Draft baseline and monitoring methodology AM00XX

"Energy efficiency improvement of a boiler by introducing oil/water emulsion technology"

I. SOURCE AND APPLICABILITY

Source

This methodology is based on the project activity "Use of Hydro Heavy Fuel Oil Technology (HHFOT) to improve energy efficiency at a power plant in Pakistan", whose baseline and monitoring methodology and project design document were prepared by Mitsubishi UFJ Securities, Japan.

For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0171: "Energy Efficiency improvement through oil/water emulsion technology incorporated into an oil-fired thermal and/or electricity power production facility" on http://cdm.unfccc.int/goto/MPappmeth

This methodology also refers to the latest approved version of the "Tool for the demonstration and assessment of additionality" and the latest approved version of ACM0002.[1]

Selected approach from paragraph 48 of the CDM modalities and procedures

"Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment"

Definitions

For the purpose of this methodology, the following definitions apply:

- **Residual fuel oil** defines oils that make up the distillation residue. It comprises all residual fuel oils, including those obtained by blending. Its kinematic viscosity is above 0.1 cm^2 (10 cSt) at 80°C. The flash point is always above 50°C and the density is always more than 0.90 kg/l (2006 IPCC Guidelines, Volume 2, Chapter 1, page 1.12).

Applicability

The methodology is applicable to project activities that introduce oil/water emulsion technology in an existing residual fuel oil fired boiler for the purpose of improving energy efficiency. The introduction of the oil/water emulsion technology includes the installation and operation of equipment to mix the residual fuel oil with water and additives prior to combustion in order to improve the efficiency of the combustion process.

The following conditions apply to the methodology:

- The boiler has an operating history of at least five years;
- Prior to the implementation of the project activity, no oil/water emulsion technology was used at the project site;
- The oil/water emulsion is prepared and consumed on the premises where the boiler exists;

[1] Please refer to: http://cdm.unfccc.int/goto/MPappmeth

- The project activity does not result in additional heat demand for pre-heating the oil/water emulsion prior to combustion; this means that either
  - (a) the oil/water emulsion is not heated prior to combustion or
  - (b) the oil/water emulsion is heated prior to combustion but in the absence of the project activity the residual fuel oil would also be pre-heated and would have the same or a higher temperature than the oil/water emulsion;
- With the implementation of the project activity, no significant operational, process or equipment modifications other than the introduction of the oil/water emulsion technology are undertaken (e.g. no other measures to improve energy efficiency);
- The implementation of the project activity does not result in an increase of heat generation in the boiler.[2]
- The remaining lifetime of the boiler is larger than the crediting period;
- No capacity expansions occur at the project facility during the crediting period.

In order to estimate the remaining lifetime or the point in time when the existing boiler would need to be replaced in the absence of the project activity, project participants shall take the following approaches into account:

a) The typical average technical lifetime of the type of equipment may be determined and documented, taking into account common practices in the sector and country, e.g. based on industry surveys, statistics, technical literature, etc.

b) The practices of the responsible company regarding replacement schedules may be evaluated and documented, e.g. based on historical replacement records for similar equipment.

The point in time when the existing equipment would need to be replaced 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.

II. BASELINE METHODOLOGY PROCEDURE

Project boundary

Only CO_2 emissions are included in the project boundary for estimating the baseline and project emissions. Emissions sources include residual fuel oil consumption in baseline situation and consumption of residual fuel oil, additive, and grid electricity in the project situation. Table 1 provides an overview of emission sources included in or excluded from the project boundary.

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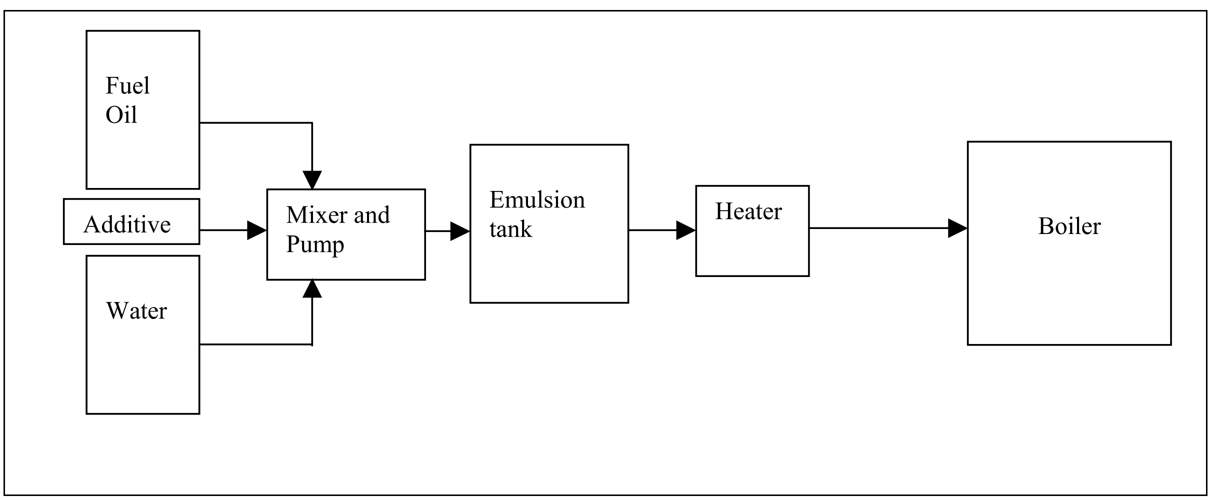
[2] In cases where the introduction of the project activity results in more heat generation, a different service level would be provided in the project activity compared to the baseline. In this case, the methodology would need to consider how the additional heat and/or power would be generated in the absence of the project activity. For example, in case of a power plant, an increased power generation as a result of the project activity may displace grid electricity with a higher or lower GHG emissions intensity than the power generation by the project activity. This situation is not covered by this methodology. In order to ensure compliance with this applicability condition, the baseline emissions are capped by the maximum fuel consumption within a historical time interval, whereas project emissions are based on the actual fuel consumption of the plant.

Table 1: Summary of gases and sources included in the project boundary, and justification / explanation where gases and sources are not included

	Source	Gas	Included?	Justification / Explanation
Baseline	Residual fuel oil consumption in the boiler	CO_2	Yes	Main greenhouse gas emitted
		CH_4	No	Excluded for simplification, this is conservative
		N_2O	No	Excluded for simplification, this is conservative
Project Activity	Residual fuel oil consumption in the boiler	CO_2	Yes	Main greenhouse gas emitted
		CH_4	No	Excluded for simplification
		N_2O	No	Excluded for simplification
	Additional electricity consumption due to the project activity	CO_2	Yes	May be an important emission source
		CH_4	No	Very minor source, excluded for simplification
		N_2O	No	Very minor source, excluded for simplification
	Additive to be combusted in the boiler	CO_2	Yes	Combustion of the additive could emit CO_2
		CH_4	No	Negligible. Excluded for simplification
		N_2O	No	Negligible. Excluded for simplification

The spatial extent of the project boundary encompasses the equipment used to prepare the emulsion as well as the boiler.

Figure 1. Spatial extent of the project boundary



Option 1

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

The latest approved version of the "Combined tool to identify the baseline scenario and to demonstrate additionality" shall be applied.

In applying Step 1 of the tool, at least the following alternative scenarios should be considered:

- Continuation of the current practices – the boiler continues to be operated in the same manner and with the same efficiency as in the past and using residual fuel oil;
- The fuel is switched from residual fuel oil to another fuel type, such as light fuel oil or natural gas;
- The boiler undergoes a major rehabilitation/retrofit to improve energy efficiency;
- A new boiler with a higher efficiency is installed to replace the existing boiler;
- The project activity (introduction of oil/water emulsion technology) not registered as a CDM project activity.

Step 1 of the tool requires identifying all alternative scenarios that are available to the project participants and that provide outputs or services with comparable quality, properties and application areas as the proposed CDM project activity. This means that all identified scenarios should be technically capable to provide the heat/steam requirements of the project activity system (i.e. the required temperature and pressure levels and the required quantity) throughout the crediting period, without any upgrade or changes. For example, if it is not possible to provide sufficient steam/heat with the continuation of the current practice or if the current practice is too unreliable to be continued, the continuation of the current practice can not be considered a credible alternative scenario.

In applying Step 3 of the tool, the following parameters should be considered as a minimum:

- Initial investment - project activity related costs only
- Annual operation and maintenance costs including but not limited to the cost of oil, additive, water, labour etc.
- Amount of residual fuel oil savings (tonnes/yr)
- Price of the residual fuel oil (currency/tonnes)
- Lifetime of the project

If equity IRR is to be calculated, data for the amount and cost of debt financing must also be provided.

This methodology is only applicable if the application of the tool results in that the continuation of current practice is the most plausible baseline scenario.

Option 2

Determination of the baseline scenario

Project proponents shall determine the most plausible baseline scenario through the application of the following steps:

Step 1. Identify all realistic and credible alternatives to the project activity

Identifying all alternative scenarios that are available to the project participants and that provide outputs or services with comparable quality, properties and application areas as the proposed CDM project activity. This means that all identified scenarios should be technically capable to provide the heat/steam requirements of the project activity system (i.e. the required temperature and pressure levels and the required quantity) throughout the crediting period, without any upgrade or changes. For example, if it is not possible to provide sufficient steam/heat with the continuation of the current practice or if the current practice is too unreliable to be continued, the continuation of the current practice can not be considered a credible alternative scenario.

The following minimum list of alternatives should be examined:

In applying Step 1 of the tool, at least the following alternative scenarios should be considered:

- Continuation of the current practices – the boiler continues to be operated in the same manner and with the same efficiency as in the past and using residual fuel oil;
- The fuel is switched from residual fuel oil to another fuel type, such as light fuel oil or natural gas;
- The boiler undergoes a major rehabilitation/retrofit to improve energy efficiency;
- A new boiler with a higher efficiency is installed to replace the existing boiler;
- The project activity (introduction of oil/water emulsion technology) not registered as a CDM project activity.

Step 2. Consistency with applicable laws and regulations

The alternative(s) shall be in compliance with all mandatory applicable legal and regulatory requirements, even if these laws and regulations have objectives other than GHG reductions, e.g. to mitigate local air pollution. (This sub-step does not consider national and local policies that do not have legally-binding status.).

If an alternative does not comply with all mandatory applicable legislation and regulations, then show that, based on an examination of current practice in the country or region in which the mandatory law or regulation applies, those applicable mandatory legal or regulatory requirements are systematically not enforced and that non-compliance with those requirements is widespread in the country. If this cannot be shown, then eliminate the alternative from further consideration.

Step 3. Eliminate alternatives that face prohibitive barriers or are economically not attractive

Scenarios that face prohibitive barriers should be eliminated by applying "Step 2 - Barrier analysis" of the latest version of the "Combined tool for identification of baseline scenario and demonstrate additionality" agreed by the CDM Executive Board.
If there is only one alternative scenario that is not prevented by any barrier, and if this alternative is not the proposed project activity undertaken without being registered as a CDM project activity, then this alternative scenario is identified as the baseline scenario. If there are still several alternative scenarios

remaining, Step 3 of the latest version of the "Combined tool for identification of baseline scenario and demonstrate additionality", agreed by the CDM Executive Board, should be applied. In applying Step 3 of the tool, the following parameters should be considered as a minimum:

- Initial investment - project activity related costs only
- Annual operation and maintenance costs including but not limited to the cost of oil, additive, water, labour etc.
- Amount of residual fuel oil savings (tonnes/yr)
- Price of the residual fuel oil (currency/tonnes)
- Lifetime of the project

If equity IRR is to be calculated, data for the amount and cost of debt financing must also be provided.

This methodology is only applicable if the application of the tool results in that the continuation of current practice is the most plausible baseline scenario.

Demonstration of additionality

The latest approved version of the "tool for the demonstration and assessment of additionality" should be applied, consistent with the guidance provided above under "Determination of the baseline scenario".

Baseline emissions

Baseline emissions include CO_2 emissions from combustion of residual fuel oil in the boiler. Baseline emissions are calculated by multiplying the quantity of residual fuel oil that would be fired in the boiler in the absence of the project activity ($FC_{BL,y}$) with an appropriate net calorific value ($NCV_{RFO,y}$), oxidation factor ($OXID_{BL,RFO}$) and CO_2 emission factor ($EF_{CO2,RFO}$), as follows:

$$BE_y = FC_{BL,y} \times NCV_{RFO,y} \times OXID_{BL,RFO} \times EF_{CO2,RFO,y} \quad \textbf{(1)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2/yr)
$FC_{BL,y}$	=	Quantity of residual fuel oil that would be fired in the boiler in the absence of the project activity in year *y* (mass or volume unit)
$NCV_{RFO,y}$	=	Net calorific value of the residual fuel oil that is fired in the boiler in year *y* (GJ/mass or volume unit)
$OXID_{BL,RFO}$	=	Fraction of carbon in the residual fuel oil that is oxidized to CO_2 in the combustion process without using the oil/water emulsion technology
$EF_{CO2,RFO,y}$	=	CO_2 emission factor of the residual fuel oil that is fired in the boiler in year *y* (t CO_2/GJ)

The quantity of residual fuel oil that would be combusted in the absence of the project activity is determined by dividing the monitored actual heat generation of the boiler by the efficiency of the boiler without using the oil/water emulsion technology.

The efficiency of boilers depends significantly on the load and operational conditions. Consequently, also the residual fuel oil consumption in the baseline depends on the load and operational conditions of the boiler. This methodology allows for two options to determine the residual fuel oil consumption in the baseline:

Option A: Assume a constant efficiency of the boiler and determine the efficiency, as a conservative approach, for optimal operation conditions (i.e. optimal load, optimal oxygen content in flue gases, adequate fuel viscosity, representative or favorable ambient conditions for the efficiency of the boiler, including temperature and humidity, etc). Divide the actual monitored heat generation of the boiler in year *y* ($HG_{PJ,y}$) by the baseline efficiency (η_{BL}), as follows:

$$FC_{BL,y} = \frac{HG_{PJ,y}}{\eta_{BL}} \quad (2)$$

Where:

$FC_{BL,y}$	=	Quantity of residual fuel oil that would be fired in the boiler in the absence of the project activity in year *y* (mass or volume unit)
$HG_{PJ,y}$	=	Heat generated by the boiler in year *y* (GJ)
η_{BL}	=	Energy efficiency of the boiler without using the oil/water emulsion technology estimated at optimal operation conditions

Option B: Establish an efficiency-load-function of the boiler, without using the oil/water emulsion technology, through on-site measurements. The fuel consumption is then determined separately for discrete time intervals *t*, based on the actual monitored heat generation during each time interval *t* and the baseline efficiency corresponding to that heat generation, determined with the efficiency-load-function:

$$FC_{BL,y} = \sum_{t=1}^{N_t} \frac{HG_{PJ,t}}{\eta_{BL,t}} \quad (3)$$

with

$$\eta_{BL,t} = f\left(HG_{PJ,t}\right) + 1.96 \cdot SE(f(HG_{PJ,t})) \quad (4)$$

and

$$N_t = \frac{8760}{T} \quad (5)$$

Where:

$FC_{BL,y}$	=	Quantity of residual fuel oil that would be fired in the boiler in the absence of the project activity in year *y* (mass or volume unit)
$HG_{PJ,t}$	=	Heat 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*
$f(HG_{PJ,t})$	=	Efficiency load function of the boiler, determined through the regression analysis
$SE(f(HG_{PJ,t}))$	=	Standard error of the result of the efficiency-load-function $f(HG_{PJ,t})$ 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:

$$\eta_x = f(HG_x) = a + b_1 HG_x + b_2 (HG_x)^2 + ... + b_n (HG_x)^n \qquad \textbf{(6)}$$

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 heat generated by the boiler during the time length *T* at the measurement *x* (GJ)[3]
x	=	Measurements undertaken at defined load levels
a, b_1, b_2,..., 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 $SE(f(HG_{PJ,t}))$ in equation (4) above. The standard error $SE(f(HG_{PJ,t}))$ has to be determined for each time interval *t*. It is recommended that project participants use the standard software to determine the standard error $SE(f(HG_{PJ,t}))$.

[3] The value of HG_x should correspond to the quantity of heat 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 heat generation should be extrapolated to the quantity that would be generated during the time length T.

In case of a linear regression equation, i.e. if n=1 in equation (6) above, the standard error can be determined as follows:

$$SE\left(f\left(HG_{BL,t}\right)\right) = \sigma * \sqrt{\left(1 + \frac{1}{N_x} + \frac{(HG_{PJ,t} - HG)^2}{\sum_{x=1}^{N_x}(HG_x - HG)^2}\right)} \quad \textbf{(7)}$$

with

$$\sigma = \frac{1}{N_x - 2} * \sqrt{(1 - R^2) * \left[\sum_{x=1}^{N_x}(\eta_x - \eta)^2\right]} \quad \text{and} \quad \textbf{(8)}$$

$$\eta = \frac{\sum_{x=1}^{N_x}\eta_x}{N_x} \quad \text{and} \quad \textbf{(9)}$$

$$HG = \frac{\sum_{x=1}^{N_x}HG_x}{N_x} \quad \text{and} \quad \textbf{(10)}$$

$$R = \frac{b_1^2 * \sum_{x=1}^{N_x}\left(HG_x - HG\right)}{\sum_{x=1}^{N_x}\left(\eta_x - \eta\right)} \quad \textbf{(11)}$$

Where:

$SE(f(HG_{PJ,t}))$	=	Standard error of the result of the efficiency-load-function $f(HG_{PJ,t})$ for time interval *t*
$f(HG_{PJ,t})$	=	Efficiency load function of the boiler, determined through the regression analysis
σ	=	Standard error of the regression equation
$HG_{PJ,t}$	=	Heat generated by the boiler during the time interval *t* (GJ)
HG_x	=	Quantity of heat generated by the boiler during the time length *T* at the measurement *x* (GJ)
HG	=	Mean heat 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)

Fraction of carbon in the residual fuel oil that is oxidized to CO_2 in the combustion process without using the oil/water emulsion technology

The baseline oxidation factor should be determined at the maximum continuous rating of the boiler, just prior to undertaking regular preventive maintenance, including boiler soot and tube cleaning. The measurement should be supervised by a competent independent third party (e.g. the DOE). The oxidation factor is calculated based on the carbon in particulate matter in the flue gas and the carbon in the fuel, as follows:

$$\mathrm{OXID}_{\mathrm{BL,RFO}} = 1 - \frac{PM * (1 - w_{ash})}{FC_{OXID} * D_{RFO,OXID} * w_{C,RFO,OXID}} \quad \textbf{(12)}$$

Where:

$OXID_{BL,RFO}$	=	Fraction of carbon in the residual fuel oil that is oxidized to CO_2 in the combustion process without using the oil/water emulsion technology
PM_s	=	Quantity of particulate material that is in the flue gas during the measurement to determine the oxidation factor (mass unit)
FC_{OXID}	=	Quantity of residual fuel oil that is fired in the boiler during the measurement to determine the oxidation factor (volume unit)
w_{ash}	=	Ash content of the residual fuel oil that is fired in the boiler during the measurement of the oxidation factor (mass fraction)
$w_{C,RFO,OXID}$	=	Carbon content of the residual fuel oil that is fired in the boiler during the measurement of the oxidation factor (mass fraction)
$D_{RFO,OXID}$	=	Density of the residual fuel oil that is fired in the boiler during the measurement of the oxidation factor (mass per volume unit)

The measurement of the oxidation factor should be supervised by a competent independent third party (e.g. the DOE). It should be undertaken under normal operating conditions.

Cap on baseline emissions

In order to ensure that heat generation is not increased as a result of the project activity, baseline emissions are capped by a historical fuel consumption and heat generation level of the boiler (see footnote 2 for an explanation). The historical annual fuel consumption generation is calculated based on the mean annual fossil fuel consumption (on an energy basis) in three calendar years (*m*) chosen among the five most recent calendar years prior to the implementation of the project activity. Project participants may deliberately choose the three calendar years *m* from the five year period.[4]

The maximum baseline emissions are calculated as follows:

$$\mathrm{BE}_{\mathrm{y,max}} = \frac{\sum_{m=1}^{3}\sum_{i} \mathrm{FC}_{\mathrm{i,m}} \times \mathrm{NCV}_{\mathrm{m}}}{3} \times \mathrm{OXID}_{\mathrm{BL,RFO}} \times \mathrm{EF}_{\mathrm{CO2,RFO,y}} \quad \textbf{(13)}$$

Where:

$BE_{y,max}$	=	Maximum baseline emissions in year *y* (t CO_2/yr)
$FC_{i,m}$	=	Quantity of residual fuel oil type *i* combusted in the boiler in the historical year *m* (mass or volume unit)
NCV_i	=	Net calorific value of the residual fuel oil type *i* (GJ/mass or volume unit)

[4] This approach aims at avoiding a potential for gaming. If a single year would be chosen among the five year period, project participants could, for example, operate a power plant longer in the year prior to the implementation of the project activity, in order to be able to expand the power generation under the CDM.

$OXID_{BL,RFO}$	=	Fraction of carbon in the residual fuel oil that is oxidized to CO_2 in the combustion process without using the oil/water emulsion technology
$EF_{CO2,RFO,y}$	=	CO_2 emission factor of the residual fuel oil that is fired in the boiler in year *y* (t CO_2/GJ)
i	=	Residual fuel oil types fired in the calendar years *m*
m	=	Three historical calendar years within the five most recent calendar years prior to the implementation of the project activity

If $BE_{y,max}$ is larger than BE_y, then $BE_{y,max}$ should be used instead of BE_y to calculate emission reductions in equation (19) below.

Project emissions

Project emissions are determined for:

1) CO_2 emissions from residual fuel oil fired in the boiler after project implementation

2) CO_2 emissions from power consumed by the project activity

3) CO_2 emissions from combustion of the additive

Project emissions are calculated as follows:

$$PE_y = PE_{RFO,y} + PE_{EL,y} + PE_{ADD,y} \tag{14}$$

Where:

PE_y	=	Project emissions in year *y* (t CO_2/yr)
$PE_{RFO,y}$	=	Project emissions from combustion of residual fuel oil in the boiler in year *y* (t CO_2/yr)
$PE_{EL,y}$	=	Project emissions from consumption of electricity due to the project activity (t CO_2/yr)
$PE_{ADD,y}$	=	Project emissions from combustion of additives used to generate the oil/water emulsion(t CO_2/yr)

The procedures to calculate these emissions are described below.

1) Project emissions from residual fuel oil fired in the boiler after project implementation

Project emissions from residual fuel oil combustion in the boiler after project implementation are determined as follows:

$$PE_{RFO,y} = FC_{PJ,RFO,y} \times NCV_{RFO,y} \times OXID_{PJ,RFO} \times EF_{CO2,RFO,y} \tag{15}$$

Where:

$PE_{RFO,y}$	=	Project emissions from combustion of residual fuel oil in the boiler in year *y* (t CO_2/yr)
$FC_{PJ,RFO,y}$	=	Quantity of residual fuel oil fired in the boiler in year *y* (mass or volume unit)
NCV_{RFO}	=	Net calorific value of the residual fuel oil that is fired in the boiler in year *y* (GJ/mass or volume unit)
$OXID_{PJ,RFO}$	=	Fraction of carbon in the residual fuel oil that is oxidized to CO_2 in the combustion process under the project activity
$EF_{CO2,RFO,y}$	=	CO_2 emission factor of the residual fuel oil that is fired in the boiler in year *y* (t CO_2/GJ)

2) Project emissions from power consumed by the project activity

The project activity may consume additional electricity for equipment, such as the oil-water emulsion mixer, the pump for supply of water for the emulsion, etc. Project emissions are calculated by multiplying the CO_2 emission factor for electricity ($EF_{CO2,EL}$) by the total amount of electricity used as a result of the project activity ($EC_{PJ,y}$). The source of electricity may be the grid or a captive power plant.

Project emissions from consumption of additional electricity by the project are determined as follows:

$$PE_{EL,y} = EC_{PJ,y} \times EF_{CO2,EL,y} \quad \textbf{(16)}$$

Where:

$PE_{EL,y}$	=	Project emissions from consumption of electricity due to the project activity (t CO_2/yr)
$EC_{PJ,y}$	=	Additional electricity consumed in year *y* as a result of the implementation of the project activity (MWh)
$EF_{CO2,EL,y}$	=	CO_2 emission factor for electricity consumed by the project activity in year *y* (t CO_2/MWh)

If electricity is purchased from the grid, the CO_2 emission factor for electricity ($EF_{CO2,EL,y}$) may be determined by one of the following options:

- Use a default emission factor of 1.3 t CO_2/MWh;
- Use the combined margin emission factor, determined according to the latest approved version of ACM0002;
- Use the approach described in small-scale methodology AMS.1.D if the quantity of electricity used by the project activity is less than 60 GWh/yr.

If electricity is generated on-site, the CO_2 emission factor for electricity ($EF_{CO2,EL,y}$) may be determined by one of the following options:

- Use a default emission factor of 1.3 t CO_2/MWh;
- Calculate the emission factor of the captive power plant at the project site, calculated based on the fuel consumption and electricity generation in year *y*, as follows:

$$EF_{CO2,EL,y} = \frac{\sum_{k} FC_{EL,CP,k,y} \times NCV_k \times EF_{CO2,k}}{EC_{CP,y}} \quad \textbf{(17)}$$

Where:

$EF_{CO2,EL,y}$	=	CO_2 emission factor for electricity consumed by the project activity in year *y* (t CO_2/MWh)
$FC_{EL,CP,k,y}$	=	Quantity of fuel type *k* combusted in the captive power plant at the project site in year *y* (mass or volume unit)
NCV_k	=	Net calorific value of fuel type *k* (GJ/mass or volume unit)
$EF_{CO2,k}$	=	Emission factor of fuel type *k* (t CO_2/GJ)
$EC_{CP,y}$	=	Quantity of electricity generated in the captive power plant at the project site in year *y* (MWh)
k	=	Fuel types fired in the captive power plant at the project site in year *y*

3) Project emissions from combustion of the additive

Emissions from combustion of the additive that is used to prepare the oil/water emulsion are likely to be small but are determined in order to retain a conservative approach. Project emissions from additive combustion are calculated based on the quantity of additive used ($F_{ADD,y}$) and the carbon content of the additive ($w_{C,ADD}$), assuming complete combustion. Emissions are determined using the following formula:

$$PE_{ADD,y} = F_{ADD,y} \times w_{C,ADD} \times \frac{44}{12} \quad \textbf{(18)}$$

Where:

$PE_{EL,y}$	=	Project emissions from consumption of electricity due to the project activity (t CO_2/yr)
$F_{ADD,y}$	=	Quantity of additive used in year *y* (tons)
$w_{C,ADD}$	=	Mass fraction of carbon in the additive

Leakage

No leakage is applicable under this methodology.

Emission Reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y \quad \textbf{(19)}$$

Where:

ER_y	=	Emission reductions during the year *y* (tCO_2/yr)
BE_y	=	Baseline emissions during the year *y* (tCO_2/yr)
PE_y	=	Project emissions during the year *y* (tCO_2/yr)

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

The crediting period shall only be renewed if the boiler is still able to operate until the end of the crediting period for which renewal is requested without any retrofitting or replacement i.e. the remaining technical lifetime of the boiler at the start of the project activity, as documented in the CDM PDD, should be larger than the duration of the previous crediting period(s) and the crediting period for which renewal is requested (14 or 21 years).

The procedure to select the baseline scenario, as outlined above, should be applied to assess whether the chosen baseline scenario is still valid.

The following data needs to be updated at the renewal of the crediting period:

- All data required to determine the baseline oxidation factor ($OXID_{BL,RFO}$);
- The constant baseline efficiency (η_{BL}) or the efficiency-load-function;
- all data required to calculate the CO_2 emission factor of the grid (only in the case that the grid electricity emission factor is chosen to be calculated *ex ante*).

Data and parameters not monitored

The following data and parameters are determined once and do not need to be monitored during the crediting period:

Data / parameter:	**$FC_{i,m}$**
Data unit:	Mass or volume unit
Description:	Quantity of residual fuel oil type *i* combusted in the boiler in the historical year *m* where *m* are three selected historical calendar years within the five most recent calendar years prior to the implementation of the project activity
Source of data:	Plant operation records
Measurement procedures (if any):	Volume flow meters. The measured quantity shall be cross-checked with the quantity of heat generated and fuel purchase receipts.
Any comment:	Document in the CDM-PDD the fuel consumption for all five calendar years and point out which years have been selected for the purpose of calculating $BE_{y,max}$.

Data / parameter:	**NCV_i**
Data unit:	GJ/mass or volume unit
Description:	Net calorific value of the residual fuel oil type *i* where • *i* are the residual fuel oil types fired in the calendar years *m*, and • *m* are three historical calendar years within the five most recent calendar years prior to the implementation of the project activity
Source of data:	Either conduct measurements or use accurate and reliable local or national data where available. Where such data is not available, use IPCC default net calorific values (country-specific, if available) if they are deemed to reasonably represent local circumstances. Choose the values in a conservative manner and justify the choice
Measurement procedures (if any):	Measurements shall be carried out at reputed laboratories and according to relevant international standards.
Any comment:	Document the net calorific values of the residual fuel oil types fired during the five most recent calendar years prior to the implementation of the project activity in the CDM-PDD.

Data / parameter:	**$EF_{CO2,EL,y}$**
Data unit:	t CO_2/MWh
Description:	CO_2 emission factor for electricity consumed by the project activity in year *y*
Source of data:	Choose between the following options: • Use a default emission factor of 1.2 t CO2/MWh; • Use the combined margin emission factor, determined according to the latest approved version of ACM0002; • Use the approach described in small-scale methodology AMS.1.D if the quantity of electricity used by the project activity is less than 15 GWh/yr.
Measurement procedures (if any):	-
Any comment:	Only applicable if electricity is purchased from the grid and if the grid emission factor is calculated once *ex-ante*

Data / parameter:	**$OXID_{PJ,RFO}$**
Data unit:	Mass fraction
Description:	Fraction of carbon in the residual fuel oil that is oxidized to CO_2 in the combustion process under the project activity
Source of data:	Use as a default value of 1

Measurement procedures (if any):	-
Any comment:	

III. MONITORING METHODOLOGY

Monitoring procedures

Monitoring includes the monitoring of the validity of the applicability conditions, monitoring of the implementation of the project activity and monitoring of the parameters listed below.

Describe and specify in the CDM-PDD all monitoring procedures, including the type of measurement instrumentation used, the responsibilities for monitoring and QA/QC procedures that will be applied. Where the methodology provides different options (e.g. use of default values or on-site measurements), specify which option will be used. All meters and instruments should be calibrated regularly as per industry standards.

Data and parameters monitored

Data / parameter:	$HG_{PJ,y}$ / $HG_{PJ,t}$
Data unit:	GJ
Description:	Heat generated by the boiler in year *y* (GJ) / Heat generated by the boiler during the time interval *t* where *t* is a discrete time interval during the year *y*
Source of data:	Measurements by project participants
Measurement procedures (if any):	Heat generation is determined as the difference of the enthalpy of the steam or hot water generated by the boiler(s) minus the enthalpy of the feed-water, the boiler blow-down and any condensate return. The respective enthalpies should be determined based on the mass (or volume) flows, the temperatures and, in case of superheated steam, the pressure. Steam tables or appropriate thermodynamic equations may be used to calculate the enthalpy as a function of temperature and pressure.
Monitoring frequency:	Continuously, aggregated annually (in case of option A) or for each time interval *t* (in case of option B)
QA/QC procedures:	
Any comment:	

Data / parameter:	**$NCV_{RFO,y}$**
Data unit:	GJ/mass or volume unit
Description:	Net calorific value of the residual fuel oil that is fired in the boiler in year *y*
Source of data:	Either conduct measurements or use accurate and reliable local or national data where available. Where such data is not available, use IPCC default net calorific values (country-specific, if available) if they are deemed to reasonably represent local circumstances. Choose the values in a conservative manner and justify the choice.
Measurement procedures (if any):	Measurements shall be carried out at reputed laboratories and according to relevant international standards.
Monitoring frequency:	In case of measurements: At least every six months, taking at least three samples for each measurement. In case of other data sources: Review the appropriateness of the data annually.
QA/QC procedures:	
Any comment:	Note that this parameters is the net calorific value of the residual fuel oil prior to the mixing it with water and the additive (i.e. it is not the net calorific value of the oil/water emulsion)

Data / parameter:	**$EF_{CO2,RFO,y}$**
Data unit:	t CO_2/GJ
Description:	CO_2 emission factor of the residual fuel oil that is fired in the boiler in year *y*
Source of data:	Either conduct measurements or use accurate and reliable local or national data where available. Where such data is not available, use IPCC default net calorific values (country-specific, if available) if they are deemed to reasonably represent local circumstances. Choose the values in a conservative manner and justify the choice.
Measurement procedures (if any):	Measurements shall be carried out at reputed laboratories and according to relevant international standards.
Monitoring frequency:	In case of measurements: At least every six months, taking at least three samples for each measurement. In case of other data sources: Review the appropriateness of the data annually.
QA/QC procedures:	Check consistency of measurements and local / national data with default values by the IPCC. If the values differ significantly from IPCC default values, collect additional information or conduct additional measurements
Any comment:	Note that this parameters is the CO_2 emission factor of the residual fuel oil prior to the mixing it with water and the additive (i.e. it is not the CO2 emission factor of the oil/water emulsion)

Data / parameter:	**η_{BL}**
Data unit:	-
Description:	Energy efficiency of the boiler without using the oil/water emulsion technology
Source of data:	Use one of the following options: (a) undertake on-site measurements, or (b) use documented manufacturer's specification of the energy efficiency for optimal operation conditions (optimal load, after maintenance, etc) if no retrofit or other change has been undertaken to the boiler and if the fuel type used corresponds to the specification of efficiency by the manufacturer
Measurement procedures (if any):	Use recognized standards for the measurement of the boiler efficiency, such as the "British Standard Methods for Assessing the thermal performance of boilers for steam, hot water and high temperature heat transfer fluids" (BS845). Use the direct method (dividing the net heat generation by the energy content of the fuels fired during a representative time period) and not the indirect method (determination of fuel supply or heat generation and estimation of the losses). Measure the efficiency at steady-state operation under optimal operation conditions (optimal load, optimal oxygen content in the flue gases, adequate fuel viscosity, representative or favorable ambient conditions for the efficiency of the boiler, etc), not using (i.e. discontinuing) the oil/water emulsion technology. Best practices for operation of boilers should be followed. The measurement should be supervised by a competent independent third party (e.g. the DOE). The measurement should be conducted immediately after scheduled preventive maintenance has been undertaken. Document the measurement procedures and results transparently in the CDM-PDD or, if undertaken during the crediting period, in the monitoring report.
Monitoring frequency:	Measurements should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • at the renewal of a crediting period.
QA/QC procedures:	
Any comment:	Only applicable if option A is chosen

Data / parameter:	$\eta_{BL,t}$
Data unit:	-
Description:	Baseline efficiency of the boiler during time interval *t* where *t* is a discrete time interval during the year *y*
Source of data:	Measurements by project participants
Measurement procedures (if any):	Establish an efficiency-load-function for the boiler ($\eta_{BL,t}$ = f($HG_{PJ,t}$)) without using the oil/water emulsion technology through on-site measurements. Use recognized standards for the measurement of the boiler efficiency, such as the "British Standard Methods for Assessing the thermal performance of boilers for steam, hot water and high temperature heat transfer fluids" (BS845). Use the direct method (dividing the net heat generation by the energy content of the fuels fired during a representative time period) and not the indirect method (determination of fuel supply or heat generation and estimation of the losses). Best practices for operation of boilers should be followed. The measurement should be supervised by a competent independent third party (e.g. the DOE). The measurement should be conducted immediately after scheduled preventive maintenance has been undertaken and under good operation conditions (optimal load, optimal oxygen content in the flue gases, adequate fuel viscosity, representative or favorable ambient conditions for the efficiency of the boiler, etc). During the measurement campaign, the load is varied over the whole operation range and the efficiency of the boiler is measured for different steady-state load levels. The efficiency should be measured for at least 10 different load levels covering the operation range. Apply a regression analysis to the measured efficiency for different load levels. Calculate the standard deviation of the regression as given in baseline emission section. Document the measurement procedures and results (i.e. efficiency at different load levels, application of the regression analysis) transparently in the CDM-PDD or, if undertaken during the crediting period, in the monitoring report.
Monitoring frequency:	Measurements should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • at the renewal of a crediting period.
QA/QC procedures:	
Any comment:	Only applicable if option B is chosen

Data / parameter:	**PM**
Data unit:	mass unit
Description:	Quantity of particulate material that is in the flue gas during the measurement to determine the oxidation factor
Source of data:	Measurements by project participants. The measurement should be supervised by a competent independent third party (e.g. the DOE).
Measurement procedures (if any):	Measurements include the determination of particulate matter emissions in the stack adopting US-EPA methods for stack sampling EPA 40 CFR Parts 60, 61 and 63 – Stationary source testing and monitoring rules. The measurement should be supervised by a competent independent third party (e.g. the DOE).
Monitoring frequency:	This parameter is needed to determine the oxidation factor $OXID_{BL.}$ Measurements to determine the oxidation factor should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • At the renewal of a crediting period.
QA/QC procedures:	
Any comment:	The method may result in the flow of particulate material (kg/h) that must, in this case, be multiplied by the duration of the measurement of the oxidation factor to provide mass quantity of particulate matter (kg)

Data / parameter:	$\mathbf{w_{ash}}$
Data unit:	Mass fraction
Description:	Ash content of the residual fuel oil that is fired in the boiler during the measurement of the oxidation factor
Source of data:	Measurements
Measurement procedures (if any):	Analysis by laboratories
Monitoring frequency:	This parameter is needed to determine the oxidation factor $OXID_{BL.}$ Measurements to determine the oxidation factor should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • At the renewal of a crediting period.
QA/QC procedures:	
Any comment:	

Data / parameter:	**$w_{C,RFO,OXID}$**
Data unit:	Mass fraction
Description:	Carbon content of the residual fuel oil that is fired in the boiler during the measurement of the oxidation factor
Source of data:	Measurements
Measurement procedures (if any):	Analysis by laboratories
Monitoring frequency:	This parameter is needed to determine the oxidation factor $OXID_{BL.}$ Measurements to determine the oxidation factor should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • At the renewal of a crediting period.
QA/QC procedures:	
Any comment:	

Data / parameter:	**$D_{RFO,OXID}$**
Data unit:	Mass per volume unit
Description:	Density of the residual fuel oil that is fired in the boiler during the measurement of the oxidation factor
Source of data:	Measurements
Measurement procedures (if any):	Analysis by laboratories
Monitoring frequency:	This parameter is needed to determine the oxidation factor $OXID_{BL.}$ Measurements to determine the oxidation factor should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • At the renewal of a crediting period.
QA/QC procedures:	
Any comment:	

Data / parameter:	**FC_{OXID}**
Data unit:	Mass or volume unit
Description:	Quantity of the residual fuel oil that is fired in the boiler during the measurement to determine the oxidation factor
Source of data:	Measurements by project participants. The measurement should be supervised by a competent independent third party (e.g. the DOE).
Measurement procedures (if any):	Volume flow meters.
Monitoring frequency:	This parameter is needed to determine the oxidation factor $OXID_{BL.}$ Measurements to determine the oxidation factor should be undertaken: • at the start of the project activity; • if a new residual fuel oil type is fired in the boiler; • if major retrofits or changes to the boiler are undertaken that may affect the fraction of carbon that is oxidized (e.g. installation of a new burner); this does not include regular preventive maintenance; • At the renewal of a crediting period.
QA/QC procedures:	
Any comment:	

Data / parameter:	**$EC_{PJ,y}$**
Data unit:	MWh
Description:	Additional electricity consumed in year *y* as a result of the implementation of the project activity
Source of data:	Actual measurements, plant operational records
Measurement procedures (if any):	Measured constantly using an electricity meter, which is calibrated regularly
Monitoring frequency:	Continuously, aggregated monthly/yearly
QA/QC procedures:	Double checked with receipts of purchase for electricity (if applicable)
Any comment:	

Data / parameter:	**$EF_{CO2,EL,y}$**
Data unit:	t CO_2/MWh
Description:	CO_2 emission factor for electricity consumed by the project activity in year *y*
Source of data:	Choose between the following options: • Use a default emission factor of 1.2 t CO2/MWh; • Use the combined margin emission factor, determined according to the latest approved version of ACM0002; • Use the approach described in small-scale methodology AMS.1.D if the quantity of electricity used by the project activity is less than 15 GWh/yr.
Measurement procedures (if any):	-
Monitoring frequency:	Annually
QA/QC procedures:	-
Any comment:	Only applicable if electricity is purchased from the grid and if the grid emission factor is calculated ex-post on an annual basis

Data / parameter:	**$FC_{EL,CP,k,y}$**
Data unit:	Mass or volume unit
Description:	Quantity of fuel type *k* combusted in the captive power plant at the project site in year *y* where *k* are the fuel types fired in the captive power plant at the project site in year *y*
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use weight or volume meters
Monitoring frequency:	Continuously, aggregated at least annually
QA/QC procedures:	Cross-checked measurement results with the quantity of heat generated and fuel purchase receipts
Any comment:	Only applicable if electricity is generated on-site

Data / parameter:	**NCV_k**
Data unit:	GJ/mass or volume unit
Description:	Net calorific value of fuel type *k* where *k* are the fuel types fired in the captive power plant at the project site in year *y*
Source of data:	Either conduct measurements or use accurate and reliable local or national data where available. Where such data is not available, use IPCC default net calorific values (country-specific, if available) if they are deemed to reasonably represent local circumstances. Choose the values in a conservative manner and justify the choice.
Measurement procedures (if any):	Measurements shall be carried out at reputed laboratories and according to relevant international standards.
Monitoring frequency:	In case of measurements: At least every six months, taking at least three samples for each measurement. In case of other data sources: Review the appropriateness of the data annually.
QA/QC procedures:	
Any comment:	Only applicable if electricity is generated on-site

Data / parameter:	**$EF_{CO2,k}$**
Data unit:	t CO_2/GJ
Description:	Emission factor of fuel type *k* where *k* are the fuel types fired in the captive power plant at the project site in year *y*
Source of data:	Either conduct measurements or use accurate and reliable local or national data where available. Where such data is not available, use IPCC default emission factors (country-specific, if available) if they are deemed to reasonably represent local circumstances. Choose the value in a conservative manner and justify the choice.
Measurement procedures (if any):	Measurements shall be carried out at reputed laboratories and according to relevant international standards.
Monitoring frequency:	In case of measurements: At least every six months, taking at least three samples for each measurement. In case of other data sources: Review the appropriateness of the data annually.
QA/QC procedures:	Check consistency of measurements and local / national data with default values by the IPCC. If the values differ significantly from IPCC default values, collect additional information or conduct additional measurements
Any comment:	Only applicable if electricity is generated on-site

Data / parameter:	**$EC_{CP,y}$**
Data unit:	MWh
Description:	Quantity of electricity generated in the captive power plant at the project site in year *y*
Source of data:	Measurements by project participants
Measurement procedures (if any):	Use electricity meters
Monitoring frequency:	Continuously, aggregated annually
QA/QC procedures:	
Any comment:	Only applicable if electricity is generated on-site

Data / parameter:	**$F_{ADD,y}$**
Data unit:	tons
Description:	Quantity of additive used in year *y*
Source of data:	Measurements by project participants
Measurement procedures (if any):	Volume or weight meters
Monitoring frequency:	Continuously, aggregated annually
QA/QC procedures:	Check the consistency of measurement results with purchase invoices
Any comment:	

Data / parameter:	**$w_{C,ADD}$**
Data unit:	Mass fraction
Description:	Mass fraction of carbon in the additive
Source of data:	Assume a mass fraction of 1 or use manufacturer's specifications or undertake measurements
Measurement procedures (if any):	
Monitoring frequency:	Once each time a new type of additive is used
QA/QC procedures:	
Any comment:	

Data / parameter:	**Changes to the boiler**
Data unit:	-
Description:	Monitor and document in monitoring reports any changes that are undertaken to the boiler or to the way the boiler is operated, such as the replacement of equipment, process modifications or other retrofits. If these changes may affect the efficiency of the boiler or the fraction of carbon that is oxidized, these parameters ($OXID_{BL}$, η_{BL} or $\eta_{BL,t}$) should be updated, subject to the guidance provided for these parameters.
Source of data:	Records by project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuously, to be documented in each monitoring report
QA/QC procedures:	
Any comment:	

Data / parameter:	**Fuels used in the boiler**
Data unit:	-
Description:	Monitor and document all fuel types used in the boiler in year *y*. If other fuels than residual fuel oils are used, the methodology is not anymore applicable. If a new residual fuel oil type is used, the efficiency of the boiler (η_{BL} or $\eta_{BL,t}$) and the fraction of carbon that is oxidized ($OXID_{BL}$) should be updated, subject to the guidance provided for these parameters.
Source of data:	Records by project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuously, to be documented in each monitoring report
QA/QC procedures:	
Any comment:	

References and any other information

2006 IPCC Guidelines for National Greenhouse Gas Inventories

American Society of Mechanical Engineers Performance Test Codes for Steam Generators: ASME PTC 4 – 1998; Fired Steam Generators

British Standard Methods for Assessing the Thermal Performance of Boilers for Steam, Hot Water and High Temperature Heat Transfer Fluids