Information note

Report on the analysis of issues concerning the methodology ACM0013

I. Background

1. At the sixty-second meeting, the CDM Executive Board (the Board) considered an information note prepared by the Methodologies Panel (the panel) on issues identified in the approved methodology ACM0013 “Consolidated baseline and monitoring methodology for new grid connected fossil fuel fired power plants using a less GHG intensive technology”. The Board also considered the recommendation by the panel to put the methodology on hold with immediate effect and to initiate a revision of the methodology. In this regard, the Board agreed to request the panel to:

(a) Carry out a thorough analysis of the issues raised in the information note, including the assumptions underlying the recommendation and the potential overestimation of emission reductions, taking into consideration the available sources of data;

(b) Prepare a report of this analysis for consideration by the Board at its next meeting; and

(c) Initiate a revision of the methodology, if the thorough analysis concludes that the methodology requires improvement.

2. This document is prepared in response to this request and contains a thorough analysis of issues related to the methodology ACM0013. The report analyses issues that were already identified in the information note prepared by the panel at its fiftieth meeting, as well as issues that were identified while conducting the thorough analysis requested by the Board.

II. Structure of the report

3. This report focuses on an analysis of issues related to the calculation of the baseline emission factor. Section III provides an overview of the methodology ACM0013. Section IV assesses issues related to Option 1 provided in the methodology to determine the baseline emission factor, i.e. the baseline emission factor based on the most likely baseline technology. Section V assesses issues related to Option 2 provided in the methodology to determine the baseline emission factor, i.e. the baseline emission factor established as an emissions benchmark. Section VI provides an overview of other issues concerning the methodology identified during the analysis, followed by conclusions and recommendations contained in Section VII.

4. The findings in this report are based on several sources of information, including:

(a) A thorough analysis of information provided in CDM-PDDs from registered projects, projects in the process of registration, and projects under validation;

(b) Relevant data published by Designated National Authorities (DNA), e.g. in relation to the calculation to the baseline emission factor or the grid emission factor databases;

(c) A literature and data review with regard to the question of what efficiencies have been achieved by fossil fuel fired power plants that are in operation in developing countries and to what extent the efficiency of newly constructed power plants improves over time;

(d) A consultancy report from a power plant engineering expert to assess to what extent the efficiency of newly constructed power plants improves over time in two countries as a result of the observed increase of both temperature and pressure of steam, based on data provided by the International Energy Agency (IEA) Clean Coal Centre.

III. Overview of the methodology ACM0013

5. The methodology ACM0013 was initially approved in September 2007. The methodology is applicable to project activities that construct new fossil fuel fired power plants, using a technology that is more energy efficient than the technology that would be used with the given fossil fuel category in the baseline. The methodology is only applicable if the fossil fuel used in the plant (i.e. coal, oil or gas) is used for more than 50% of the electricity generation in the host country (or other applicable area). The methodology requires data on electricity generation and fuel consumption from other power plants connected to the grid, and for this reason the methodology is only applicable if this data is available.

6. Two major revisions were made in March and September 2010 to ensure that the claimed emission reductions are limited to improvements in efficiency, and to clarify the definition of the reference year.

7. As of 31 October 2011, six projects (five from India and one from China) are registered under ACM0013, two projects are under review, three projects are requesting registration, and another 37 projects are under validation. Collectively, these 48 projects are expected to claim total annual emission reductions of 41 million CERs.[1]

8. An important element of the methodology ACM0013 is the determination of the baseline emission factor. The methodology provides a procedure where project participants shall use the lower emission factor between two options:

(a) Option 1: The baseline emission factor is determined based on the most likely technology that is identified in the baseline selection procedure through investment analysis; and

(b) Option 2: The baseline emission factor is calculated based on the average emission factor of the top 15% performers of recently built plants, as monitored during a reference year.

IV. Analysis of issues related to Option 1 to determine the baseline emission factor

9. This section analyses issues related to Option 1 to determine the baseline emission factor. The current requirements in the methodology are described in Sub-section 1, followed by an overview of the level of efficiencies that were determined in PPDs, as contained in Sub-section 2. Sub-section 3 assesses how the efficiency of the baseline plants was derived in PDDs. Sub-section 4 assesses and compares the levels identified in PDDs against other available data. Sub-section 5 draws conclusions and provides recommendations to improve Option 1.

1. <u>Methodological requirements under Option 1</u>

10. Under Option 1, the project participants shall identify which power plant would most likely be constructed in the baseline scenario. This baseline plant shall be determined through an investment analysis, by comparing the economic attractiveness of different power plants that could be constructed as an alternative investment to the project activity. The baseline emission factor is then calculated based on the efficiency of the baseline power plant and the CO_2 emission factor of the relevant fuel type.

[1] The UNFCCC website listed 55 projects in the pipeline. One of them was rejected. Six of them are duplicate submissions according to the titles of the projects. For duplicate submissions, the most recent versions of the PDDs are analyzed in this study.

11. In considering alternative scenarios for power generation, project participants shall consider, inter alia, the construction of one or several other power plants which deliver similar services (e.g. peak vs. base load power) and which may:

(a) Use the same fossil fuel category as in the project activity, but technologies other than that used in the project activity; or

(b) Use fossil fuel categories other than that used in the project activity; or

(c) Use renewable or nuclear power generation technologies.

12. From the above, the economically most attractive baseline scenario alternative is identified using investment analysis. The project participants should use the levelized cost of electricity production in $/kWh as a financial indicator for investment analysis and account for all relevant costs and subsidies. A sensitivity analysis shall be performed to confirm that the conclusion regarding the financial attractiveness is robust to reasonable variations in the critical assumptions.

13. The CO_2 emission factor of the baseline fuel type is determined based on default values by the IPCC. As a conservative approach, the lower end of the uncertainty band at a 95% confidence level is chosen.

2. What efficiencies were identified under Option 1 in PDDs as baseline efficiency?

14. Table 1 below provides an overview of the level of the baseline efficiency that was determined under Option 1 in PDDs.

Table 1: Baseline Efficiency under Option 1 in PDDs

Country	Status	Fuel	Min	Avg	Max	Number of projects
Argentina	Under validation	NG	33.7%	33.7%	33.7%	1
Brazil	Under validation	Fuel oil	32.0%	32.4%	32.9%	2
China	Registered	Coal	38.6%	38.6%	38.6%	1
	Requesting registration	Coal	38.1%	38.5%	39.0%	2
	Review Requested	Coal	38.1%	38.1%	38.1%	1
	Under validation	Coal	35.8%	37.8%	40.4%	9
India	Registered	Coal	31.8%	34.6%	36.0%	5
	Requesting registration	Coal	36.6%	36.6%	36.6%	1
	Review Requested	Coal	36.6%	36.6%	36.6%	1
	Under validation	Coal	31.8%	33.7%	38.1%	24
Iran	Under validation	NG	34.5%	34.5%	34.5%	1

3. How was the baseline efficiency determined in PDDs?

15. The analysis of information contained in PDDs shows that different approaches were applied by project participants in determining the baseline efficiency (η_{BL}) under Option 1 of the methodology. One reason for this could be that the methodology does not provide specific guidance on how this parameter should be estimated. The methodology only specifies that “as a conservative approach, the efficiency should be determined as the efficiency at optimum load, e.g. as provided by the manufacturers”.

16. Appendix I provides information on how the baseline efficiency (η_{BL}) was determined for each project according to information provided in the PDDs. In most PDDs, a government publication (e.g. tariff orders, bulletins, spreadsheets developed by the DNAs in order to calculate the emission factor for the electricity system, etc) was used as the reference for determining the baseline efficiency (η_{BL}). The approaches used can be categorized as follows:

(a) **Based on the expected gross station heat rates (GSHR) and assumptions on the auxiliary fuel consumption.**

This approach was used by 26 projects in India, including three registered projects.

The GSHR expresses the amount of fuel required per amount of electricity generated, not accounting for auxiliary electricity consumption. Hence, it expresses the gross efficiency of the power plant, where a higher value indicates a lower efficiency. The values of GSHR used in PDDs range from 2385 to 2703.9 kCal/KWh. These values were referenced from different sources. However, the values chosen are varied, as follows.

Thirteen projects (expected to be commissioned from 2011 to 2015) adopted the value of 2450 kCal/KWh, which is sourced from the 2007 tariff regulation by the Indian Central Electricity Regulatory Commission (CERC) for existing power plants connected to the grid that are larger than 500 MW. The same value is suggested to be taken to estimate the baseline efficiency for new plants in ACM0013 according to the 'User's Guide of the CO_2 Baseline Database for the Indian Power Sector' (Version 5.0), published by the Indian Central Electricity Authority (CEA) in November 2009.[2] Also included in this group is one project which used the same reference but a slightly different value of 2453 kCal/KWh.

Similarly, nine projects (expected to be commissioned from 2014 to 2015) used the value of 2425 kCal/KWh, from the updated 2009 tariff regulation by the Indian CERC for *existing* power plants connected to the grid that are larger than 500 MW. This value is assumed for units used in the calculation of the build margin of the electricity grids, where data was not provided by station, in the Version 6 of the CEA database.

One project under validation (expected to be commissioned in 2013) used the value of 2385 kCal/KWh. Although the PDD makes reference to the Version 5 of the CEA database, the value could not be found in the database or its User's Guide.

One registered project (expected to be commissioned in 2011) uses a value of 2398 kCal/KWh which corresponds to the weighted average design station heat rate received from a sample of 56 existing plants, according to the 2006-2007 Annual Thermal Performance Review report published by the CEA. In addition, one registered project and one project under validation (expected to be commissioned in 2012 and 2013) use a value of 2704 kCal/KWh which corresponds to the weighted average design SHR according to the 2007-2008 Annual Thermal Performance Review report.[3]

---

[2] Although 2450 kCal/KWh is not a minimum efficiency standard, it determines the applicable tariff and is set to encourage performance above this level to achieve higher profitability. The most recent version, Version 6 of the database and the User's Guide, published in March 2011, provided no suggestion on how the baseline efficiency for ACM0013 should be determined under Option 1.

[3] It is not entirely clear from the available information whether the SHR refers to net or gross electricity generation. However, the reports present in the same table the operating SHR on a gross basis. This suggests that also the design SHR was provided on a gross basis.

It is noted that the values chosen for auxiliary power consumption values were variable. It is set at 0% for 11 projects, 6% for 5 projects, 7% for 7 projects, 7.5% for two projects and 8.5% for one project. In the case of one project, the auxiliary fuel consumption was not documented in the CDM-PDD.[4]

Due to the different values applied for the GSHR and the auxiliary power consumption, the resulting baseline efficiencies also show a high variability, ranging from 31.8% to 35.9%, for the project activities applying this approach.

(b) **Based on values used for the build margin calculations in the grid emission factor tool.**

This approach is used in the case of five Chinese PDDs (including one project requesting registration and one project under review).

Based on the 2007 "Bulletin on determining baseline emission factor for China Grid", the baseline efficiency (η_{BL}) was estimated to be 35.82% from the weighted average efficiency of the fifteen 600 MW plants built in 2005. This value was used for two project activities commissioned in 2009 and currently under validation.

Based on the 2009 "Bulletin on determining baseline emission factor for China Grid", the baseline efficiency (η_{BL}) was estimated to be 38.10% from the weighted average efficiency of the top 30 plants from the seventy nine 600 MW plants built in 2007. This value was used by one project activity commissioned in 2008 (currently requesting registration) and two project activities commissioned in 2011 (currently one requesting registration and one under validation).

(c) **Based on top performing existing plant.**

This approach is used in four Indian projects, including two registered projects, one project requesting registration and one project under review.

The baseline efficiency (η_{BL}) is derived from the best performing existing plant that has a full operation history in the historical reference year according to Option 2 of the methodology and that uses the same technology as the baseline power plant. The efficiency value is based on published databases on electricity production and fuel consumption of power plants.

The parameters used in this approach are the same as those used in Option 2 of the methodology. The documentation and consistency issues identified for Option 2 in the latter section apply.

(d) **Based on average efficiency of the grid.**

This approach is used in two Brazilian projects.

The baseline efficiency (η_{BL}) was estimated as the average operating efficiency of all *existing* thermal power plants using the same fuel (fuel oil) in the isolated grid according to the data on fuel consumption and electricity generation from Eletrobras reports.

---

[4] The values larger than 0% all referred to the CERC without specifying the exact reference, while the tariff regulation only specifies 7% and 8.5% for steam driven boiler feed pumps and electrically driven boiler feed pumps respectively and does not mention 6%.

(e) **Based on non-governmental or unspecified publications.**

This approach is used in one Argentinean, eight Chinese, one Indian and one Iranian projects.

The baseline efficiency (η_{BL}) was estimated from information contained in documents from manufacturers or other publications.

(i) One Argentinean project, one Iranian project and one Chinese project relied on parameters from the feasibility study report of the project activity or manufacturer's data for the baseline technology;

(ii) Three Chinese projects (including one registered project and one project requesting registration) used an approach similar to the majority of the Indian projects, but sourced the GSHR and the auxiliary consumption rate from a non-governmental publication;

(iii) For two Chinese projects, the baseline efficiency (η_{BL}) was sourced from "official statistical data". No reference information was provided for what official data was used;

(iv) For one Chinese project, the baseline efficiency (η_{BL}) was determined based on the coal consumption for power generation contained in the entry of "ultra-super-critical power generation" in a Chinese online encyclopedia. However, the value can no longer be found on the webpage;

(v) One Chinese project relied on a scientific article. No reference information was provided for the article;

(vi) One Indian project (expected to be commissioned in 2013) took the average gross design efficiency of all existing plants in the country that have a 500 MW capacity and use sub-critical technology. The value was sourced from a scientific report published in 2008.

4. Assessment of the efficiencies derived in PDDs

17. The analysis of the PDDs and the comparison with other sources of information, revealed the following shortcomings in the methodology ACM0013 and in its application in CDM-PDDs:

(a) **Lack of a consistent approach and lack of a justification of assumptions.** As shown above and in more detail in Appendix I, a wide range of approaches and assumptions were applied in deriving the baseline efficiency under Option 1 of the methodology. For example:

(i) For the *same* technology and fuel type (e.g. sub-critical technology and domestic coal), the baseline efficiencies range from 31.8% to 38.1%. The range is defined by projects 3690 (minimum) and CDM7097[5] (maximum), which are expected to be commissioned in 2012 and 2013 respectively;

(ii) For the 12 projects applying the same efficiencies from the expected GSHR at 2450 kCal/KWh, the different values assumed for auxiliary power consumption (0% to 7%) resulted in a considerable range (difference of up to 2.5% between 32.63% and 35.1%) of values for the baseline efficiency (η_{BL}), without justification for the difference in the assumptions. However, in

[5] If a project is referred to by a four-digit number, the number is the UNFCCC official reference number. If a project is referred to by CDM and a four-digit number, it is a project still under validation and the number is from the UNEP/RISOE CDM pipeline information.

practice it is likely that the auxiliary power consumption is of similar magnitude for the different plants;

(iii) In some other cases (e.g. projects CDM7310 and CDM7665) the same technology and *different* sources of fossil fuels (domestic coal and a mix of domestic and imported coal) were identified for the most likely baseline scenario but nevertheless the same value for the baseline efficiency (η_{BL}) was applied to the projects;

(iv) For two registered projects (2716 and 3690, expected to be commissioned in 2011 and 2012), the efficiencies are based on the *same* type of publication, i.e. the Annual Thermal Performance Review report published by the CEA, but for the year 2006-2007 and the year 2007-2008 respectively; however, the resulting efficiencies are different by more than 4%.

(b) **Lack of project-specific considerations.** The actual efficiency of a power plant will depend not only on the category, quality of fuel used and technology employed but also on design and operating conditions. The following project site specific conditions/properties have an impact in the actual efficiency of a coal power plant, inter alia: (i) coal properties;[6] (ii) cooling technology (water or air) and the ambient conditions;[7] and (iii) application of air pollution control equipment. These factors at the project site should be taken into account when estimating the efficiency of the identified baseline technology and fuel. Most PDDs do not consider these site-specific factors but derive the baseline efficiency based on other plants that may face different site-specific conditions.

A sensitivity analysis was performed, to evaluate the impacts of the coal properties. The power plant engineering expert simulated their impact on a typical plant design in China and India. Based on the best quality and worst quality of coal that are produced domestically, taking into account the composition of carbon, hydrogen, oxygen, the content of moisture and ash and the lower heating value, the efficiencies could vary by 0.5 efficiency point in China and 0.3 efficiency point in India. The impact would be even higher if the impact from coal treatment, ash removal and the use of imported coal is considered.

According to an 2010 IEA report,[8] a once-through sea water cooling system is 2.4% more efficient than the closed circuit wet tower, while air cooling would be 5% less efficient. Also, with 1 degree C increase in ambient temperature, the heat rate (the inverse of the efficiency) should increase by 0.15%.

(c) **Use of data from existing plants.** In many cases, data from *existing* plants is used to determine the baseline efficiency of the *new* power plant that would be constructed in the baseline. A data vintage of at least five years is observed for projects to be commissioned in 2012 or later. The use of data from existing plants is not appropriate because power plants constructed in the past tend to have a lower efficiency than new power plants (see Section V.4 for further information). This results in a systematic under-estimation of the baseline efficiency.

18. In addition to this analysis, the values for the baseline efficiency derived in PDDs were compared to other sources of information.

---

6 Carbon content, moisture, hydrogen, volatiles and ash.

7 E.g. temperature and humidity of air, temperature of cooling water.

8 <www.iea.org/ciab/papers/power_generation_from_coal.pdf>.

19. For China, the baseline efficiencies derived for Option 1 in PDDs range from 38.1% to 40.41% for super-critical technologies and from 35.82% to 38.1% for sub-critical technologies (both technologies are selected as the baseline technology in PDDs). These ranges were compared with a database prepared by the China Electricity Council (CEC, 2010) which contains information on the measured fuel consumption and power generation of power plants.[9] Based on the specific coal consumption information from the 2010 CEC report, the efficiencies of the 135 above-average plants (above 500 MW) were calculated. For super-critical coal power plants, which are assumed to be the baseline in most PDDs for projects in China, the average efficiency of all existing plants corresponds to 39.36% and the best plant reports an efficiency of 40.7%. Hence, the measured efficiencies of *existing* power plants included in the CEC report tend, for the same technology, to be higher than the efficiencies used in PDDs for *new* power plants that would be constructed in the baseline.

V. Analysis of issues related to Option 2 to determine the baseline emission factor

20. This section analyses issues related to Option 2 of the methodology to determine the baseline emission factor. The requirements in the methodology are described in Sub-section 1, followed by an overview of issues related to the consistency and documentation of data used to apply this option. The key questions arising from the note prepared by the panel at its 50th meeting are:

(a) Whether and to what extent there is a significant time gap between the commissioning of the project plant and the commissioning of the peer group plants used to calculate baseline efficiency; and

(b) Whether and to what extent the efficiency of newly constructed power plants increases over time;

21. These issues are assessed in Sub-sections 3 and 4. These questions are important to analyze whether the efficiency of the peer group plants is a reasonable proxy for the efficiency of the plant which would be built by the project proponent in the absence of the CDM project activity. Based on this analysis, Section 5 assesses the current approach and compares it with other available data.

1. Methodological requirements under Option 2

22. In Option 2, the baseline emission factor is determined as an emissions benchmark based on a peer group of recently constructed power plants. The peer group consists of similar power plants using the same fossil fuel category, constructed in the previous five years, with a comparable size as the project, and operated in the same load category.

23. The methodology requires that the operational efficiency of each power plant in the peer group shall be calculated based on the net calorific value (NCV) of the fossil fuel consumed, fuel consumption and net electricity generation by each power plant. These data shall be documented in the PDD for validation.

24. Based on the rank of the operational efficiencies, the top 15% performer plants shall be identified. The average emission factor of these plants is then determined as the baseline emission factor under Option 2. Finally, the lower emission factor between Option 1 and Option 2 shall be used for the baseline emission calculations.

---

[9] The plants are categorized as follows: ultra-super-critical (1000 MW), ultra-super-critical (600 MW), super-critical, sub-critical, Russian / Eastern Europe imported technology and air cooling. Plant specific information is provided only for those plants that are above average within one of these categories. This includes 135 plants. The report does not contain information on the commissioning year of each plant, so these plants were matched with the plants in the IEA Clean Coal Centre database. 76 plants out of the 135 plants were matched successfully, and the commissioning year information was obtained for these 76 plants.

2. Documentation and consistency of data used for Option 2

25. For determining the baseline efficiency under Option 2, the methodology requires that the PDDs shall document the data on the fuel consumption and electricity generation of all identified power plants considered in the identification of the peer-group power plants. In addition, the methodology is only applicable if data on fuel consumption and electricity generation of recently constructed power plants are available. The assessment of the PDDs showed that the required data have not been used or have not been documented.

26. For project activities located in China, the data and assumptions used to calculate the baseline efficiency are not documented in the PDDs. The PDDs refer to documents published by the host country DNA for ACM0013, stating that the DNA provides this calculation “in line with the requirements from the methodology”. Nevertheless, this statement could not be corroborated as the documents published by the DNA[10] do not provide information on:

(a) Which plants are being identified in the peer groups;

(b) Which plants belong to the top 15% performers;

(c) The fuel consumption and electricity generation at each of the identified plants; and

(d) When the identified power plants were commissioned.

27. In India, all PDDs refer to data from the publicly available CEA database to determine the baseline efficiency.[11] For some of the units/plants, the database only provides the values of the “net generation in GWh” and “absolute emissions in tCO_2” and data on fuel consumption and net calorific values (NCVs) of the fuels used are not provided. For some project activities in India, the source of the relevant parameters (fuel consumption, net electricity generation, NCV, etc) is not documented in the PDDs. For other Indian project activities, “sales receipts and invoices” from the identified power plants/units are mentioned as sources of data. As discussed further below, there is inconsistency in the information provided among these PDDs and since no exact data source is provided in the PDDs, there is no means of crosschecking or verifying which of the different values provided are correct, although DOEs may be in a position to verify them.

28. Furthermore, as shown in Appendix II, which provides information pertaining to the power plants in the peer group identified for the project activities in India, there are data inconsistencies with respect to: (i) the quantity of fossil fuel used; (ii) the NCV; (iii) the net electricity generation by the referred power plant; and, therefore also iv) the estimated actual efficiency of the identified power plant. It should be noted that the inconsistencies among the different PDDs occur even though the PDDs claimed to use the same data source, namely sales receipts and invoices from the identified power plants.

29. The example provided in Table 2 below shows the inconsistency of parameters for two plants operated by the company “Sipat Stps”, using the data provided in the PDDs of the relevant project activities. In this case, for the same plant and the same year, different PDDs report different data on how much fuel the plant consumed, how much electricity it generated and what the average NCV of the fuel was. These inconsistencies in the data result in a difference in the efficiencies of up to 1.9% points for the same plant in the same year. It is also noted that in some of the PDDs the two plants have exactly the same resulting efficiencies, while the input data to arrive at this same efficiency varies for each PDD. This puts in question whether the data on fuel consumption,

10 <http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File1829.pdf>;
<http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2330.pdf>;
<http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2537.pdf>.

11 <http://www.cea.nic.in/reports/planning/cdm_co2/cdm_co2.htm>. This database is also used for the purpose of calculating the grid emission factor.

electricity generation and NCVs was actually collected from the plants, as required by the methodology.

30. Similar inconsistencies can be observed for many other PDDs in India.

Table 2: The Parameters Provided for the Sipat Stps plant in Various PDDs

Name	Unit No.	Reference year	Efficiency	Sum of FC (ton/year)	NCV (GJ/ton)	Sum of EG (MWh/year)
SIPAT STPS	1	2008-2009	32.99%	630511	15.16	876000
			34.11%	672389	13.75	876000
			33.00%	1397208	15.16	2085385
				586920	15.16	876000
				586920	15.16	876000
			31.81%	2721481	15.16	4087665
			36.91%	621960	13.74	876000
		2009-2010	34.89%	597378	15.13	876000
			35.85%	2791336	13.78	3830779
			31.81%	3137559	13.78	4087665
				3137559	13.78	4087665
				3137559	13.78	4087665
			35.86%	2791336	13.78	3831000
				2791336	13.78	3831000
				2791336	13.78	3831000

3. <u>What are the observed data vintages of the peer group plants in Option 2?</u>

31. Another question is whether the plants included in the peer group to calculate the emissions benchmark have a similar vintage than the project plant. If the plants in the peer group are constructed and commissioned several years before the project plant, this may affect the level of the emissions benchmark as the efficiency of power plants may improve over time. Therefore, power plants planned and constructed many years before the project plant may have significantly lower efficiencies and may not well represent the likely course of action for a baseline power plant that would be constructed to date. This section therefore assesses the magnitude of data vintage, while Section 4 below analyses to what extent the performance of power plants is likely to improve over time.

32. The methodology requires that plants included in the peer group, used to calculate the emissions benchmark, have a full operation history in the ‘reference year *v*’. This reference year refers to the latest year of a five year period in which the peer group power plants started commercial operation. The most recent year for which data is available should be used; however, it should not begin more than two years prior to the date of submission of the PDD for validation of the project activity.

33. Appendix III and Table 3 below illustrate the data vintage in years between the commissioning of the plants included in peer group and the project activity. The analysis includes all projects for which such data was provided in the PDDs, in total 32 projects located in India and Iran, the countries where such data was available from PDDs. The PDDs of the other 16 project activities do not provide the information on the commissioning year of the peer plants or the top 15% performer plants.

34. Table 3 below illustrates, in "number of years", the minimum, maximum and average values for different categories of identified power plants (i.e. oldest peer group, newest peer group, oldest top 15% performer plants, newest top 15% performer plants).

35. The gap in commissioning years between the plants in the peer group and the project activity is typically in the range of 5 – 10 years, as indicated in the information note prepared by the panel at its fiftieth meeting. This time frame appears significant, given that the technology and efficiency of power plants may substantially increase over such time frames (see Section V.4 below).

Table 3: Data vintage in years between the commissioning of the project activity plant and the commissioning of the peer group plants

	Oldest peer group plant	**Newest peer group plant**	**Oldest top 15% plant**	**Newest top 15% plant**
Minimum	4.8	0.8	2.8	0.8
Maximum	19.1	7.2	9.8	8.7
Average	9.7	5.0	7.6	6.4

4. Does the efficiency of newly constructed power plants improve over time?

36. For the purpose of assessing to what extent the efficiency of newly constructed power plants improves over time, data from three different sources were analyzed:

(a) The trend in the efficiency of new power plants in India and China was estimated using data from the IEA Clean Coal Center[12] and applying a power plant simulation software,[13] drawing on expertise from a power plant engineer;

(b) Information from the grid emission factor database was evaluated for the host countries which host most projects that use the methodology, India and China;

(c) Data on measured power plant efficiencies from the China Electricity Council[14] and data on the commissioning year of power plants from the IEA Clean Coal Center were matched in order to evaluate the trend in power plant efficiencies.

37. The assessment of the information contained in these three sources is presented hereunder.

38. The IEA Clean Coal Centre maintains a global database on coal power plants. Data on efficiency is only provided for very few plants. However, for a number of plants key design parameters are provided, including the temperature and pressure of steam, the coal type used and whether air pollution control is installed. As explained later in this section, the data clearly demonstrated that power plants with super-critical steam conditions were commissioned in the past twenty years in China and India, and power plants with the ultra-super-critical steam conditions were

[12] <http://www.iea-coal.org.uk/>.

[13] THESIS (THermodynamic and Economic SImulation System). It was mainly developed in the 1970s and 1980s at the RWTH Aachen and Tennessee Technological University and has been continuously updated since then.

[14] China Electricity Council. 2010. Benchmarking Results from Energy Efficiency Indicators of 600MW Thermal Generation Units in China.

commissioned in China. According to the IEA,[15] the installation of super-critical and ultra-super-critical technologies has been key to improve design efficiency, in conjunction with modern steam turbine designs. The database also contains the commissioning year of each power plant.

39. The IEA Clean Coal Centre data was used to quantify the trend in the efficiency of newly constructed power plants. For this purpose, all plants with a capacity of at least 500 MW were selected and the design efficiency was modelled for those plants for which key design features were available, using simulation software.[16] Plausible assumptions were made on other plant design parameters. It should be stressed that the aim of the simulation study is not to provide accurate efficiencies of the power plants, but to provide information on the *trend* in efficiency over time.

40. For India, the database prepared by the IEA Clean Coal Centre contains sufficiently detailed data on the technology design for 40 plants commissioned over the period of 1984 to 2013. Among these 40 plants, the plants commissioned prior to 2007 applied almost identical technology in terms of steam pressure, steam temperature and reheat temperature. In 2007, plants using super-critical technology were commissioned with a steam pressure of 250 bar instead of 180 bar which is a common sub-critical pressure in power plants. For the plants to be commissioned after 2012, the design steam temperature increases from 540 to 571 degree C. According to the power plant simulations conducted by the power plant engineering expert, the increase in design efficiency from 2000 to 2010 was estimated to be around 1.3% points.

41. For China, the IEA Clean Coal Center database contains information on technology design and the commissioning year for 169 plants commissioned over the period 1985 to 2011. The information shows a clear trend in improvement of technology over time. According to the power plant simulations conducted by the power plant engineering expert, the increase in design efficiency from 2000 to 2010 was estimated to be around 1.4% points. The following can be observed from the database with regard to technology improvement of the newly commissioned plants over time:

(a) In 1992, the first super-critical coal power plants were commissioned, which meant an increase in the steam pressure to 250 bar;

(b) In 2003-2004, the reheat temperature of the newly commissioned plants increased from around 540 to 570 degree C, and the steam pressure increased to 260 bar;

(c) In 2007, among the newly commissioned plants, the highest generation capacity increased from 600 MW to 1000 MW, the highest steam pressure increased to around 270 bar, and the highest steam temperature and the highest reheat temperature increased to 600 degree C. In 2010, the first ultra-super-critical power plants were commissioned, with a further increase in the steam pressure to around 370 bar.

42. The Chinese DNA publishes the baseline emission factor of Chinese regional grids annually.[17] In the attachments to these documents, the DNA also explained the calculation of the build margin emission factor for the electricity grids. The information gathered from these documents shows that the efficiency of the newly constructed coal-fired power plants have increased steadily at a rate of about 1% point per year over a period from 2005 to 2008, as shown in Table 4.

---

15 <www.iea.org/ciab/papers/power_generation_from_coal.pdf>.

16 As for unknown parameters the same assumptions are made for all plants (e.g. it is assumed that all plants use the same coal quality).

17 <http://cdm.ccchina.gov.cn/web/NewsInfo.asp?NewsId=2193>;
<http://cdm.ccchina.gov.cn/web/NewsInfo.asp?NewsId=3239>;
<http://qhs.ndrc.gov.cn/qjfzjz/t20090703_289357.htm>;
<http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2552.pdf>.

Table 4: Summary of Supporting Information for the Chinese Build Margin Emission Factors

Document year	2007	2008	2009	2010
Commissioning year of plants	2005	2006	2007	2008
Capacity (MW)	600	600	600	600 and above
Number of plants covered in the document	14	Top 30 out of 64	Top 30 out of 79	Top 30 out of 79
Efficiency	35.82%	37.28%	38.10%	39.08%
Improvement over previous year		1.46%	0.82%	0.98%

43. The Indian DNA also publishes information on the grid emission factor. However, this database only contains information on the electricity generation and total CO_2 emissions at the plant level. From this data, it was not possible to derive the operational efficiencies of the plants and to arrive to a conclusion on the improvement of efficiency of newly constructed power plants over time.

44. The China Electricity Council publishes annually measured data on the efficiency of Chinese power plants. The information is clustered according to different technologies and for each technology the average specific fuel consumption is published as well as the specific fuel consumption for each plant that is above the average. The data only cover power plants larger than 500 MW. The database includes information on 135 plants. The efficiency was calculated from data on the specific fuel consumption. As this database does not provide information on the commissioning year of the power plants, the data were matched with information on the commissioning year in the database from the IEA Clean Coal Centre. This results in a data set of 76 plants, of which 8 plants apply air-cooling technologies which are generally less efficient. Among the water-cooling plants, 59 plants were commissioned in the most recent 10 years (1999-2008). For these plants, a regression analysis, using the least square method, shows that the efficiency increased on average by 0.17% points per year.

45. To sum up, all evaluated data sources confirm that the efficiency of newly constructed power plants increased over time in the past decade. The rate of the increase may vary over time and the different data sources show different rates of increase, varying from about 1% point per decade to up to 1% point per year over a short period of four years. The simulation study allows to infer that a trend towards improved efficiency will at least continue for the next decade, as new processes and technologies are developed, such as materials that allow for higher steam temperatures and pressures.

5. Assessment of the values derived based on Option 2

46. The 2010 China Electricity Council report was also used to assess the values derived for the Chinese project activities based on Option 2. The report does not contain information on the commissioning year of each plant. This does not allow to calculate the baseline efficiency in accordance to the methodology ACM0013 which requires to use data from the plants commissioned in the five most recent years. However, using data from *all* existing plants, including plants that were commissioned more than five years ago, the mean efficiency of the top 15% performers of *all* existing plants was calculated to be 41.3%. The result may be even higher if only the plants commissioned within the five most recent years (and not all plants) were included in the sample. The value of 41.3% is significantly higher than the efficiencies assumed in majority of the PDDs which range from 36.6% to 41.3% for China.[18] The reason for the difference could not be identified, as the data underlying the determination of the values in the PDDs are not available.

[18] The average efficiency of the top 15% performers is not directly documented in the PDDs of the Chinese projects. The average efficiency of the top 15% performer plants was indirectly derived based on the emission factors of Options 1 and 2 and the baseline efficiency provided for Option 1 (i.e. the Option 1 baseline

VI. Analysis of other issues

47. In addition to the issues with regard to the determination of the baseline emission factor, a number of other issues were identified in the review of the methodology which are summarized below.

1. Investment analysis

48. In the procedure to identify the most plausible baseline scenario, the methodology requires that, when calculating the suitable financial indicator for all alternatives remaining after Step 1 (i.e. levelized cost of electricity production in $/kWh), "revenues (including subsidies/fiscal incentives, ODA, etc. where applicable), and, as appropriate, non-market cost and benefits in the case of public investors" must be considered. It is recommended to further clarify which revenues should be considered. Revenues should not include revenues from sales of electricity generation provision, given that the methodology requires to determine the levelized costs of electricity generation; however, other revenues and benefits may need to be included in the annual cash flow, including subsidies, tax benefits, or revenues from selling co-products, such as fly ash.

49. Other related methodologies, such as the methodology AM0029 for the construction of new gas fired power plants, require both an investment comparison analysis and a benchmark analysis. The benchmark analysis is included to assess whether the project is financially viable on its own. A similar approach may be considered for ACM0013. Additional guidance should also be provided on how to conduct the sensitivity analysis.

2. Documentation of key assumptions and parameters

50. Many PDDs do not provide information on key assumptions and parameters underlying the calculations. Additional guidance could be provided on what exact data and information should be documented in the PDDs to be validated or verified by the DOE. This should include data on key features of the project activity and its baseline alternatives. This would also facilitate the identification of any changes to the project activity, taken at a later stage, which may have large impacts on the economic attractiveness of the proposed project activity.

VII. Overall conclusions and recommendations

1. Option 1: Most likely technology

51. The assessment of the PDDs showed a number of shortcomings in the methodology and its application, including the following:

(a) The methodology does not provide detailed guidance on how the baseline efficiency should be determined under this option. This resulted in widely varying approaches, assumptions and data used across PDDs in determining the baseline efficiency, with significantly differing results for the baseline efficiency, including for baseline plants that use the same technology and fuel type. For a number of PDDs, the data used to determine the baseline efficiency appear inconsistent among different PDDs. For the same technology and fuel type, e.g. sub-critical technology and domestic coal, the baseline efficiencies for Indian project activities range from 31.8% to 38.1%;

(b) Concerning data sources for this option, instead of using manufacturer's design information for a *new* plant that would be constructed in the absence of the CDM project activity, most projects use data from *existing* plants. A data vintage of at least five years is observed for projects to be commissioned in 2012 or later, while various

---

efficiency was multiplied by the Option 1 baseline emission factor and divided by the Option 2 baseline emission factor). This approach assumes the same NCV of coal for the two options.

sources demonstrated an improvement in the efficiency of newly constructed power plants from 1.3% points over 10 years up to 3% points over four years;

(c) In many cases, assumptions used in deriving the baseline efficiency are unclear or inconsistent. The different values assumed for auxiliary power consumption could result in a difference in the baseline efficiency (η_{BL}) by 2.5% points. In other cases, the assumptions made are unrealistic and may, in some cases, result in an underestimation of the baseline efficiency;

(d) Furthermore, the determination of the baseline efficiency lacks some project-specific considerations, such as the coal type or cooling options available at the specific project site. The resulting baseline efficiency could contain an uncertainty margin of at least 0.3-0.5% point depending on the coal quality or 7% depending on the type of cooling method employed.

2. Option 2: top 15% performer plants

52. The evaluation of all available information showed a number of significant deficiencies in the methodology and its application, including the following:

(a) The information, which the methodology requires to be documented in the CDM-PDD, is not provided in many cases. Where it is provided, the inconsistency in the information could result in differences in the efficiencies of a peer group plant by up to 2% points;

(b) On average, there is a gap of 5 to 10 years between the project activities and the peer group plants, and the average gap is seven years between the project activities and the top 15% performer plants, while various sources demonstrated an improvement in the efficiency of newly constructed power plants from 1.3% points over 10 years up to 3% points over four years.

3. Impact of underestimating the baseline efficiency

53. A potential underestimation of the baseline efficiency in the methodology would result in an overestimation of emission reductions. An impact assessment was conducted to assess the magnitude of the potential overestimation of emission reductions. The details of this impact assessment are included in Appendix IV. The impact assessment is based on the deficiencies identified in this report and summarized in Section VII.1 and VII.2.

54. For Option 1, the efficiencies of the same baseline technology are reported at significantly different values and in most cases are considerably underestimated. The impact is assessed by applying the second[19] highest efficiency reported for the baseline sub-critical technology from the PDDs of the Indian project activities to all the Indian project activities, for which sub-critical technology is identified to be the baseline technology.

55. For Option 2, there is a significant data vintage between the commissioning of the project plant and the commissioning of the plants that were used to establish the baseline. The actual data vintage was determined for each Indian project and the average of 7 years[20] was assumed for the Chinese project activities for which such information is not available. During this period, two possible scenarios are considered, i.e. that the efficiency of newly constructed power plants increase on average by 0.13% and 0.3% points annually. These values were derived as follows:

(a) The value of 0.13% corresponds approximately to the lowest trend increase, observed from the data sources that were analyzed. 0.13% has been determined based on the

---

19 The highest efficiency reported for the baseline sub-critical technology in India was incorrectly determined on a gross basis.

20 See Table 3. The average value is derived from the projects for which such information is available.

simulation results, undertaken by the engineering expert. The results show an increase in the efficiency of 1.3% points for China and 1.4% for India from 2000 to 2010 (see paragraphs 40 and 41 of this report);

(b) The value of 0.3% has been derived from the information provided by the Chinese DNA in the calculation of Build Margin of the Grid (see paragraph 42 of this report). The information shows an increase of 1% point per year in 4 years. It is conservatively assumed that this trend could not be maintained for longer periods and an efficiency improvement of 3% points was assumed for a period of 10 years.

56. The results of the impact assessment are summarized in Table 5 below. They refer to all 44 coal-fired projects activities applying ACM0013 which are registered, requesting registration or under validation. The project activities from Argentina, Brazil and Iran are not included.

Table 5: Summary of Results of the Impact Assessment

	Scenario A	Scenario B
Annual efficiency increase assumption (%)	0.13%	0.30%
Annual emission reduction (MtCO2/year)	40	40
Potential overestimation (MtCO2/year)	20	25
Potential overestimation/Emission reduction (%)	**50.5%**	**62.1%**

4. Recommendations

57. Considering that many of the deficiencies identified in the application of ACM0013 resulted from a lack of clear requirements in the methodology, the panel agreed that, inter alia, the following aspects of ACM0013 Version 4 should be clarified or revised, to ensure appropriate application of the methodology in its current form, in particular:

(a) For the alternatives involving the same fossil fuel as the project activity, there should be evidence in the PDD to prove that such alternatives are considered. Such evidence shall include feasibility studies conducted by/for project participants, which contain information on the capital costs and operational efficiency of the alternatives. Such feasibility studies shall also ensure and document that baseline efficiencies for Option 1 are obtained based on good practice for key power plant parameters such as excess air, condenser pressure, etc.;

(b) The baseline efficiency of Option 1 (“ηBL”) shall be determined as the efficiency at optimum load, as provided in feasibility studies conducted for the identified baseline power generation technology and for the project site. Historical performance of other plants should be excluded as a basis for Option 1;

(c) For Option 2, fuel consumption and net electricity generation for the plants identified in Steps 3 and 5 shall be documented in the PDDs. The DOE shall check the fuel consumption and electricity generation of all identified power plants against plant records on fuel consumption and net electricity fed into the grid.

58. The panel will further continue its work on the revision of ACM0013, with regard to, inter alia, the baseline efficiency identified under Option 2, by including procedures to incorporate the impact from the increase of the efficiencies of the newly constructed power plants during the period from the commissioning of the top 15% performer plants to that of the project activity, as a result of the availability and application of new technologies. The procedures could be based on historical efficiency information of newly constructed power plants in the grid. Where such information may not be available, default values for the annual efficiency increase could be provided.

- - - - -

Appendix I: Approaches Used to Determine the Baseline Efficiency (η_{BL}) under Option 1

Ref #	Country	Status	Baseline	Eff. Option 1 (ηBL)	Approach Option 1
2716	India	Registered	Subcritical using imported coal (same as in project scenario)	35.9%	Calculated from the Annual Thermal Performance Review 2006-07 and auxiliary power consumption at 0%
3690	India	Registered	Subcritical using domestic coal	31.8%	Calculated from the Annual Thermal Performance Review 2007-08 and auxiliary power consumption at 0%
3225	India	Registered	Subcritical using domestic coal	35.1%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 0%
4629	India	Registered	Subcritical using domestic coal	34.1%	Taken from the best performing efficiency of the most likely baseline scenario, equation 5 of the methodology
4533	India	Registered	Subcritical technology using imported coal	36.0%	Taken from the highest efficiency of sub-critical technology plant identified as per Option 2 in meth v3
4798	India	Requesting registration	Subcritical technology using imported coal	36.6%	Sourced from top performing sub critical technology plant in the geographical boundary (India), published by CEA
4807	India	Review Requested	Subcritical technology based coal fired power generation using linkage coal	36.6%	Refers to the "TORANGALLU EXT - 1" Unit. This unit has been selected to be "most likely baseline scenario" that would have come up in the absence of the project activity
CDM 5376	India	Under validation	Subcritical using domestic coal	32.6%	Calculated as per the station heat rate from CEA database V4 and auxiliary power consumption at 7%
CDM 5996	India	Under validation	Subcritical using domestic coal	32.6%	Calculated as per the station heat rate from CEA database V4 and auxiliary power consumption at 7%
CDM 6277	India	Under validation	Subcritical using domestic coal	35.1%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 0%
CDM 6528	India	Under validation	Subcritical	33.0%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 8.5%

Ref #	Country	Status	Baseline	Eff. Option 1 (ηBL)	Approach Option 1
CDM 7097	India	Under validation	Subcritical using domestic coal	38.1%	Calculated as per the average gross design efficiency of 500 MW sub-critical technology based power plants installed in the country http://www.pewclimate.org/docUploads/india-coal-technology.pdf
CDM 7104	India	Under validation	Subcritical	32.6%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 7%
CDM 7278	India	Under validation	Subcritical	32.4%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 6%
CDM 7310	India	Under validation	Subcritical using domestic coal	32.6%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 7%
CDM 7382	India	Under validation	Subcritical	32.8%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 7.5%
CDM 7464	India	Under validation	Subcritical	32.8%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 7.5%
CDM 7564	India	Under validation	Subcritical	33.3%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 6%
CDM 7665	India	Under validation	70% domestic coal and 30% imported coal	32.6%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 7%
CDM 7704	India	Under validation	70% domestic coal and 30% imported coal	32.6%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 7%
CDM 7821	India	Under validation	Subcritical	35.1%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 0%
CDM 8035	India	Under validation	Subcritical using domestic coal	35.1%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 0%
CDM 8082	India	Under validation	Subcritical using sub-bituminous coal	33.3%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 6%

Ref #	Country	Status	Baseline	Eff. Option 1 (ηBL)	Approach Option 1
CDM 8110	India	Under validation	Subcritical using sub-bituminous coal	33.3%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 6%
CDM 8120	India	Under validation	Subcritical using sub-bituminous coal	33.3%	calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 6%
CDM 8176	India	Under validation	Subcritical	31.8%	Calculated from the Annual Thermal Performance Review 2007-08 and auxiliary power consumption at 0%
CDM 8192	India	Under validation	Subcritical	35.5%	Calculated as per the station heat rate from CEA database V6 and auxiliary power consumption at 0%
CDM 8209	India	Under validation	Subcritical	32.6%	Calculated as per the station heat rate from CEA database V5 and auxiliary power consumption at 7%
CDM 8385	India	Under validation	Subcritical	35.5%	Calculated as per the station heat rate from CEA database V6 and auxiliary power consumption at 0%
CDM 8402	India	Under validation	Subcritical	35.5%	Calculated as per the station heat rate from CEA database V6 and auxiliary power consumption at 0%
CDM 8654	India	Under validation	Subcritical	35.1%	Calculated as per the station heat rate from tariff order of CERC and auxiliary power consumption at 0%
3288	China	Registered	Supercritical	38.6%	Calculated based on the parameters from the FSR
4785	China	Review Requested	Supercritical	38.1%	Sourced from “Bulletin on determining baseline emission factor for China Grid" (updated in July 2009, NDRC)
4814	China	Requesting registration	Supercritical	38.1%	Sourced from “Bulletin on determining baseline emission factor for China Grid" (updated in July 2009, NDRC)
5027	China	Requesting registration	Supercritical	39.0%	Calculated according to the Unit Cost Referenced index of Fossil-fired Power Engineering and Design of 2007, compiled by Electric Power Planning and Design Institute and published by China Electric Power Press in 2008.

Ref #	Country	Status	Baseline	Eff. Option 1 (ηBL)	Approach Option 1
CDM 4488	China	Under validation	Subcritical	35.8%	Sourced from "Bulletin on determining baseline emission factor for China grid" (updated in August, 2007, NDRC)
CDM 4695	China	Under validation	Subcritical	35.8%	Sourced from "Bulletin on determining baseline emission factor for China grid" (updated in August, 2007, NDRC)
CDM 5445	China	Under validation	Subcritical	37.3%	Sourced from unspecified official statistical data
CDM 5455	China	Under validation	Subcritical	37.3%	Sourced from unspecified official statistical data
CDM 5929	China	Under validation	Subcritical	38.1%	Sourced from "Bulletin on determining baseline emission factor for China Grid" (updated in July 2009, NDRC)
CDM 6413	China	Under validation	Supercritical	40.4%	Calculated from the article of Energy efficiency analysis of national 600MW unit thermal power generating.
CDM 7685	China	Under validation	Subcritical	37.9%	Calculated based on http://baike.baidu.com/view/3121388.html?fromTaglist (in chinese)
CDM 8310	China	Under validation	Supercritical	38.9%	Calculated according to the Unit Cost Referenced index of Fossil-fired Power Engineering and Design of 2007, compiled by Electric Power Planning and Design Institute and published by China Electric Power Press in 2008.
CDM 8427	China	Under validation	Supercritical	38.9%	Calculated according to the Unit Cost Referenced index of Fossil-fired Power Engineering and Design of 2007, compiled by Electric Power Planning and Design Institute and published by China Electric Power Press in 2008.
CDM 3190	Brazil	Under validation	Fuel oil, other technology	32.9%	Estimated according to the Eletrobras Reports of the isolated system. Average efficiency of the Thermal Power Plants of the grid
CDM 5436	Iran	Under validation	Single cycle gas power plant	34.5%	Latest gas power plants in Iran were all equipped with V94.2A turbines with a name plate efficiency of 34.5%

Ref #	Country	Status	Baseline	Eff. Option 1 (ηBL)	Approach Option 1
CDM 4553	Brazil	Under validation	Fuel oil, other technology	32.0%	Estimated according to the Eletrobras Reports of the isolated system. Average efficiency of the Thermal Power Plants of the grid
CDM 6210	Argentina	Under validation	Natural gas, other technology	33.7%	Firm Proposal 70612E1N1 (03/07) Rev. 001G; Page 3.1; Performance Guarantee data; General Electric Energy

Appendix II: The Parameters Provided for the Peer Group Plants in Various PDDs

Name	Unit No	Reference year	Efficiency	Fuel Consumption (ton/year)	Net Electricity Generation (MWh/year)
BELLARY TPS	1	2008-2009	32.78%	800177	1106000
			31.65%	1904680	2860830
		2009-2010	36.03%	1782732	2704789
			36.03%	1782732	2704790
				1782732	2704790
				1782732	2704790
DADRI (NCTPP)	5	2009-2010	34.58%	276937	395331
			31.81%	2075886	2884133
				2075886	2884133
				2075886	2884133
			34.55%	276937	395000
				276937	395000
				276937	395000
KAHALGAON	5	2007-2008	34.72%	2011362	2334935
			34.81%	2005402	2334935
			35.52%	1868000	2334935
		2008-2009	34.04%	1825730	2111000
			34.08%	1825730	2111000
			34.09%	1825730	2111000
			34.08%	2046343	2557929
				1688800	2111000
				1688800	2111000
			32.85%	1933511	2416889
			35.53%	1868000	2335000
			36.85%	1688800	2111000
		2009-2010	34.44%	2154268	2516505
			35.17%	1428238	2111000
			32.85%	2090221	2416818
				2090221	2416818
				2090221	2416818
			34.45%	2154268	2517000
				2154268	2517000
				2154268	2517000
	6	2008-2009	34.04%	665081	769000
			34.09%	665081	769000
			34.08%	2046343	2557929
				615200	769000
				615200	769000
			32.85%	1933511	2416889
			36.85%	615200	769000
		2009-2010	34.44%	2365616	2763390
			35.17%	520282	769000
			32.85%	2090221	2416818
				2090221	2416818
				2090221	2416818
			34.44%	2365616	2763000

				2365616	2763000
				2365616	2763000
	7	2008-2009	32.85%	1933511	2416889
		2009-2010	0.3285	2090221	2416818
				2090221	2416818
				2090221	2416818
MUNDRA TPP PH-I	1	2009-2010	31.81%	580307	806250
				580307	806250
				580307	806250
	2	2009-2010	0.3181	580307	806250
				580307	806250
				580307	806250
R_GUNDEM STPS	7	2007-2008	35.22%	2453400	4089000
			35.96%	2529074	4089000
			35.97%	2529074	4089000
		2008-2009	33.79%	2542054	3919000
			35.23%	2453400	4089000
			36.54%	2351400	3919000
RAJIV GANDHI TPS HISAR	1	2009-2010	31.81%	58257	80940
				58257	80940
				58257	80940
RIHAND	3	2007-2008	35.50%	2573800	3785000
			35.87%	2680456	3785000
			35.88%	2680456	3785000
		2008-2009	34.05%	2931416	3987588
			34.06%	2931416	3987588
			34.06%	2896017	4258848
				2711560	3987588
				2711560	3987588
			35.51%	2573800	3785000
			36.82%	2711560	3987588
		2009-2010	35.14%	2700260	3988000
	4	2007-2008	35.50%	2749240	4043000
			35.87%	2863166	4043000
			35.88%	2863166	4043000
		2008-2009	34.01%	2931416	3988000
			34.05%	2931416	3987588
			34.06%	2931416	3987588
			34.06%	2896017	4258848
				2711560	3987588
				2711560	3987588
			32.83%	2846383	4185858
			35.51%	2749240	4043000
			36.82%	2711560	3987588
		2009-2010	35.14%	2700260	3988000
			35.42%	2525363	3572841
			32.83%	3077185	4185878
				3077185	4185878
				3077185	4185878

			35.42%	2525363	3573000
				2525363	3573000
				2525363	3573000
SANJAY GANDHI	5	2008-2009	32.80%	1306686	1612000
			32.84%	1306686	1611580
			33.94%	1097617	1611580
			32.84%	2158568	2878090
				1208685	1611580
				1208685	1611580
			31.81%	2167654	2890205
		2009-2010	30.50%	2770454	3173661
			33.42%	1147732	1612000
			31.65%	2343376	2890164
				2343376	2890164
				2343376	2890164
			30.51%	2770454	3174000
				2770454	3174000
				2770454	3174000
SIPAT STPS	1	2008-2009	32.99%	630511	876000
			34.11%	672389	876000
			33.00%	1397208	2085385
				586920	876000
				586920	876000
			31.81%	2721481	4087665
			36.91%	621960	876000
		2009-2010	34.89%	597378	876000
			35.85%	2791336	3830779
			31.81%	3137559	4087665
				3137559	4087665
				3137559	4087665
			35.86%	2791336	3831000
				2791336	3831000
				2791336	3831000
	2	2008-2009	32.99%	2272286	3157000
			34.04%	2423211	3157000
			34.11%	2423211	3157000
			33.00%	1397208	2085385
				2115190	3157000
				2115190	3157000
			31.81%	2721481	4087665
		2009-2010	34.55%	2174162	3157000
			35.85%	2831232	3885532
			31.81%	3137559	4087665
				3137559	4087665
				3137559	4087665
			35.85%	2831232	3885530
				2831232	3885530
				2831232	3885530
TALCHER STPS	3	2007-2008	35.37%	2738400	3911833
			35.95%	2835656	3911833
			35.96%	2835656	3911833

		2008-2009	35.38%	2738400	3912000
	4	2007-2008	35.37%	2738400	3911833
			35.95%	2835656	3911833
			35.96%	2835656	3911833
		2008-2009	35.38%	2738400	3912000
	5	2007-2008	35.37%	2738400	3911833
			35.95%	2835656	3911833
			35.96%	2835656	3911833
		2008-2009	33.94%	2612895	3452754
			35.38%	2738400	3912000
			36.69%	2416928	3452754
	6	2007-2008	35.37%	2738400	3911833
			35.95%	2835656	3911833
			35.96%	2835656	3911833
		2008-2009	33.89%	2543899	3362000
			33.93%	2543899	3361580
			33.94%	2543899	3361581
			33.94%	2631617 2353106 2353106	3759453 3361580 3361580
			35.38%	2738400	3912000
			36.69%	2353107	3361581
		2009-2010	35.33%	2263957	3362000
VINDH_CHAL STPS	9	2007-2008	35.28%	2638680	3998000
			35.69%	2745503	3998000
			35.69%	2745503	3998000
		2008-2009	33.52%	2669254	3741000
			33.67%	2614405	3741000
			33.85%	2669254	3741000
			33.67%	2651976 2431650 2431650	4079963 3741000 3741000
			32.28%	2750123	4230960
			35.28%	2638680	3998000
			36.41%	2461627	3741000
		2009-2010	35.31%	2807493	4213668
			35.39%	2515061	3741000
			32.28%	2973111 2973111 2973111	4230966 4230966 4230966
			35.32%	2807493 2807493 2807493	4214000 4214000 4214000
	10	2007-2008	35.28%	1842060	2791000
			35.69%	1916633	2791000
			35.69%	1916633	2791000
		2008-2009	33.52%	2879741	4036000
			33.67%	2820566	4036000
			33.85%	2879741	4036000
			33.67%	2651976	4079963

				2623400	4036000
				2623400	4036000
			32.28%	2750123	4230960
			35.28%	1842060	2791000
			36.41%	2655741	4036000
		2009-2010	35.31%	2535902	3806047
			35.39%	2713388	4036000
			32.28%	2973111	4230966
				2973111	4230966
				2973111	4230966
			35.31%	2535901	3806000
				2535901	3806000
				2535901	3806000

Appendix III: Data Vintage in Years between the Commissioning of the Project Activity Plant and the Commissioning of the Peer Group Plants

Ref #	Country	Expected Commissioning date	Oldest peer group plant	Newest peer group plant	Oldest top 15% plant	Newest top 15% plant
2716	India	1-Feb-11	8.1	2.9	N/A	N/A
3225	India	1-Aug-11	8.6	2.9	8.6	7.8
3690	India	1-Jan-12	9.0	4.8	6.9	4.8
4629	India	24-Nov-14	10.5	5.9	9.8	7.7
4533	India	30-Sep-13	10.7	6.5	9.0	8.7
4798	India	1-Nov-11	8.8	4.6	7.1	6.7
4807	India	1-Jan-14	8.3	3.9	6.1	5.0
CDM5376	India	1-May-12	19.1	4.1	N/A	N/A
CDM5996	India	1-Jan-12	9.0	3.3	7.3	6.9
CDM6277	India	1-Apr-12	9.2	5.0	7.2	5.0
CDM6528	India	1-Aug-13	9.2	4.6	7.0	6.4
CDM7097	India	1-Jul-13	9.1	5.3	8.4	6.1
CDM7104	India	1-Jul-14	9.4	5.5	7.3	5.5
CDM7278	India	1-Sep-13	9.3	5.5	6.3	5.5
CDM7310	India	1-Jul-13	9.1	4.5	6.9	6.3
CDM7382	India	1-Jan-15	10.6	6.8	7.6	6.8
CDM7464	India	1-Jun-15	11.1	7.2	8.0	7.2
CDM7564	India	1-May-14	8.6	4.8	7.1	6.1
CDM7665	India	1-Mar-14	9.8	5.2	7.6	7.0
CDM7704	India	1-Mar-14	9.8	5.2	7.6	7.0
CDM7821	India	1-Dec-15	10.8	6.9	9.3	8.7
CDM8035	India	1-May-12	8.0	3.3	5.8	5.1

CDM8082	India	1-Oct-15	10.0	5.5	8.5	7.5
CDM8110	India	1-Apr-15	9.5	5.0	8.0	7.0
CDM8120	India	1-Apr-15	9.5	5.0	8.0	7.0
CDM8176	India	1-Apr-13	10.2	6.0	8.2	6.0
CDM8192	India	1-Apr-15	9.5	5.2	7.3	6.3
CDM8209	India	1-Mar-14	9.8	5.2	7.7	7.0
CDM8385	India	1-Jun-15	9.7	5.3	7.5	6.4
CDM8402	India	1-Nov-15	10.1	5.8	7.9	6.8
CDM8654	India	1-Dec-14	9.8	5.9	9.8	6.7
CDM5436	Iran	6-Nov-06	4.8	0.8	2.8	0.8

Appendix IV: Summary of the Impact Assessment

								Revised Baseline efficiency						
		Emissions		Baseline efficiency			Commissioning gap	Option 1	Option 2		Adopted		ER Overestimation	
Ref #	Capacity (MW)	Baseline (tCO2/year)	Project (tCO2/year)	Option 1	Option 2	Adopted	(years)		Scenario A 0.13%	Scenario B 0.3%	Scenario A	Scenario B	Scenario A	Scenario B
India														
2716	1320	8,376,931	6,537,414	35.9%	36.2%	36.2%	5.5	36.6%	37.0%	37.9%	37.0%	37.9%	161,338	363,173
3225	1320	8,376,931	7,183,914	35.1%	36.8%	36.8%	8.2	36.6%	37.8%	39.2%	37.8%	39.2%	235,145	523,428
3690	3960	27,001,725	24,755,849	31.8%	34.1%	34.1%	5.8	36.6%	34.8%	35.8%	36.6%	35.8%	1,866,513	1,319,777
4629	3960	25,833,209	23,693,284	34.1%	34.1%	34.1%	8.7	36.6%	35.2%	36.7%	36.6%	36.7%	1,778,680	1,844,224
4533	3960	24,199,573	22,964,875	36.0%	36.0%	36.0%	8.8	36.6%	37.1%	38.6%	37.1%	38.6%	748,638	1,660,453
4798	1980	11,779,188	10,961,535	36.6%	36.0%	36.6%	6.9	36.6%	37.5%	38.7%	37.5%	38.7%	282,219	631,490
4807	1400	9,837,671	8,901,219	36.6%	35.9%	36.6%	5.5	36.6%	37.4%	38.3%	37.4%	38.3%	189,843	427,315
CDM5376	1320	8,573,661	6,967,806	32.6%	34.2%	34.2%	11.6	36.6%	35.7%	37.7%	36.6%	37.7%	556,330	791,996
CDM5996	1320	8,555,164	6,480,468	32.6%	34.2%	34.2%	7.1	36.6%	35.1%	36.4%	36.6%	36.4%	555,130	500,683
CDM6277	1980	11,870,290	10,761,885	35.1%	31.8%	35.1%	6.1	36.6%	35.9%	36.9%	36.6%	36.9%	486,487	586,938
CDM6528	1370	9,025,192	7,922,828	33.0%	34.6%	34.6%	6.7	36.6%	35.4%	36.6%	36.6%	36.6%	504,011	496,397
CDM7097	1320	7,963,341	7,319,022	38.1%	36.5%	38.1%	7.3	36.6%	39.0%	40.3%	39.0%	40.3%	192,418	430,440
CDM7104	1320	9,278,201	8,200,668	32.6%	34.1%	34.1%	6.4	36.6%	34.9%	36.0%	36.6%	36.0%	638,808	493,515
CDM7278	1980	3,857,049	3,252,519	32.4%	34.1%	34.1%	5.9	36.6%	34.8%	35.8%	36.6%	35.8%	265,567	189,195
CDM7310	1320	8,044,102	7,776,212	32.6%	34.1%	34.1%	6.6	36.6%	35.0%	36.1%	36.6%	36.1%	545,873	442,561
CDM7382	1320	8,031,533	6,853,309	32.8%	34.1%	34.1%	7.2	36.6%	35.0%	36.2%	36.6%	36.2%	552,991	478,266
CDM7464	2640	15,169,708	12,744,424	32.8%	34.1%	34.1%	7.6	36.6%	35.1%	36.4%	36.6%	36.4%	1,044,472	952,376
CDM7564	700	3,978,720	3,272,764	33.3%	32.9%	33.3%	6.6	36.6%	34.2%	35.3%	36.6%	35.3%	355,476	223,283
CDM7665	1320	8,675,182	8,135,114	32.6%	34.1%	34.1%	7.3	36.6%	35.1%	36.3%	36.6%	36.3%	588,698	522,446
CDM7704	1320	8,675,182	8,135,114	32.6%	34.1%	34.1%	7.3	36.6%	35.1%	36.3%	36.6%	36.3%	588,698	522,446
CDM7821	660	4,000,872	3,785,687	35.1%	35.4%	35.4%	9.0	36.6%	36.6%	38.1%	36.6%	38.1%	132,269	284,698

CDM8035	4000	26,007,389	21,858,718	35.1%	35.4%	35.4%	5.5	36.6%	36.1%	37.0%	36.6%	37.0%	862,059	1,149,407
CDM8082	1320	9,020,078	7,928,371	33.3%	32.9%	33.3%	8.0	36.6%	34.4%	35.7%	36.6%	35.7%	805,892	607,452
CDM8110	1980	13,530,117	11,892,557	33.3%	32.9%	33.3%	7.5	36.6%	34.3%	35.6%	36.6%	35.6%	1,208,838	857,989
CDM8120	1320	9,020,078	7,928,371	33.3%	32.9%	33.3%	7.5	36.6%	34.3%	35.6%	36.6%	35.6%	805,892	571,993
CDM8176	1320	8,647,652	7,959,283	31.8%	35.5%	35.5%	7.1	36.6%	36.4%	37.6%	36.6%	37.6%	255,177	488,327
CDM8192	1320	8,509,811	7,993,372	35.5%	35.9%	35.9%	6.8	36.6%	36.8%	38.0%	36.8%	38.0%	204,178	456,845
CDM8209	1980	13,082,293	11,783,030	32.6%	34.1%	34.1%	7.3	36.6%	35.1%	36.3%	36.6%	36.3%	887,764	792,087
CDM8385	660	4,547,862	4,069,962	35.5%	35.9%	35.9%	7.0	36.6%	36.8%	38.0%	36.8%	38.0%	111,744	249,843
CDM8402	1320	8,095,725	9,139,925	35.5%	35.9%	35.9%	7.4	36.6%	36.9%	38.1%	36.9%	38.1%	210,515	469,827
CDM8654	1980	12,479,314	11,509,762	35.1%	0.0%	35.1%	8.3	36.6%	36.2%	37.6%	36.6%	37.6%	511,447	824,059
China														
3288	2000	9,071,586	8,765,803	38.6%	38.7%	38.7%	7	-	39.6%	40.8%	39.6%	40.8%	208,234	466,536
4785	2000	8,828,262	8,155,017	38.1%	37.0%	38.1%	7	-	39.0%	40.2%	39.0%	40.2%	205,940	461,178
4814	2000	8,077,118	7,614,591	38.1%	39.5%	39.5%	7	-	40.5%	41.6%	40.5%	41.6%	181,668	407,255
5027	2000	7,201,629	6,864,989	39.0%	41.3%	41.3%	7	-	42.2%	43.4%	42.2%	43.4%	155,303	348,561
CDM4488	2000	8,246,896	7,614,591	35.8%	38.7%	38.7%	7	-	39.6%	40.8%	39.6%	40.8%	189,297	424,108
CDM4695	2000	8,077,118	7,614,591	35.8%	39.5%	39.5%	7	-	40.5%	41.6%	40.5%	41.6%	181,669	407,257
CDM5445	2000	8,056,620	7,542,757	37.3%	39.7%	39.7%	7	-	40.6%	41.8%	40.6%	41.8%	180,573	404,841
CDM5455	1320	5,288,109	4,986,443	37.3%	39.8%	39.8%	7	-	40.7%	41.9%	40.7%	41.9%	118,131	264,872
CDM5929	1000	4,498,158	4,157,654	38.1%	39.6%	39.6%	7	-	40.5%	41.7%	40.5%	41.7%	101,166	226,791
CDM6413	1320	4,899,455	4,600,883	40.4%	36.6%	40.4%	7	-	41.3%	42.5%	41.3%	42.5%	107,902	242,034
CDM7685	2000	8,516,448	8,427,061	37.9%	40.5%	40.5%	7	-	41.4%	42.6%	41.4%	42.6%	187,045	419,592
CDM8310	1320	4,897,277	4,783,460	38.9%	40.1%	40.1%	7	-	41.0%	42.2%	41.0%	42.2%	108,622	243,600
CDM8427	2000	7,239,973	7,154,695	38.9%	41.2%	41.2%	7	-	42.1%	43.3%	42.1%	43.3%	156,326	350,846