GHG emission reductions through optimization of boiler operation in Indonesia

Explanatory note

1. Mechanism of emission reductions

Many industrial facilities own multiple boilers to provide heat. Furthermore, it is common for an industrial facility to own and operate boilers of various load-efficiency characteristics or fuel types. However, such boilers are not always operated in an optimal manner. During periods of intermediate demand, multiple boilers and generators may continue to be operated outside their optimal load when it is more efficient to shut down one and operate another boiler at full capacity. Less efficient boilers may be continued to operate while the more efficient ones are shut down due to factors such as historical practice.

Utility Facility Operation Optimization Technology attempts to optimize the operation of boilers through application of software algorithm using linear programming method. Specifically, the program instructs the operator of boilers to select the optimal configuration of boilers to meet the utility demand of the industrial facility. The objective function for the purpose of the methodology is to meet the heat demand with the least amount of CO_2 emissions, though other types of objective can be chosen such as minimal cost or least amount of energy consumed. Factors such as type of fuel, output capacity and load-efficiency characteristics are taken into account.

Utility Facility Operation Optimization Technology can be implemented in a wide range of industrial facilities, with varying circumstances. This methodology includes measures to address irregular situations which may occur in the industrial facilities which the project is undertaken.

2. Establishment and calculation of reference emissions

2.1. Basic structure of the calculation of reference emissions

The methodology calculates reference emissions by multiplying the steam generation after implementation of the project by historical specific emission factor of steam, obtained through linear regression analysis of historical one-year data (taken hourly) before implementation of the project. The one-year history is deemed appropriate since it is long enough to cover possible variation of operation and ensures enough data points to yield a reliable regression equation.

Reference emissions calculated as above is compared with the project emissions, calculated on the basis of actual fuel consumption after the implementation of the project.

2.2. Ensuring conservativeness

The methodology ensures conservativeness by assuming that emission reductions of fuel and electricity consumed by auxiliary equipments (e.g. fans and pumps) which is expected to occur as a result of reduction in fuel consumption from the project is not included. Furthermore, it is assumed in case of equipment substitution that the new boiler, upon introduction, will substitute existing boilers with a higher emission factor (boilers that are less efficient or uses a higher emitting fuel) up to the point where the new boiler is operating at full load. In reality, new boilers do not always replace higher emitting facilities providing the same type of utility, and they may operate at less than 100% load. Therefore, the assumption is conservative.

2.3. Measures to be taken when the regression does not meet the required level of the methodology

Upon determination of historical specific emission factor, there could be situations where one or few of the boilers yield poor correlation between steam generation and CO_2 emissions due to various reasons such as equipment malfunction, which affects the overall regression. To address this, a procedure is included in the methodology where, if the overall regression coefficient R^2 is less than 0.49, then the performance of individual boiler with low regression are recalibrated and examined, and their relationship between steam generation and CO_2 emissions is measured in a one-month campaign.

The result of this campaign is fed into the original one-year data to yield an adjusted one-year database, upon which historical emission factor is re-calculated. For example, if the relationship between steam generation and hourly total CO_2 emissions by the boiler in question during the one-month campaign ($ST_{j,ch}$ and $HE_{j,ch}$, respectively) is established to be $HE_{j,ch}$, = a_j* $ST_{j,ch}$ +b_j, then CO_2 emissions of that boiler for hour h of the one-year historical period is calculated from its steam generation on that hour as $HE_{j,xh}$, = $a_j \times ST_{j,xh}$ +b_j, instead of calculating from its fuel consumption on that hour as $HE_{j,ch}$, = $FC_{j,ch} \times NCV_i \times EF_i$, where

NCV_i and EF_i are net calorific value and CO_2 emission factor of the fuel used in the boiler. If the overall regression R^2 becomes higher than 0.49, then the methodology is applicable since it can be assumed that the original monitoring of fuel consumption was flawed but was corrected.

2.4. Indicative example of "Provisions for recalculation of reference emissions when new boilers are introduced"

It is plausible for many industrial facilities which operate many boilers that they are occasionally replaced, overhauled or added. If this happens, then the assumption that the historical relationship between steam generation and CO_2 emissions will continue becomes untenable. A provision to address this situation is introduced in the methodology. An indicative example is shown below.

Assume an industrial facility with boilers A, B, C, D and E, with descending order of specific CO_2 emission factor with the specification and performance for the hour as shown below. When a new boiler F is added (or replaces existing boilers) after the implementation of the project, new boiler F is deemed to replace boilers A and B whose specific CO_2 emission factor is higher than boiler F, since the combined steam generation of the boilers A and B is below what boiler F can generate. New boiler F only partially replaces boiler C and does not replace boiler D even though their specific CO_2 emission factor is higher than boiler F, since the combined steam generation by boilers A to C exceeds that of what boiler F an generate at full capacity. The resulting $HE_{adj,j,xh}$ is calculated as shown in Table 1. By this algorithm, hourly CO_2 emissions are adjusted downwards by approximately 10% from 26.1t-CO_2 to 23.5t-CO_2.

Table 1: Illustrative example of adjustment procedure when a new boiler is introduced.

Boiler	Capacity	Design and actual efficiency	Load factor	Fuel	Emission factor of fuel (EF_i)	Historical CO_2 emissions from the boiler ($HE_{j,xh}$)	Design CO_2 emission factor of boiler (EF_j)	Steam generation	Adjustment to $HE_{j,xh}$	Adjusted $HE_{i,xh}$ ($HE_{adj,j,xh}$)
	Tph	%	%		t-CO_2/TJ	t-CO_2/hr	t-CO_2/TJ	t-steam/hr		t-CO_2
A (existing)	10	70%	50%	Diesel	74.1	1.42	105.9	5.00	adjust	0.83
B (existing)	20	85%	80%	Diesel	74.1	3.73	87.2	16.00	adjust	2.67
C (existing)	30	75%	100%	Gas	56.1	6.00	74.8	30.00	partially adjust	5.04
D (existing)	40	85%	100%	Gas	56.1	7.06	66.0	40.00	no adjust	7.06
E (existing)	50	95%	100%	Gas	56.1	7.90	59.1	50.00	no adjust	7.90
Total (where appropriate)	150					26.11		141.00		23.50
F (new)	50	90%	100%	Gas	56.1		62.33			

*For the purpose of simplicity, boilers are assumed to operate at their respective design efficiencies.