Joint Crediting Mechanism Approved Methodology ID_AM007
"GHG emission reductions through optimization of boiler operation in Indonesia"

A. Title of the methodology

GHG emission reductions through optimization of boiler operation in Indonesia, ver 1.10

B. Terms and definitions

Terms	Definitions
Utility Facility Operation Optimization Technology	Technology to optimize the operation of existing utility facilities such as boilers through application of software algorithm using linear programming method or non-linear programming method.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	The project achieves energy conservation in boilers, through operation optimization by applying Utility Facility Operation Optimization Technology.
Calculation of reference emissions	Reference emissions are calculated on the basis of monitored project steam generation and specific CO_2 emissions per steam generated, through analysis of historical relationship between steam generation and fuel consumption of boilers.
Calculation of project emissions	Project emissions are calculated on the basis of monitored fuel consumption and emission factor of fuel consumed after implementation of the project.
Monitoring parameters	● Energy consumption and steam generation in boilers; and ● Number of hour(s) recorded for steam generation.

D. Eligibility criteria

This methodology is applicable to projects that satisfy all of the following criteria.

Criterion 1	The project is implementation of operation optimization of boilers to generate steam, through introduction of Utility Facility Operation Optimization Technology.
Criterion 2	The site of introduction is an existing industrial facility which includes two or more boilers to generate steam.
Criterion 3	Historical data for fuel consumption, fuel characteristics (type of fuel, net calorific value) and generation of steam is identifiable for individual boiler for at least one year, as specified in the methodology.
Criterion 4	All steam demand is met internally and not sourced from outside the industrial facility.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Emissions from fossil fuel consumption by boilers	CO_2
Project emissions	
Emission sources	GHG types
Emissions from fossil fuel consumption ~~for~~ by boilers	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Reference emissions are calculated under the assumption that the current boilers continue to be used. When new boilers are introduced to substitute existing boilers or as capacity expansion, procedure to recalculate reference emissions is provided.

In order to establish reference emissions, CO_2 emissions are calculated on the basis of regression obtained through regression analysis of historical CO_2 emissions, with historical steam generation as variables.

Ensuring net emission reductions

The methodology ensures conservativeness by not including the associated reduction of fuel for auxiliary equipments (e.g. fans and pumps) which is expected to occur as a result of the project. Furthermore, the methodology ensures net reduction by adopting a conservative assumption when boilers are replaced.

F.2. Calculation of reference emissions

Step 1. Calculation of historical emissions

Historical emissions are calculated as follows:

- Obtain data on hourly fuel consumption for the historical period of one year preceding introduction of Utility Facility Operation Optimization Technology up to the period not earlier than 6 months before submission of the draft PDD to the secretariat.
- Calculate hourly CO_2 emissions according to the following formulae.

$$HE_{j,xh} = \sum_i (FC_{i,j,xh} \times NCV_i \times EF_i) \quad (1)$$

$$HE_{xh} = \sum_j HE_{j,xh} \quad (2)$$

Where

HE_{xh}	=	Historical CO_2 emissions on hour h in the historical 1-year period x. [tCO_2/h]
$HE_{j,xh}$	=	Historical CO_2 emissions from boiler j on hour h in the historical 1-year period x. [tCO_2/h]
$FC_{i,j,xh}$	=	Consumption of fossil fuel i by the boiler j on hour h in the historical 1-year period x.[mass or volume unit/h]
NCV_i	=	Net calorific value of fossil fuel type i.[-GJ/mass or volume unit]
EF_i	=	CO_2 emission factor of fossil fuel type i. [tCO_2/GJ]

Step 2. Regression analysis

Plot the data with hourly data of historical steam generation by the boilers (ST_{xh}) on the *x*-axis and hourly total CO_2 emissions by the boilers (HE_{xh}) on the *y*-axis. Omit data obtained during periods of startup, shutdown, maintenance or malfunction of equipment or measurement device, and periods of operating outside the operating range specified by the project participants or by the equipment manufacturer.

Perform a linear regression analysis. If the regression coefficient R^2 of the plotted data is smaller than 0.49, omit statistical outliers with a plot outside 2 times the standard deviation from the regression line.

Repeat the process until the R^2 of the plotted data is larger than 0.49. Perform a linear regression analysis with the remaining data to derive a linear regression equation as follows

$$HE_{xh} = a \times ST_{xh} + b \tag{3}$$

Where

HE_{xh}	=	Historical CO_2 emissions from boilers on hour *h* in the historical 1-year period *x*. [tCO_2/h]
ST_{xh}	=	Historical steam generation by the boilers on hour *h* in the historical 1-year period *x*. [tonnes steam/h]
a	=	Parameter derived as a result of linear regression analysis (specific emission factor).[tCO_2/tonnes steam]
b		Parameter derived as a result of linear regression analysis (y-intercept). [tCO_2/h].

If the resulting regression coefficient R^2 remains below 0.49 as a result of the analysis, then conduct the following procedure.

- Perform regression analysis for individual boiler for the same historical 1-year period *x*. Obtain regression coefficient *R* for each boiler by using the same procedure as stated above.
- Identify boilers which resulted in the resulting regression coefficient R^2 is lower than 0.49. For such boiler, re-calibrate measurement equipments attached to the boiler (fuel flow meters, steam flow meters). Conduct a one-month campaign without operating the Utility Facility Operation Optimization Technology. Perform a linear regression analysis based on the data obtained during the one-month campaign, by using the same procedure as stated above, to yield a regression equation as follows:

$$HE_{j,ch} = a_j \times ST_{j,ch} + b_j \quad (4)$$

Where

$$HE_{j,ch} = \sum_i (FC_{i,j,ch} \times NCV_i \times EF_i) \quad (5)$$

$HE_{j,ch}$	=	Historical CO_2 emissions from the boiler *j* on hour *h* in the one-month campaign *c*. [tCO_2/h]
$ST_{j,ch}$	=	Historical steam generation by the boiler *j* on hour *h* in the one-month campaign *c*. [tonnes steam/h]
a_j, b_j	=	Parameters derived as a result of linear multivariate regression analysis for individual boiler *j* based on the data obtained in the one-month campaign.
$FC_{i,j,ch}$	=	Consumption of fuel *i* by the boiler *j* on hour *h* in the one-month campaign *c*. [mass or volume unit/h]
NCV_i	=	Net calorific value of fossil fuel type *i*. [GJ/mass or volume unit]
EF_i	=	CO_2 emission factor of fossil fuel type *i*. [tCO_2/GJ]

- Re-perform steps 1 and 2 but by substituting for the boiler which has conducted the campaign, $ST_{j,xh}$ by [$(HE_{j,xh} - bj) / a_j$] for cases where only steam flow meters are found to be deficient, and $HE_{j,xh}$ by ($a_j \times ST_{j,xh}.+b_j$) in all other cases. $ST_{j,xh}$ is the historical steam generation by the boiler *j* on hour *h* in the historical 1-year period *x*.
- If the regression coefficient R^2 of the regression analysis according to step 2 with the adjusted data is still below 0.49, the methodology is not applicable.

Step 3. Calculation of reference emissions

Reference emissions are calculated as follows:

$$RE_p = \sum_h (a \times ST_{p,h} + b)$$

$$= (a \times ST_{p,1} + b) + (a \times ST_{p,2} + b) + \cdots + (a \times ST_{p,H-1} + b) + (a \times ST_{p,H} + b)$$

$$= a \times \sum_h ST_{p,h} + b \times H_p$$

$$= a \times ST_p + b \times H_p \quad (6)$$

Where

RE_p	=	Reference emissions during the period *p*. [tCO_2/p]
$ST_{p,h}$	=	Process steam generation on hour *h* during the period *p*. [tonnes steam/h]

a	=	Parameter derived as a result of linear regression analysis (specific emission factor). [tCO_2/tonnes steam]
b	=	Parameter derived as a result of linear regression analysis (y-intercept). [tCO_2/h].
ST_p	=	Process steam generation during the period p. [tonnes steam/p]
H_p	=	Number of hour(s) h recorded for steam generation during the period p. [h/p]

Annex: Provisions for recalculation of reference emissions when new boilers are introduced.

When new boilers are introduced, reference emissions obtained as above are no longer valid, and need to be recalculated under the following procedure. To undergo this procedure, historical data for energy consumption and generation of each boiler is required. The procedure applies to cases when new boilers replace existing boilers, and when new boilers are introduced to provide additional capacity.

Step i: Calculate historical CO_2 emissions on hour *h* in the historical period *x* for all existing boilers.

The calculation is conducted according to the following equation.

$$HE_{j,xh} = \sum_i FC_{i,j,xh} \times NCV_i \times EF_i \quad (7)$$

Where

$HE_{j,xh}$	=	Historical CO_2 emissions from the boiler j on hour h in the historical 1-year period x. [tCO_2/h]
$FC_{i,j,xh}$	=	Consumption of fuel i by the boiler j on hour h in the historical 1-year period x. [mass or volume unit/h]
NCV_i	=	Net calorific value of fossil fuel type i. [GJ/mass or volume unit]
EF_i	=	CO_2 emission factor of fossil fuel type i. [tCO_2/GJ]

Step ii: Calculate design CO_2 emission factor of existing boiler

For each existing boiler, calculate its design CO_2 emission factor as follows

$$EF_j = \frac{EF_{i,j}}{\eta_j} \quad (8)$$

Where

$EF_{,j}$	=	Design CO_2 emission factor of boiler *j*. [tCO_2/GJ-steam]
$EF_{i,j}$	=	Weighted average CO_2 emission factor of the fuel *i* consumed by boiler *j* in the historical 1-year period *x*. [tCO_2/ GJ-fuel]
η_j	=	Design efficiency of existing boiler *j*. [dimensionless][GJ-fuel/ GJ-steam]

For boilers providing the same utility as the new boiler, rank each existing boiler according to the descending order of design CO_2 emission factor.

Step iii: Adjust CO_2 emission factor of existing boiler ($HE_{j,xh}$)

Adjust CO_2 emission factor of existing boiler ($HE_{j,xh}$), starting from the existing boiler whose design CO_2 emission factor is highest, up to the theoretical maximum amount of utility that can be provided by the new boiler (assuming a capacity factor of 100%), as follows:

$$HE_{adj,j,xh} = HE_{j,xh} \times \min\left(\frac{EF_{new}}{EF_j}, 1\right) \quad (9)$$

Where EF_{new} is EF_j for the new boiler.

Step iv: Recalculate HE_{xh}

Recalculate HE_{xh} (Historical CO_2 emissions on hour *h* in the historical 1-year period *x*) based on the adjusted and non-adjusted values of $HE_{j,xh}$.

Step v: Recalculate the regression analysis

Linear multivariate regression analysis as described in step 2 is recalculated, using $HE_{adj,xh}$ obtained above instead of $HE_{x,h}$.

When boilers are introduced during the 1-year historical period, undergo the recalculation steps i and v for the period before introduction of new boilers.

G. Calculation of project emissions

Project emissions are calculated on the basis of fuel consumption.

$$PE_p = \sum_i (FC_{i,p} \times NCV_i \times EF_i) \quad (10)$$

Where

PE_p	=	Project emissions during the period *p*. [tCO_2/p]
$FC_{i,p}$	=	Consumption of fossil fuel *i* by the boiler during the period *p*. [mass or volume unit/p]

NCV_i	=	Net calorific value of fossil fuel type *i*. [GJ/mass or volume unit]
EF_i	=	CO_2 emission factor of fossil fuel type *i*. [tCO_2/GJ]

H. Calculation of emissions reductions

Emission reductions are calculated as follows:

$$ER_p = RE_p - PE_p \quad (11)$$

Where

ER_p	=	Emission reductions during the period *p*. [tCO_2/p]
RE_p	=	Reference emissions during the period *p*. [tCO_2/p]
PE_p	=	Project emissions during the period *p*. [tCO_2/p]

I. Data and parameters fixed *ex ante*

The source of each data and parameter fixed *ex ante* is listed as below.

Parameter	Description of data	Source
$FC_{i,j,xh}$	Consumption of fuel *i* by the boiler *j* on hour *h* in the historical 1-year period *x*.	Site record.
$FC_{i,j,ch}$	Consumption of fuel *i* by the boiler *j* on hour *h* in the one-month campaign *c*.	Site record.
NCV_i	Net calorific value of fossil fuel type *i*.	In the order of preference: a) values provided by the fuel supplier; b) measurement by the project participants; c) regional or national default values; d) IPCC default values provided in table 1.2 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied.
EF_i	CO_2 emission factor of fossil fuel type *i*.	In the order of preference: a) values provided by the fuel supplier; b) measurement by the project participants; c) regional or national default values; d) IPCC default values provided in table 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied.

ST_{xh}	Historical steam generation by the boilers on hour *h* in the historical 1-year period *x*.	Site record.
$ST_{j,ch}$	Historical steam generation by the boiler *j* on hour *h* in the one-month campaign *c*.	Site record.
$ST_{j,xh}$	Historical steam generation by the boilers *j* on hour *h* in the historical 1-year period *x*.	Site record.
a, *b*	Parameters derived as a result of linear multivariate regression analysis.	Calculated according to step 2 in section F2.
a_j, b_j	Parameters derived as a result of linear multivariate regression analysis.	Calculated according to step 2 in section F2.

History of the document

Version	Date	Contents revised
01.1	DD MM YYYY	Revisions to: ● Add a monitoring parameter and equation to calculate the original equation appropriately; ● Correct units of the default values on the monitoring spreadsheet; and ● Change editorially.
01.0	18 May 2015	JC4, Annex 2 Initial approval.