0.89
India	0.85	0.83	0.82	0.86

(1) Operating margin is based on ex ante option of "Tool to Calculate the Emission Factor for an Electricity System", Ver.1.1 (p.4)

Table B: Values for all grids for FY 2005-06 to 2008-09, including inter-grid and cross-border electricity transfers.

Weighted Average Emission Rate (tCO₂/MWh) (incl. Imports) (2)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	0.84	0.82	0.81	0.83
South	0.73	0.72	0.72	0.76
India	0.81	0.80	0.79	0.82

Simple Operating Margin (tCO₂/MWh) (incl. Imports) (1) (2)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	1.02	1.01	1.00	1.01
South	1.01	1.00	0.99	0.97
India	1.02	1.01	1.00	1.01

Build Margin (tCO₂/MWh) (not adjusted for imports)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	0.67	0.63	0.60	0.68
South	0.71	0.70	0.71	0.82
India	0.68	0.65	0.63	0.71

Combined Margin in tCO₂/MWh (incl. Imports) (1) (2)				
	2005-06	2006-07	2007-08	2008-09
NEWNE	0.85	0.82	0.80	0.84
South	0.86	0.85	0.85	0.90
India	0.85	0.83	0.81	0.86

(1) Operating margin is based on ex ante option of "Tool to Calculate the Emission Factor for an Electricity System", Ver.1.1 (p.4)

(2) Import adjustments are based on approach (c) of "Tool to Calculate the Emission Factor for an Electricity System", Ver.1.1 (p.4)

Appendix D – Summary of Methodology ACM0002 / Version 10

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