



Approved baseline and monitoring methodology AM0018

“Baseline methodology for steam optimization systems”

I. SOURCE, DEFINITIONS AND APPLICABILITY

Sources

This consolidated baseline and monitoring methodology is based on the following proposed new methodologies:

NM0037-rev “Energy efficiency project by modification of CO₂ removal system of Ammonia Plant to reduce steam consumption” prepared by Indo Gulf Fertilisers Ltd.

This methodology also refers to the latest approved versions of the following tools:¹

- “Tool for the demonstration and assessment of additionality”;
- “Tool to calculate project emissions from electricity consumption”;
- “Tool to calculate project emissions from fossil fuel consumption”.

Selected approach from paragraph 48 of the CDM modalities and procedures

“Existing actual or historical emissions, as applicable”

Definitions

For the purpose of this methodology the following definition applies:

Production output. The relevant production output from the process (unit or system) where steam is optimised.

Applicability

This methodology is applicable to steam optimization projects in production processes with homogeneous and relatively constant outputs with continuous monitoring of steam output.

This baseline methodology shall be used in conjunction with the approved monitoring methodology AM0018 (“Monitoring methodology for steam optimization systems”).

This methodology applies to steam optimization projects in production process if the following conditions are met:

- The process unit(s) where steam is optimised produces a homogeneous output;
- The production volume in the process unit(s) where steam is optimised is reasonably constant under steady state conditions;
- Steam consumption is monitored continuously;

¹ Please refer to: < <http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>>.

- For steam optimised in the project activity is produced in a cogeneration system, it should be demonstrated that the steam generated at boiler end is reduced by the quantity of steam saved by the project activity;
- The steam saved in the project activity if used then it shall be demonstrated that it does not lead to increase in GHG emissions.

In addition, the project should comply with the applicability conditions as described in the tools applied in this methodology.

II. BASELINE METHODOLOGY PROCEDURE

Project boundary

The project boundary would cover the following:

- Steam generator
- Source of electricity for additional electrical loads (if any) due to project activity
- Process area where the steam consumption is expected to be reduced

The spatial extent of the project boundary includes:

- The steam generating unit(s);
- Backpressure or extraction turbines in cogeneration projects should be included in the project boundary in cases where medium or low-pressure steam at the outlet of the turbine is optimized;
- In cases where electricity consumption increases as a result of the project activity, the electricity source should be included;
- Process unit(s)/system where the specific steam consumption is expected to be reduced.

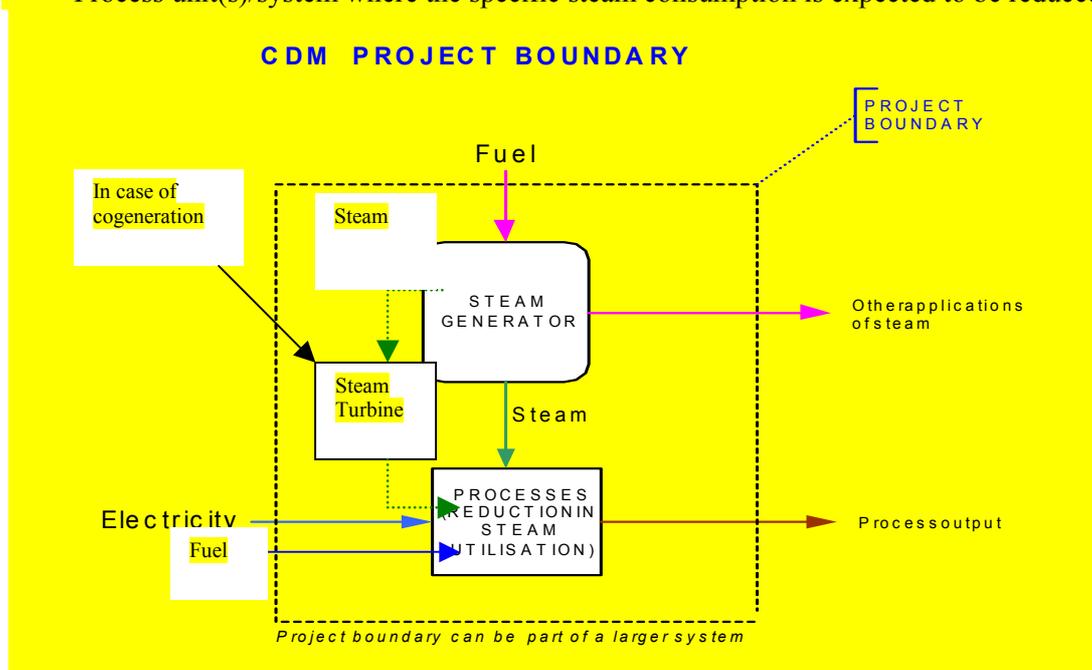


Figure 1: CDM Project Boundary



The greenhouse gases included in and excluded from the project boundary are shown in Table 1.

Table 1: Emissions sources included in or excluded from the project boundary

	Source	Gas	Included?	Justification / Explanation
Baseline	Fossil fuel combustion in steam generator	CO ₂	Yes	Main source of emission
		CH ₄	No	Excluded for simplification. This is conservative.
		N ₂ O	No	Excluded for simplification. This is conservative.
	Electricity used in electrical equipment	CO ₂	Yes	It can be significant source
		CH ₄	No	Excluded for simplification. This is conservative.
		N ₂ O	No	Excluded for simplification. This is conservative.
Project activity	Fossil fuel combustion in steam generator	CO ₂	Yes	Main source of emission
		CH ₄	No	Excluded for simplification. This emission source is assumed to be very small.
		N ₂ O	No	Excluded for simplification. This emission source is assumed to be very small.
	Electricity consumption due to project activity	CO ₂	Yes	It can be significant source
		CH ₄	No	Excluded for simplification. This emission source is assumed to be very small.
		N ₂ O	No	Excluded for simplification. This emission source is assumed to be very small.
	Additional fossil fuel consumption in any other equipment due to project activity	CO ₂	Yes	It can be significant source
		CH ₄	No	Excluded for simplification. This emission source is assumed to be very small.
		N ₂ O	No	Excluded for simplification. This emission source is assumed to be very small.

Procedure for determining the lifetime of the project activity when an inefficient component is replaced by more efficient one

Project participants shall use the following guidelines estimate the remaining lifetime of the equipment or to estimate the remaining time that the existing equipment could operate before it needs to be replaced in the absence of the project activity:

- The typical average technical lifetime of the type of equipment shall be determined and documented in the CDM-PDD, taking into account common practices in the sector and country, e.g. based on industry surveys, statistics, technical literature, etc.;
- The practices of the responsible company regarding replacement schedules shall be evaluated and documented in the CDM-PDD, e.g. based on historical replacement records for similar equipment, maintenance schedules required by legislation etc.

The point in time when the existing equipment would need replacement in the absence of the project activity should be chosen in a conservative manner, i.e. the earliest point in time should be chosen in cases where only a time frame can be estimated and should be documented in the CDM-PDD.

The emission reductions can be claimed for the minimum period between the crediting period and the expected lifetime of the equipment.



Additionality

*The additionality of the project activity shall be demonstrated and assessed using the latest version of the “**Tool for the demonstration and assessment of additionality**” agreed by the CDM Executive Board, which is available on the UNFCCC CDM web site².*

Procedure for the identification of the most plausible baseline scenario and the demonstration of additionality

The selection of the most plausible baseline scenario shall be performed in accordance with the latest approved version of the “Combined tool to identify the baseline scenario and to demonstrate additionality”. The following section provides guidance that must be followed in addition to the information provided in the tool.

Step 1: Further guidance on identification of alternative scenarios

The tool requires identification of all plausible and credible alternative scenarios to the project activity, including projects of a similar nature that deliver an output of comparable quality and service level.

The identified scenarios should be technically feasible alternatives that provide the same steam or fuel efficiencies/reductions throughout the crediting period.

The alternative baseline scenarios, which should be considered, include inter alia:

- Continuing the current practice - the plant operates without project activity;
- Steam saving project activity is implemented without CDM;
- Part of the project activity is implemented without CDM;
- Any other steam optimization project at process end, which can save steam and which is not taken up as CDM project;
- Any other energy saving projects on steam generation side which can save fuel.

The methodology is only applicable where the baseline selection demonstrates that the baseline scenario is that the plant continues to operate in the current fashion, i.e. without implementation of steam optimization project.

Baseline emissions

The methodology applies to projects where energy efficiency is achieved by reducing specific steam consumption in an industrial process where the most likely baseline scenario is the continuation of production using current processes and efficiencies (though steam production efficiency may improve as indicated below due to the modification of the output of the industrial facility).

The baseline Specific Steam Consumption Ratio SSCR is determined using the following 3 Steps:

Step 1: Benchmark the baseline output;

Step 2: Benchmarking baseline steam consumption;

Step 3: Benchmarking of Process Specific Steam Consumption Ratio (SSCR).

² Please refer to: < <http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>>.



Based on historical data from the existing process, a benchmark Specific Steam Consumption Ratio (SSCR, steam consumption per product output) is defined as the baseline energy efficiency. The improvement of the benchmark after project implementation is monitored and the corresponding steam savings and CO₂ emission reductions from fuel combustion in the boiler are determined.

The methodology addresses also possible increases in electricity consumption as a result of the project activity (using the small-scale methodology) and captures the impact of future retrofits and their impact on steam and CO₂ savings.

The methodology sets a specific energy consumption (SSCR) for each representative production rate. A “normal” production range can be defined based on the relationship between production rates and energy consumption. Based on general experience the energy consumption per unit of production is not significantly sensitive up to +/-5% of nameplate capacity. Production data points that fall outside the normal production range (figures higher than +5% or lower than -5% of verifiable³ nameplate capacity) should be excluded when determining the specific steam consumption ratio. This implies each production figure that is outside normal range should be excluded in Step 1 below and each steam consumption figure that corresponds to a production figure that is excluded, must ~~can~~ be excluded from Step 2 calculations determining the baseline steam consumption. The estimated baseline SSCR is based on data for one month at the minimum. If there are variations in production due to seasonal factors or other reasons during the year, then one-year data shall be used. It should be ensured that the data used in estimating the baseline SSCR factor corresponds the production capacity at the time of the implementation of the project activity. In situations where more than 10% of the days, of the total days for which data is used, the daily specific steam consumption ratio cannot be estimated because of the fact that production values for those days fall outside the normal range, then the procedure provided in Step 3 shall be used to estimate daily specific steam consumption ratio for such days.

Step 1: Benchmarking baseline output

A representative production figure ($P_{rep,BL}$) is calculated based on historical production data for each shift, batch or day.

The production figures of $P_{1,BL}$, $P_{2,BL}$, $P_{3,BL}$ given in Equation (1) below should be selected based on the normal range of rated plant capacity.

$$P_{rep,BL,d} = \frac{(P_{1,BL,s/b} + P_{2,BL,s/b} \dots + P_{n,BL,s/b})}{n_d} \times A \quad (1)$$

Where:

$P_{1,BL,s/b}$, $P_{2,BL,s/b}$... $P_{n,BL,s/b}$	=	Baseline production figures per shift/per batch (Mass/volume unit)
$P_{rep,BL,d}$	=	Representative average production for a day in the baseline (Mass/volume unit)
A	=	Maximum number of shifts/day or batches/day during crediting period
n_d	=	Number of batches/shifts in operation for each day

³ E.g. on the basis of construction or design specifications.

Note: If the operation runs on a maximum of three 8 hour shifts per day, $A=3$. If for a particular day for some reason, the operation only ran one shift, then $n=1$ for that particular day. If the maximum number of batches produces per day is six ($A=6$), but for a particular day the number of batches produced are three, then $n=3$ for that day. In case a shift or batch has operated partially, then such shift and batch should not be taken in account while determining no. of shifts/batches in operation.

Step 2: Benchmarking baseline steam consumption

The specific steam consumption for the baseline is determined from historical steam consumption data that correspond to the representative production figures determined in Step 1.

$$SSCR_{PR,d} = \frac{S_{rep,PR}}{P_{rep,PR}} \quad (2)$$

Where:

$S_{rep,BL,d}$	=	Representative steam consumption for a day that correspond to $P_{rep,BL,d}$ (Mass unit)
$S_{1,BL,s/b} S_{2,BL,s/b} \dots S_{n,BL,s/b}$	=	Baseline steam consumption figures per shift/batch that correspond to $P_{1,BL,s/b}, P_{2,BL,s/b} \dots P_{n,BL,s/b}$ (Mass unit)
A	=	Maximum number of shifts/day or batches/day for the operation for the crediting period
n	=	Number of batches/shifts in operation for each day

Batch figures should be used instead of daily figures in the following cases:

- If the batch production time is more than 24 hours;
- If the number of batches in a day is not an integral number (e.g. 2.3 batches per day).

The period for which historical data on production and steam consumption are monitored (to determine the SSCR) should represent seasonal demand variation factors (if any) with regard to (representative) production, energy use and equipment performance. If there is little or no seasonal demand variation, one-month baseline data (daily average of production figures and corresponding steam consumption figures) are considered adequate. **In case a variation in season demand is observed then one-year data shall be used.**

Step 3: Benchmarking of Process Specific Steam Consumption Ratio (SSCR)

The SSCR is determined by the ratio of above two parameters.

$$SSCR_{BL,d} = \frac{S_{rep,BL,d}}{P_{rep,BL,d}} \quad (3)$$

Where:

$SSCR_{BL,d}$	=	Daily specific steam consumption ratio in the baseline (kg/unit mass or volume of production)
$S_{rep,BL,d}$	=	Representative steam consumption for the day in baseline (kg)
$P_{rep,BL,d}$	=	Representative production for the day in the baseline (mass or volume unit)

The daily values for SSCR estimated using data for a month (in cases where seasonal variations exist, year) are averaged to arrive at baseline SSCR.

$$SSCR_{avg,BL} = \frac{\sum_{d=1}^{d=D_w} SSCR_{BL,x}}{D_w} \quad (4)$$

$SSCR_{avg,BL}$	=	Average Specific Steam Consumption Ratio in the baseline
$SSCR_{BL,x}$	=	Daily/batch-wise Specific Steam Consumption Ratio of the x th day in the baseline
D_w	=	Number of days (month or year, as applicable) baseline data used for establishing the specific steam consumption ratio

Procedure to determine the baseline SSCR ($SSCR_{BL}$) for days when the production falls outside the normal range (i.e. above or below 5% of verifiable nameplate capacity)

To apply this methodology, the number of days for which the baseline production falls outside the range, must not exceed 10% of the plant operating days in the year or period chosen for the baseline (for example 36 days if the plant operates for 365 days or 3 days if the baseline of one month is chosen and plant operates every day in the baseline month).

If the number of days are more than 10%, the following procedure should be used for allocating SSCR for the days when the baseline production falls outside the +/-5% production range.

- (1) Where a month's data is used, the lowest SSCR figure calculated for the month should be allocated to each day or batch for the month where production falls outside the normal range;
- (2) Where a year's data is used the minimum SSCR figure for the year should be allocated to every day/batch where production falls outside the normal range.

The average of the daily/batch SSCR figures for the year for the baseline should be calculated after allocating the SSCR for the days when production fell outside the normal range.

Note that the above procedure does not apply to days when the relevant plant is shut, i.e. the SSCR should not be calculated for the days when the relevant plant is shut. To calculate the annual average SSCR, the sum of the daily SSCR figures is divided by the total number of working days.

Project emissions

The project SSCR value is estimated using the following Steps:

- Step 5: Determine representative output;
Step 6: Monitor steam consumption;
Step 7: Determine average steam consumption;

- Step 8:** Determine the Specific Steam Consumption Ratio for the day;
- Step 9:** Estimate additional CO₂ emissions due to additional electricity consumption in project scenario;
- Step 10:** Estimate additional CO₂ emissions due to additional steam/ fuel consumption in project scenario.

Actual output ($P_{act,PR}$) needs to be monitored for each shift or batch either by maintaining a shift/batch operational logbook or by DCS (Distributed Control System).

Step 5: Determine representative output

The representative production rate for the day or batch ($P_{rep, PR}$) is determined by selecting and averaging the representative production figures (i.e. within the normal production range, as described in the baseline section above).

$$P_{rep,PR} = \frac{(P_{1,PR} + P_{2,PR} \dots + P_{m,PR})}{m} \times A \quad (5)$$

Where:

- $P_{rep,PR}$ = Representative production for the day (Mass/volume unit)
- $P_{1,PR}, P_{2,PR}, \dots, P_{m,PR}$ = Shift/batch production figures for project scenario (Mass/volume unit)
- A = Maximum number of shifts/day or batches/day during crediting period
- m = Number of batches/shifts in operation for each day

Note: If the operation runs on a maximum of three 8 hour shifts per day, $A=3$. If for a particular day for some reason, the operation only ran one shift, then $m=1$ for that particular day. If the maximum number of batches produces per day is six ($A=6$), but for a particular day the number of batches produced are three, then $m=3$ for that day. In case a shift or batch has operated partially, then such shift and batch should not be taken in account while determining no. of shifts/batches in operation.

Step 6: Monitor steam consumption

Steam consumption should be monitored for every shift/batch either by maintaining an hourly logbook or with a DCS (Distributed Control System).

Step 7: Determine average steam consumption

Average shift/batch steam consumption rate for the day ($S_{rep,PR}$) is determined by selecting and averaging the steam consumption rate figures that correspond to the representative output rates.

$$S_{rep,PR} = \frac{(S_{1,PR} + S_{2,PR} \dots + S_{m,PR})}{m} \times A \quad (6)$$

Where:

- $S_{1,PR}, S_{2,PR}, \dots, S_{m,PR}$ = Shift/batch steam consumption figures for the project that correspond to $P_{1,PR}, \dots, P_{m,PR}$ (kg)
- $S_{rep,PR}$ = Representative steam consumption for the day (that correspond to $P_{rep,PR}$) (Mass unit)



- A = Maximum number of shifts/day or batches/day during the crediting period
- n = Number of batches/ shifts in operation for each day

Note: If the operation runs on a maximum of three 8 hour shifts per day, A=3. If for a particular day for some reason, the operation only ran one shift, then m=1 for that particular day. If the maximum number of batches produces per day is six (A=6), but for a particular day the number of batches produced are three, then m=3 for that day. In case a shift or batch has operated partially, then such shift and batch should not be taken in account while determining no. of shifts/batches in operation.

Step 8: Determine the Specific Steam Consumption Ratio for the day

The Specific Steam Consumption Ratio is determined by the ratio of the two parameters calculated above.

$$SSCR_{PR} = \frac{S_{rep,PR}}{P_{rep,PR}} \quad (7)$$

Where:

- $SSCR_{PR,d,y}$ = Specific Steam Consumption Ratio for the project activity for day d in year y
- $S_{rep,PR}$ = Representative steam consumption for the day (corresponding to Prep1)
- $P_{rep,PR}$ = Representative production for the day

Procedure to determine SSCRPR for days where the production falls outside normal production range (i.e. the production rate is above or below 5% of verifiable nameplate capacity)

Option-1: If the daily/batch production figure intermittently falls outside the normal range (i.e. less than 10% of the operating days or no. of batches in the year) and design modifications are not required in the plant or process to meet the extra production capacity⁴

- (1) The following procedure should be used for allocating SSCR ($SSCR_{PR}$) under project activity for the days/batches when the production falls outside the range. Maximum SSCR figure for the month should be allocated to each day or batch of the particular month when the production falls outside the normal range;
- (2) When the SSCR falls outside the range for every day/batch of the month, the maximum SSCR figure for the year should be allocated to every day/batch of that particular month. Note that the maximum number of days where the production can fall outside the range under this Option is 36 days (10% of the days in a year). For batch production processes, the maximum number of batches allowed to fall outside the normal range is 10% of the total number of batches.

The allocated SSCR figure is used to calculate the emission reductions for the day. This procedure does not apply to days when the relevant plant is shut, i.e. the SSCR is not calculated for the days when the relevant plant is shut (emission reductions are zero for these days).

⁴ Such production expansions can only happen when there is an additional margin provided for the nameplate capacity. Such production runs can be taken up for small intervals and less frequently.



Option-2: If the daily/batch production figure falls outside the normal production range more than 10% of the time and design modifications are not required in the plant or process to meet the extra production capacity

There exists a possibility that the plant production rate may increase or decrease permanently or for periods more than 10% of days or batches in year due to, for example a change in demand for longer periods. When this new demand is met without changing the production process, technology or design, the project proponents can apply this methodology by following the approach described below:

- (1) For a plant that consistently operates at rates higher than the normal production range rates, the nameplate capacity should be re-verified.⁵ Based on the re-verified nameplate capacity, the normal production range (higher and lower limits of +/-5%) should be defined. The SSCR figure for the credit period can be estimated based on the new nameplate production capacity by applying the procedure described in this methodology;
- (2) If the plant consistently operates at rates lower than the normal production range, the SSCR figure for the credit period should be determined as per Option-1 (this is the conservative approach);
- (3) (a) Where feasible, estimate the SSCR by drawing the characteristic curve for SSCR vs. production in the baseline and extrapolating the curve to derive the SSCR figure for the new production rate in the project scenario. This Step can be implemented by project proponents in one of the following ways:
 - Before implementation of the project i.e. in baseline, if it is envisaged that production will increase above or decrease below the normal range during the crediting period; or
 - During the crediting period after removing the modifications installed under CDM project activity and operating the plant with expanded production quantities.(b) If available, the most relevant and updated manufacturer's specifications for the unit/system can be used to determine the SSCR for the new production rates achieved.
- (4) The baseline SSCR for increased or decreased production is determined from the SSCR vs. production characteristic curve or the most relevant up to date manufacturer's specifications;
- (5) If a plant re-verified its higher production capacity and subsequently operates at lower production range (which is below the normal range of the new (re-verified) capacity), the procedure under Option-1 should be followed to allocate the SSCR figures for the days/batches when production was outside the normal range.

Option-3: If the production capacity is expanded permanently by implementing modifications to the process plant or design⁶ to meet the additional production capacity

For the scenario where the plant production capacity is modified without affecting the CDM project activity, the following Steps must be considered:

⁵ Re-verification should take into account the maximum production capacity achieved in the year by the plant.

⁶ The changes in plant processes should not include CDM project activity itself. If any changes in CDM project are made, the CDM project will be considered invalid and further emission reductions from CDM project cannot be claimed.

- (1) Re-verification⁷ of nameplate capacity should be done and the new normal production range of +/-5% should be defined. The SSCR figure for the credit period can be estimated based on the new nameplate production capacity by applying the procedure described in the methodology;
- (2) If possible and where it is practical to disconnect the modifications installed under the CDM project activity, the plant should be operated within the normal range of the new production capacity at least for one month⁸ to collect the data of steam consumption and baseline SSCR;
- (3) The average SSCR figure for the baseline should be determined from the new production run as explained described in Step 2.

Project emissions from additional electricity consumption as a result of project activity

Step 9: Estimate additional CO₂ emissions due to additional electricity consumption in project scenario

If the steam optimisation project requires additional electricity, the additional electricity consumption should be monitored and the “Tool to calculate project emissions from electricity consumption” should be used to estimate the project emissions associated with additional electricity consumption.

The following is an illustration of a potential case where additional electricity consumption may take place. This case is referred to Step-13-case-2 (point no. 2).⁹

$$\text{If } \frac{EG_{Tur,PR}}{P_{act,BL}} < \frac{EG_{Tur,BL}}{P_{act,PR}}$$

Estimate the additional project electricity emissions using above referred tool for the reduced electricity which is estimated as follows:

$$E_{PR} = \left(\frac{EG_{Tur,BL}}{P_{act,BL}} - \frac{EG_{Tur,PR}}{P_{act,PR}} \right) \times P_{act,PR} \quad (8)$$

To calculate project emissions for the electricity with the “Tool to calculate project emissions from electricity consumption”, the emission factor used for determining these emissions should be the highest amongst the active electricity sources of the plant.

E_{PR}	=	Reduced annual electricity from the extraction or backpressure turbine due to project activity
$EG_{Tur,PR,y}$	=	Electricity generation by the turbine in year y (kWh)
$EG_{Tur,BL}$	=	Electricity generation by turbine in the baseline year, immediately preceding the implementation of project activity (kWh)

⁷ This re-verification should take into account new design and specifications for the plant after capacity expansion.

⁸ In case the specific steam consumption is affected by seasonal variation, the baseline SSCR should be established based on production run of one month in various seasons. The choice of seasons for such production run should be justified in the PDD.

⁹ This is an illustration where the efficiency of cogeneration turbine decreases in project as compared to baseline.



$P_{act,BL}$ = The relevant annual production from the process (unit or system) where steam is optimised in the baseline year immediately preceding implementation of the project activity (same production stream which is used for estimation of baseline SSCR, in mass or volume unit)

$P_{act,PR,y}$ = The relevant annual production from the process (unit or system) where steam is optimised in year y

Project emissions from additional steam/fuel consumption as a result of project activity.

Step 10: Estimate additional CO₂ emissions due to additional steam/ fuel consumption in project scenario

If the steam optimisation project requires additional steam or fuel consumption, the steam and/or fuel should be monitored separately in the project activity. When the steam consumption is monitored, apply equations 11 (Use annual monitored steam quantity¹⁰ which is consumed additionally as a result of project activity, instead of S_{net} in equation 11) and 13 to determine fuel consumption (for example in the boiler) associated with steam consumption. Project emissions should be determined by applying the “Tool to calculate project emissions due to fossil fuel consumption”.

Leakage Emissions

There are no leakage emissions identified for the steam optimisation projects. In case, any leakage emissions are associated, the project activity is not eligible under this methodology.

Emission reductions

Emission reduction value is estimated using the following Steps:

Step 11: Estimate the difference in SSCR for the baseline and project scenarios;

Step 12: Estimate net daily reduction in steam consumption;

Step 13: Estimate the net daily reduction in energy due to reduction in steam consumption;

Step 14: Estimate daily reduction in input energy to the boiler;

Step 15: Estimate CO₂ emission reductions in the boiler per day;

Step 16: Estimate the net CO₂ emission reductions due to project.

Step 11: Estimate the difference in SSCR for the baseline and project scenarios

$$SSCR_{diff} = SSCR_{avg,BL} - SSCR_{PR} \quad (9)$$

Where:

$SSCR_{diff}$ = Daily difference in SSCR for the baseline and project scenarios (Mass unit/day)

¹⁰ The steam consumed in project scenario should be monitored separately particularly when it is at different temperature and pressure than saved steam or at a different place than the steam saved under CDM project activity. If additional steam consumed is of same temperature and pressure and consumed at same process where CDM project activity is implemented, the steam monitoring in project case for the purpose of estimating SSCR can account for this steam also, rather than estimating separate project emissions under separate head.



- SSCR_{avg,BL} = Annual average Specific Steam Consumption Ratio in the baseline (Mass unit/unit mass or volume of production)
- SSCR_{PR} = Daily Specific Steam Consumption Ratio for the project activity (Mass unit/unit mass or volume of production)

Step 12: Estimate net daily reduction in steam consumption

$$S_{net} = SSCR_{diff} \times P_{act,PR} \quad (10)$$

Where:

- S_{net} = Net reduction in steam consumption per day (Mass unit/day)
- SSCR_{diff} = Difference in SSCR for baseline and project scenarios
- P_{act,PR} = Actual production figure on the day/for each batch (Mass/volume unit) (please also refer to equation 15)

If the actual production for the plant is above¹¹ the normal range of production, use the following equation:

$$\text{If } P_{act,PR} > P_{nameplate}$$

$$\text{then } P_{act,PR} = P_{nameplate} \quad (11)$$

Where:

- P_{act} = Actual production output figure on the day/for the batch
- P_{nameplate} = Baseline¹² nameplate daily (per shift/batch) production capacity of the plant

¹¹ This Option is only applicable for the production above the normal range and not for the production below the normal range. For production below the normal range, actual production value will be used in place of P_{act}.

¹² The nameplate capacity used here is original (or expanded verified nameplate capacity as per Option-2 of step-8).

**Step 13: Estimate the net daily reduction in energy due to reduction in steam consumption**

Steam consumption of the process where the CDM project activity is implemented is monitored at the usage point, but the actual reduction of steam generation occurs in the boiler, depending upon whether the plant has a cogeneration system or not. In the case of cogeneration where the steam saved is the extraction steam from a turbine, a different approach is required to estimate the fuel reduction for the boiler. Case-1 to Case-3 describes the various scenarios for which different approaches can be used:

Case-1: Steam directly supplied from boiler

In cases where the steam used in the process is supplied directly or through a pressure reducing valve from the boiler, the following equation can be used to determine the daily reduction in energy due to a reduction in steam consumption:

$$E_{net} = S_{net} \times E_s \quad (12)$$

Where:

E_{net}	=	Net reduction in steam energy consumption per day (kCal or kJ)
S_{net}	=	Net reduction in steam consumption per day (Mass unit)
E_s	=	Net enthalpy of steam generated in the boiler (kCal/mass unit or kJ/mass unit)

and

$$E_s = E_{tot} - E_{fw} - E_{bw} \quad (13)$$

Where:

E_s	=	Net enthalpy of steam being supplied by boiler (kCal/mass unit or kJ/mass unit)
E_{tot}	=	Total enthalpy of steam at the boiler outlet (kCal/ mass unit or kJ/ mass unit)
E_{fw}	=	Heat content of feed water (kCal/mass unit or kJ/mass unit)
E_{bw}	=	Heat content of blow down water (flow and temperature of water and either continuous or intermittent blow down to be monitored on regular basis) (kCal/kg steam generation or kJ/kg steam generation)

Case-2: Steam supplied is the extraction or backpressure steam of a mechanical steam turbine driving process equipment or a steam turbine producing electricity

In such cases, it has to be ensured that the steam saving project is accompanied by either of following actions to ensure that the amount of steam saved by the project activity is actually reduced from the boiler generation.¹³

¹³ This means that the PDD should describe all the projects, which are implemented to ensure the saving of steam and hence saving of equivalent amount of fuel from boiler.

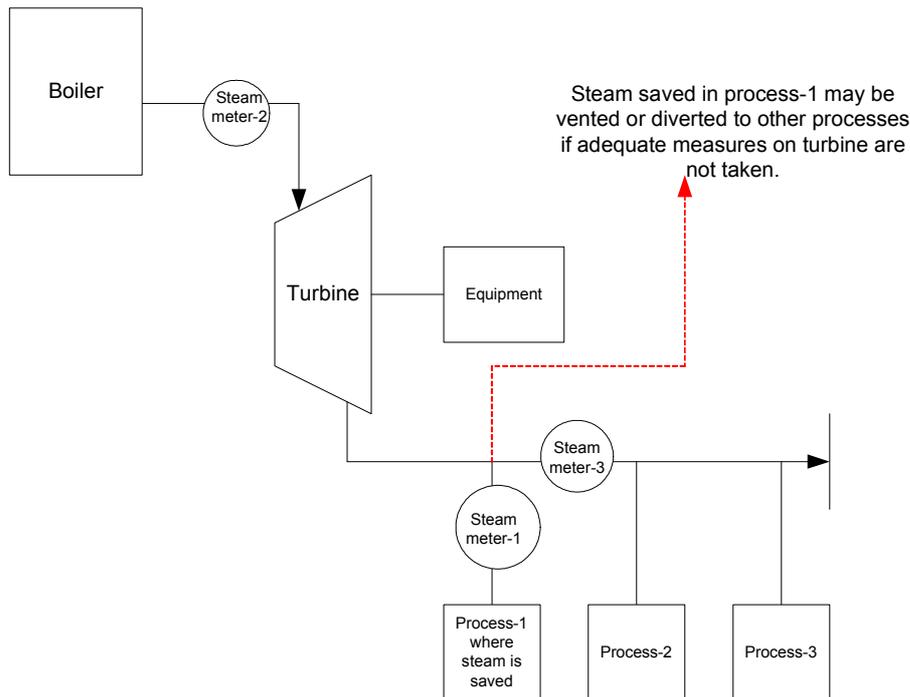


Figure 2: Illustration showing the configuration of a process supplied by back-pressure or extraction steam of a turbine

- (1) In case of a mechanical turbine, the equipment, which was driven by steam turbine, is converted to an electrical drive. The electricity consumption of the drive should be monitored to determine project emissions;
- (2) The steam turbine in the baseline is replaced by a more efficient turbine,¹⁴ requiring less steam to drive the same equipment or produce the same electrical energy as in baseline. The project proponent should demonstrate that the reduction in energy entering the turbine (monitored by steam meter-1 at the turbine inlet) is equivalent or more than the energy (steam) saved by CDM project (monitored by steam meter-1 in fig 2).¹⁵ If the energy saving from turbine is less than that by CDM project activity, this methodology is not applicable, as it can be reasonably expected based on energy balance that there is some of amount of steam vented or diverted to other processes. In the case where the electrical turbine produces less specific electricity¹⁶ in project scenario than in the baseline, the difference between the annual baseline electricity and project electricity generation should be claimed as the project emissions. Please refer Step-9 for estimation of project emissions for these cases;

¹⁴ This could be a condensing turbine, or a highly efficient backpressure or extraction turbine to do the required work or produce electricity.

¹⁵ This should take into account the fact that steam flow at inlet of turbine also accounts for steam going into other processes than the process where CDM project is implemented. The measurements of meter-1, meter-2 and meter-3 should be taken into account while calculating the difference between savings of CDM project and savings of turbine.

¹⁶ Specific electricity is the electricity generation of turbine divided by the total production (the same production which was used to calculate SSCR).

- (3) In case the turbine replacement is part of the CDM steam optimization project, steam consumption at the inlet of the turbine should be monitored (the steam meter-2 shown at the inlet of turbine can be used for this purpose).¹⁷ Note that in these cases, the steam consumption for the purpose of SSCR determination in the baseline and project scenario should be estimated by calculating the difference between turbine inlet steam and steam consumption by other processes to isolate the impact of other processes in the overall steam consumption. Steam meter 2 and 3 as shown in fig. 2 should be used for this purpose.

Please note that for the following situations this methodology is not applicable:

- The steam equivalent to the amount of saved steam is vented to atmosphere;
- The steam saved is directed to another application where, in the baseline, this application had an energy requirement met by a fossil fuel source only.

Step 14: Estimate daily reduction in input energy to the boiler

$$E_{in} = E_{net} / \eta_b \quad (14)$$

Where:

- E_{in} = Energy input in boiler (kCal/day or kJ/day)
 E_{net} = Net reduction in steam energy consumption per day (kCal/day or kJ/day)
 η_b = Boiler efficiency that is monitored periodically by direct or indirect method

Step 15: Estimate CO₂ emission reductions (C_{er}) in the boiler per day

$$C_{er} = E_{in} \times \sum (CEF_{fuel} \times \%H_{fuel}) \quad (15)$$

Where:

- C_{er} = CO₂ emission reductions in the boiler per day (Tons CO₂/day)
 E_{in} = Energy input into boiler (kCal/day or kJ/day)
 CEF_{fuel} = Carbon emission factor for fuel based on actual laboratory tests[c2] (Tons CO₂/kJ or Tons CO₂/kCal)
 $\%H_{fuel}$ = % of energy supplied by each type of fuel consumed per day

Step 16: Estimate the net CO₂ emission reductions due to project

$$C_{ernet} = \sum_D (C_{er} - E_{PR}) \quad (16)$$

¹⁷ In this case it should be noted that turbine output should also be relatively constant output for this methodology to be applicable to the project. But for the purpose of SSCR and S_{net} calculations, output of process (such as process-1 in fig 2) should be used. If the CDM project activity is the turbine efficiency improvement only, then the output of turbine (daily electricity generation of electrical turbine or BHP of mechanical turbine monitored on daily basis by dynamometer) can be used.



Where:

- C_{ernet} = Net CO₂ emission reductions due to the project (Tons CO₂ per day)
 C_{er} = CO₂ emission reductions in the boiler (Tons CO₂ per day)
 E_{PR} = Project emissions due to additional electricity or fuel/steam consumption as a result of project activity (Tons CO₂ per day)
 D = Day in the project year, for which project data is collected and emission reduction is estimated

Note-1: E_{PR} can be calculated using the “Tool to calculate project emissions from electricity consumption” and/or the “Tool to calculate project emissions due to fossil fuel consumption” as mentioned in Step-10 above.

Note-2: In case there is a retrofit in the plant, implemented during crediting period, having an effect on the steam consumption of CDM project activity, the project proponents should submit a deviation on how such retrofit is monitored to estimate its effect on emission reduction.

Effect of future retrofitting on baseline and project emissions:

The following test should be applied while monitoring the effect of future retrofitting within the project boundary (change in output level, process change, equipment change *etc.* affecting specific steam consumption) on baseline and project emissions:

The following question should be asked if retrofit measures reduce the steam consumption within the project boundary:

Question: Does retrofitting reduce the steam consumption of the CDM project activity? (I.e. there is a reduction in estimated project emissions, though not caused by the CDM project activity itself.)

Action: The enhanced steam saving due to the impact of retrofit on CDM project activity needs to be estimated and deducted from claimed emission reductions.

Changes required for methodology implementation in 2nd and 3rd crediting periods

At the start of the second and third crediting period for a project activity, the continued validity of the baseline scenario shall be assessed by applying the procedure to identify the baseline scenario.

**Data and parameters not monitored**

In addition to the parameters listed in the tables below, the following provisions on data and parameters not monitored in the tools referred to in this methodology apply:

Data / parameter:	$P_{1,BL}, P_{2,BL}, \dots, P_{n,BL}$
Data unit:	Mass/volume unit
Description:	Production figures for each shift or each batch (whichever is applicable) in the baseline
Source of data:	Plant operation data
Measurement procedures (if any):	Standard plant procedure
Any comment:	Follow the procedure provided in Step-1 for selecting the production/output values (based on +/-5% of nameplate capacity). Also follow Option-3 procedure of Step-8, where baseline SSCR may have to be re-estimated based on new production and steam consumption values for increased production scenarios.

Data / parameter:	A
Data unit:	
Description:	The maximum number of shifts or batches per day in the plant – this depends on the system that the operation work on for example, 3 shifts per day
Source of data:	Plant data
Measurement procedures (if any):	
Any comment:	Follow instructions in Step-2, when batches have to be used in estimation of SSCR

Data / parameter:	n or m
Data unit:	
Description:	The actual number of shifts or batches during which production occurred for each day – for example, if the plant was shut for 2 of the 3 shifts, n is equal to 1 for that particular day
Source of data:	Plant data
Measurement procedures (if any):	
Any comment:	Follow instructions in Step-2, when batches have to be used in estimation of SSCR



Data / parameter:	$S_{1,BL}, S_{2,BL}, \dots, S_{n,BL}$
Data unit:	Mass unit
Description:	Steam consumption figures per shift or per batch for the baseline, corresponding to $P_{1,BL}, P_{2,BL}, \dots, P_{n,BL}$
Source of data:	Plant data
Measurement procedures (if any):	Steam meter (calibrated for temperature and pressure of steam to be monitored)
Any comment:	For cogeneration system follow instruction in Step-13 case-2 (point-3)

Data / parameter:	D_w
Data unit:	
Description:	Number of working days of plant in the baseline
Source of data:	Plant data
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$P_{nameplate}$
Data unit:	Mass or Volume unit per shift or per batch
Description:	Nameplate production capacity of process unit where steam is reduced/optimised
Source of data:	Plant data
Measurement procedures (if any):	Manufacturer's data for the original plant or re-verified data for cases where production capacity is changed during crediting period
Any comment:	Follow instructions in Step-8 for re-verified nameplate capacity

Data / Parameter:	$EG_{Tur,BL}$
Data unit:	kWh
Description:	Electricity generation by turbine in the baseline year, immediately preceding the implementation of project activity (kWh)
Source of data:	Plant data
Measurement procedures (if any):	Electricity recording meter
Any comment:	Use calibrated meter



III. MONITORING METHODOLOGY

Source

This methodology is based on the ‘Energy efficiency project by modification of CO₂ removal system of Ammonia Plant to reduce steam consumption’, India, whose baseline study, monitoring and verification plan and project design document were prepared by Indo-Gulf Fertilisers Ltd. For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0037 rev: “Energy efficiency project by modification of CO₂ removal system of Ammonia Plant to reduce steam consumption” on <http://cdm.unfccc.int/methodologies/PAmethodologies/approved.html>.

Applicability

This methodology is applicable to steam optimization projects in production processes with homogeneous and relatively constant outputs with continuous monitoring of steam output.

This monitoring methodology shall be used in conjunction with the approved baseline methodology AM0018 (“Baseline methodology for steam optimization systems”).

Monitoring Methodology

The monitoring methodology requires monitoring of the following:

- The output rate is to be monitored shift-wise (for continuous processes) or batch-wise (for batch processes);
- The steam consumption rate for the process, where the optimisation has taken place, needs to be monitored shift wise (for continuous processes) or batch wise (for batch processes);
- Boiler efficiency (see below for different monitoring methodologies);
- Steam enthalpy (see below for details);
- Additional electricity consumption due to the project activity needs to be monitored shift wise (for continuous processes) and batch wise (for batch processes).¹⁸;
- The fuel composition analysis and calorific value.

The following methods can be used to estimate boiler efficiency. Depending upon the method, the monitoring parameters are different.

Direct Boiler Efficiency Method (Input-Output Method):

The following parameters need to be monitored:

- Input fuel to the boiler (by fuel meter, level gauge or by weighing balance in case of solid fuels or any other method);
- Output steam of boiler (by steam meter). This steam is different than the steam consumed in the CDM project activity.

¹⁸ In case of non-availability of monitoring facility of electrical equipment, the nameplate rating can be used as a basis for calculation of power consumption.



The boiler efficiency is to be estimated as follows:

$$\eta_{\text{boiler}} = E_s : E_i \quad (17)$$

where

$$\begin{aligned} \eta_{\text{boiler}} &= \text{Efficiency of the boiler} \\ E_s &= \text{Enthalpy of steam (kCal/hr)} \\ E_i &= \text{Input energy of fuel (kCal/hr)} \end{aligned}$$

$$E_s = E_{\text{net}} \times S \quad (18)$$

where

$$\begin{aligned} E_s &= \text{Enthalpy of steam (kCal/hr)} \\ E_{\text{net}} &= \text{Net enthalpy of steam monitored as given ahead (kCal/kg)} \\ S &= \text{Steam flow monitored by flow meter (kg/hr)} \end{aligned}$$

$$E_i = \text{NCV}_{\text{fuel}} \times F \quad (19)$$

where

$$\begin{aligned} E_i &= \text{Input energy of fuel (kCal/hr)} \\ \text{NCV}_{\text{fuel}} &= \text{Net Calorific Value of Fuel monitored as given ahead (kCal/kg)} \\ F &= \text{Fuel consumption rate monitored as given ahead (kg/hr)} \end{aligned}$$

Indirect Boiler Efficiency Method (Input loss Method):

Estimating boiler efficiency using the indirect method should be done as per British Standard BS-845. The following parameters need to be monitored. For calculations of efficiency based on following monitored (and assumed radiation losses) parameters, please refer BS-845:

- Excess air or % Oxygen in dry flue gas, % Carbon Monoxide in dry flue gas, Flue Gas temperature need to be monitored (on regular intervals or continuously through DCS);
- In case of solid fuels, heat loss due to unburnt fuel in bottom ash and fly ash loss needs to be monitored. The bottom ash weight measurements in grate and fly ash weight measurement collected in cyclone needs to be done. The calorific value of bottom ash and fly ash needs to be tested separately in an in-house or external laboratory;
- Monitoring of combustion air temperature will be done, particularly in case combustion air preheater is provided to boiler;
- Monitoring of moisture in air needs to be conducted.

Note: In case of mix fuel (generally mix solid fuel), the only method possible for efficiency estimation is 'Direct Efficiency' method, because fuel flow needs to be monitored in such case. Indirect efficiency method cannot be applied, because flue gas analysis will be very difficult in case of mix fuel.

Steam enthalpy

The following parameters will be monitored to evaluate the net steam enthalpy:

- Monitoring of enthalpy of steam needs to be done by recording generation pressure and temperature. Refer to steam tables for the enthalpy of steam at given pressures and temperatures;



- Monitoring of boiler Feed Water (FW) temperature needs to be conducted (before de-aerator and economizer). The mass flow of feed water (kg/hr) can either be directly measured using flow meters or an estimated or metered quantity of blow-down can be added in the steam flow to arrive at the feed-water flow. The enthalpy of FW can be estimated by multiplying the mass flow by the specific heat (1) and temperature (Deg C) of FW;
- The net enthalpy can be estimated by subtracting the enthalpy of FW from the enthalpy of steam.

The monitoring methodology requires monitoring of the following key parameters:

- The production rate should be monitored on a shift basis (for continuous processes) or per batch (for batch processes);
- The steam consumption rate for the part of the process where the optimisation has taken place, should be monitored on a shift basis (for continuous processes) or per batch (for batch processes);
- Boiler efficiency;
- Steam enthalpy;
- Additional electricity/steam/fuel consumption due to the project activity should be monitored on a shift basis (for continuous processes) or per batch (for batch processes);
- Specific monitoring related to the cogeneration scenario;
- The fuel composition analysis and calorific values.

Data and parameters monitored

Data / parameter:	$P_{1,PR}, P_{2,PR}, \dots, P_{m,PR}$
Data unit:	Mass/volume unit
Description:	Production per shift or per batch for the project scenario
Source of data:	Plant data
Measurement procedures (if any):	Standard plant procedure
Monitoring frequency:	Every shift/batch
QA/QC procedures:	Use a calibrated measuring device, complying to QA/QC procedures of plant
Any comment:	Follow the procedure provided in Step-5 for selecting the production/ output values (based on +/-5% of nameplate capacity). Also follow procedures in Step-8, which may have influence on selection of output values if nameplate capacity is changed as a result of expansion of output in crediting period.



Data / parameter:	$S_{1,PR}, S_{2,PR}, \dots, S_{m,PR}$
Data unit:	kg
Description:	Steam consumption figures per shift or per batch for project, corresponding to $P_{1,PR}, \dots, P_{m,PR}$
Source of data:	Plant data
Measurement procedures (if any):	Steam meter
Monitoring frequency:	Per shift or per batch
QA/QC procedures:	Steam meter should be calibrated for temperature and pressure of steam to be monitored as per internal QA/QC procedures of plant
Any comment:	<ul style="list-style-type: none"> For cogeneration system follow instruction in Step-13 case-2 (point-3); Also follow procedures in Step-8 which may influence the selection of production figures if nameplate capacity is changed as a result of expansion of output in crediting period.

Data / Parameter:	$EG_{Tur,PR,y}$
Data unit:	kWh
Description:	Electricity generation by the turbine in year y (kWh)
Source of data:	Plant data
Measurement procedures (if any):	Electricity recording meter
Monitoring frequency:	Daily figures aggregated annually
QA/QC procedures:	Use calibrated meter
Any comment:	

Data / parameter:	$P_{act,PR}$
Data unit:	Mass or volume per day
Description:	Actual production output figure on the day/for each batch
Source of data:	Plant
Measurement procedures (if any):	Standard plant procedure
Monitoring frequency:	Daily
QA/QC procedures:	
Any comment:	

Data / parameter:	E_{tot}
Data unit:	kCal/kg or kJ/kg
Description:	Total enthalpy of steam at the boiler outlet
Source of data:	Plant data
Measurement procedures (if any):	Steam meter for flow measurement. Pressure gauge and Temperature indicator for pressure and temperature measurements respectively. Steam table for enthalpy determination at given pressure and temperature.
Monitoring frequency:	Daily
QA/QC procedures:	Regular calibration procedures to be adopted for all monitoring instruments



Any comment:	
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Data / parameter:	E_{fw}
Data unit:	kCal/kg or kJ/kg
Description:	Heat content of feed water
Source of data:	Plant data
Measurement procedures (if any):	Water flow meter for flow measurement and temperature indicator for temperature measurements respectively. Enthalpy to be estimated by multiplying mass flow, temperature (deg C) and specific heat of water (1 kCal/kg/deg C)
Monitoring frequency:	Daily
QA/QC procedures:	Regular calibration procedures to be adopted for all measuring instruments
Any comment:	

Data / parameter:	E_{bw}
Data unit:	kCal/kg steam generation or kJ/kg steam generation
Description:	Heat content of blow down water (flow and temperature of water and either continuous or intermittent blow down to be monitored on regular basis)
Source of data:	Plant data
Measurement procedures (if any):	Water flow meter for measuring continuous blow down (or estimate flow by level difference of boiler drum for intermittent blow down) and Temperature indicator for temperature measurements respectively. Enthalpy to be estimated by multiplying mass flow, temperature (deg C) and specific heat of water (1 kCal/kg/deg C)
Monitoring frequency:	Daily
QA/QC procedures:	Regular calibration procedures to be adopted for all measuring instruments
Any comment:	



Data / parameter:	η_b
Data unit:	
Description:	Efficiency of boiler, to be monitored periodically by direct or indirect method
Source of data:	International standards such as BS-845
Measurement procedures (if any):	The efficiency of the boiler should be determined in the baseline and project case. For baseline boiler efficiency, please refer comments section). In project case, it should be monitored continuously. At any given average load the baseline efficiency (as estimated from baseline efficiency-load function) and the project efficiency of boiler should be compared and the higher value of efficiency should be selected for η_b .
Monitoring frequency:	Daily
QA/QC procedures:	
Any comment:	<p><u>Note-1:</u></p> <p>Follow international standards (e.g. British standard BS 845) for estimation of efficiency of individual equipment. Following are two methods briefly explained.</p> <p><u>Direct Boiler Efficiency Method (Input-Output Method) to determine boiler efficiency:</u></p> <p>The efficiency by direct method can be determined by dividing the monitored actual heat generation of the boiler by the heat input to the boiler.</p> <p><u>Indirect Boiler Efficiency Method (Loss Method):</u></p> <p>Under this method the % of losses can be measured to calculate (1-losses) to estimate efficiency.</p> <p><u>Note-2:</u></p> <p>Baseline Efficiency of the boiler shall be one of the following:</p> <ul style="list-style-type: none"> i) Assume a constant efficiency of the boiler and determine the efficiency, as a conservative approach, for optimal operation conditions (i.e. design fuel, optimal load, optimal oxygen content in flue gases, adequate fuel conditioning (temperature, viscosity, moisture, size/mesh etc), representative or favorable ambient conditions (ambient temperature and humidity)); or ii) Highest of the efficiency values provided by two or more manufacturers for similar boilers, as used in the project activity; or iii) Maximum efficiency of 100%; iv) Estimated from load v/s efficiency curve established through measurement and described in Annex I. In case of multiple boilers the efficiency for individual boilers should be estimated and combined to arrive at aggregate efficiency. One efficiency value for entire system is not acceptable as it is influenced by the characteristics of individual equipment if they operate at different loads.



Data / parameter:	CEF _{fuel}
Data unit:	Ton CO ₂ /kJ or Ton CO ₂ /kCal
Description:	Carbon emission factor for fuel
Source of data:	Laboratory or latest IPCC guidelines
Measurement procedures (if any):	This should be taken based on actual tests conducted in reputed laboratory. Use latest IPCC emission factor, if reliable test reports are not available.
Monitoring frequency:	For each fuel supply and for all fuels in fuel mix
QA/QC procedures:	Use standard test procedures for test of fuels
Any comment:	

Data / parameter:	%H _{fuel}
Data unit:	
Description:	% of energy supplied by each type of fuel consumed per day
Source of data:	Plant data
Measurement procedures (if any):	Fuel meter or weighing device
Monitoring frequency:	Daily
QA/QC procedures:	Use calibrated meters
Any comment:	

Data / parameter:	D _{w, y}
Data unit:	
Description:	Number of working days of plant in year y
Source of data:	Plant data
Measurement procedures (if any):	
Monitoring frequency:	As and when occurs
QA/QC procedures:	
Any comment:	

IV. REFERENCES AND ANY OTHER INFORMATION

International standards to determine Boiler efficiency (e.g. BS 845).

Annex I: Process for Energy Efficiency determination of baseline boiler

The efficiency of boiler depends significantly on the load and operational conditions.

Establish an efficiency-load-function of the boiler, through on-site measurements. The fuel consumption is then determined separately for discrete time intervals t , based on the actual monitored steam generation during each time interval t and the baseline efficiency corresponding to that steam generation determined with the efficiency-load-function:

$$\eta_{BL,t} = f(HG_{j,t}) + 1.96 \cdot SE(f(HG_{j,t})) \quad (1a-111)$$

and

$$N_t = \frac{8760}{T} \quad (1a-112)$$

Where:

$FC_{BL,y}$	=	Quantity of fuel that would be fired in the boiler in the absence of the project activity in year y (mass or volume unit)
$HG_{j,t}$	=	Steam generated by the boiler during the time interval t where t is a discrete time interval during the year y (GJ)
$\eta_{BL,t}$	=	Baseline energy efficiency of the boiler during time interval t where t is a discrete time interval during the year y
$f(HG_{j,t})$	=	Efficiency load function of the boiler, determined through the regression analysis
$SE(f(HG_{j,t}))$	=	Standard error of the result of the efficiency-load-function $f(HG_{j,t})$ for time interval t where t is a discrete time interval during the year y
t	=	Discrete time interval of duration T during the year y
N_t	=	Number of time intervals t during year y
T	=	Duration of the discrete time intervals t (h)

Each time interval t should have the same duration T . In choosing the duration T , the typical load variation of the boiler should be taken into account. The maximum value for T is 1 hour, resulting in 8760 discrete time intervals t per year y ($N_t = 8760$). If the load of the boiler may vary considerably within an hour, a shorter time interval T should be chosen by project participants (e.g. 15 minutes).

The efficiency-load-function should be derived by applying a regression analysis to at least 10 measurements x within the load range where the boiler can be operated. It is recommended that project participants apply standard software to apply the regression analysis. More details on the procedure to measure the efficiency at different loads are provided in the monitoring methodology. Each measurement x delivers a data pair of heat generation (HG_x) and efficiency of the boiler (η_x). Project participants should choose an appropriate regression equation to apply to the measurement results. For example, in case of a polynomial function, the following regression equation would be applied:

$$\eta_x = f(HG_x) = a + b_1HG_x + b_2(HG_x)^2 + \dots + b_n(HG_x)^n \quad (1a-113)$$

Where:

- (η_x, HG_x) = The pair of data recorded from measurement x at a defined load level
- η_x = Efficiency of the boiler at measurement x
- HG_x = Quantity of steam generated by the boiler during the time length T at the measurement x (GJ)¹⁹
- x = Measurements undertaken at defined load levels
- a, b_1, b_2, \dots, b_n = Parameters of the regression equation estimated using the regression analysis

In order to ensure that the results of the regression analysis are conservative, the baseline efficiency is adjusted for the upper bound of uncertainty of the result of efficiency-load-function at a 95% confidence level by introducing the standard error $SE(f(HG_{j,t}))$ in equation (1a-112) above. The standard error $SE(f(HG_{j,t}))$ has to be determined for each time interval t . It is recommended that project participants use the standard software to determine the standard error $SE(f(HG_{j,t}))$.

In case of a linear regression equation, i.e. if $n=1$ in equation (1a-114) above, the standard error can be determined as follows:

$$SE(f(HG_{j,t})) = \sigma * \sqrt{\left(1 + \frac{1}{N_x} + \frac{(HG_{j,t} - HG)^2}{\sum_{x=1}^{N_x} (HG_x - HG)^2}\right)} \quad (1a-114)$$

with

$$\sigma = \frac{1}{N_x - 2} * \sqrt{(1 - R^2) * \left[\sum_{x=1}^{N_x} (\eta_x - \eta)^2\right]} \quad \text{and} \quad (1a-115)$$

$$\eta = \frac{\sum_{x=1}^{N_x} \eta_x}{N_x} \quad \text{and} \quad (1a-116)$$

$$HG = \frac{\sum_{x=1}^{N_x} HG_x}{N_x} \quad \text{and} \quad (1a-117)$$

$$R = \frac{b_1^2 * \sum_{x=1}^{N_x} (HG_x - HG)}{\sum_{x=1}^{N_x} (\eta_x - \eta)} \quad (1a-118)$$

¹⁹ The value of HG_x should correspond to the quantity of steam that would be generated in the time length T at the defined load level. If the measurement has a different duration than T , the measured quantity of steam generation should be extrapolated to the quantity that would be generated during the time length T .



Where:

$SE(f(HG_{j,t}))$	=	Standard error of the result of the efficiency-load-function $f(HG_{j,t})$ for time interval t
$f(HG_{j,t})$	=	Efficiency load function of the boiler, determined through the regression analysis
σ	=	Standard error of the regression equation
$HG_{j,t}$	=	Steam generated by the boiler during the time interval t (GJ)
HG_x	=	Quantity of steam generated by the boiler during the time length T at the measurement x (GJ)
HG	=	Mean steam generation by the boiler during the time length T of all measurements x (GJ)
η_x	=	Efficiency of the boiler at measurement x
η	=	Mean efficiency of the boiler of all measurements x
R	=	Adjusted R square
x	=	Measurements undertaken at defined load levels
N_x	=	Number of measurements x undertaken to establish the efficiency-load-function (at least 10)
t	=	Discrete time interval of duration T during the year y
T	=	Duration of the discrete time intervals t (h)



History of the document

Version	Date	Nature of revision(s)
02	EB 39, Annex 2 16 May 2008	<ul style="list-style-type: none">• Procedures provided for estimation of SSCR in case production level falls outside normal range.• Procedures provided for estimation of emission reduction where steam saved is output of steam turbine.• New applicability conditions inserted.• Methodology is written in new format.• Monitoring tables are changed to new formats with changes in description of parameters.• New equations provided for project emissions.• Editorial and language changes.
01.1	25 January 2007	<ul style="list-style-type: none">• Equation 5, the denominator on lhs was changed from 'z' to 'm';• On page 7, below equation 15, the reference "The Carbon emission factor of the selected grid is determined by the combined margin method, mentioned in point no.29 of the UNFCCC document "Indicative simplified baseline and monitoring methodologies for selected small scale CDM project activity categories" was changed to AMS1.D.• On page 10, equation 7, the units of variables Es were corrected from kcal/kg to kcal/hr.
01	EB 17, Annex 2 6 December 2004	Initial adoption