Appendix I

Additional Information for the Proposed Methodology

"Energy Saving by Introduction of High Efficiency Once-through Boiler"

1. Market Condition of Boilers in Indonesia

1.1 Number of boiler units sold in Indonesia

According to the interviews with the major boiler suppliers in Indonesia, all of them mentioned that there is no official statistics on industrial boilers[1]. Followings are the summary of interview with major boiler suppliers concerning boiler market condition in Indonesia.

Table 1: Summary of the boiler market survey in Indonesia

Company	Origin of Boilers	Interviewed	Annual sales	
			Boiler Type	Units
A	Europe and Africa	Yes	FT (Coal) FT (Oil&Gas)	60-70 30-40
B	Indonesia	Yes	FT (Coal) FT (Oil&Gas)	70 (in total)
C	Indonesia	No	WT (Coal)	N/A
D	Japan	Yes	OT (Oil&Gas)	2
E	China	No	FT&WT (Coal)	N/A
F	Japan/China	No	FB (Coal)	N/A

FT: Fire tube, WT: Water tube, OT: Once-through, FB: Fluidized bed
Source: Based on interview results

1.2 Reference Boiler

While coal boilers are widely applied by local companies due to cheaper fuel price, international companies tend to avoid coal fired boilers due to the higher emission of GHGs and pollutants. As below, the boiler efficiency is discussed separately for oil and gas boilers and coal boilers.

(1) Oil and gas fired boiler

Oil and gas fire tube boilers are widely used in Indonesia while water tube boilers are not considered as the reference boilers since that type of boiler has small share in Indonesian market According to CDM AMS-II.D, para. 26, for baseline parameters for new construction/capacity addition, the baseline parameters could be determined based on manufacturer's specifications. The latest features of the fire tube boilers of the major manufactures in Indonesia, i.e. company A and B, are collected through interview survey and summarized as below.

[1] Interview was conducted in July 2016.

Table 2: Common and average features of oil and gas fire tube boilers sold in Indonesia

Company	Boiler efficiency	Operation load	Option
A	89%	40%-100%	No economizer or other related efficiency improvement functions
B	88.4%	25%-100%	

Source: Based on interview results

Both company A and B mentioned that most customers prefer to have boilers without economizer or other related efficiency improvement functions considering initial high investment cost.

Company A mentioned the efficiency is 89% based on 103 degree-C and 0.8 MPa of the steam pressure, while the efficiency is 88.4% at the standard condition of Company B, namely three ton per hour, 90 degree-C of boiler feed water, 1.3 MPa of the steam pressure, using diesel oil. The boiler engineer of Japanese boiler company confirmed that there is no efficiency variation according to change of boiler feed water temperature if economizer is not applied. Accordingly, the boiler efficiency 89% can be considered to be conservative for the oil and gas fired fire tube boilers in Indonesia.

(2) Coal boiler

Coal boiler is also widely installed in Indonesia. The efficiency of coal boiler in Indonesian market is summarized as in the Table 3.

Table 3: Features of Coal Fired Boilers sold in Indonesia

Company	Boiler efficiency	Remarks
B	85%	Fire tube with chain grate
E	80-81%	Fire tube and water tube with chain grate
F	85-88%	Circulating fluidized bed system and pulverizer

The efficiency of coal fired boiler is variable between 80-88% as shown in the table above depending on combustion type, and characteristic and quality of coal. Some manufacturers apply fluidized bed system and pulverizer to increase combustion efficiency of coal which can achieve 88% of efficiency in the catalogue.

Meanwhile, “Methodological tool determining the baseline efficiency of thermal or electric energy generation systems ver. 2.0” in CDM sets the default efficiency of baseline coal fired boiler to be 80%.

Also, based on the interview to companies in Japan, the efficiency of oil and gas boiler is higher than that of coal boiler in general.

Considering facts above, efficiency of coal boiler is lower than that of oil and gas boiler even with the various options which are not common yet in Indonesia. Thus, it is conservative to set the default efficiency of coal boiler at 89% to be the same as oil and gas boiler. In case of fuel switch from coal to oil or coal to gas, boiler efficiency 89% can be applied as the efficiency of the reference boiler.

(3) Conservativeness of setting of boiler efficiency

The advantage of once-through boiler (project boiler) is that the high efficiency can be maintained under the low range of operation load. On the other hand, efficiency of oil and gas fired fire tube boiler is low at the smaller operation load range. Figure 1 is the test result of efficiency comparison between once-through boiler and fire tube boiler of a boiler manufacturer.

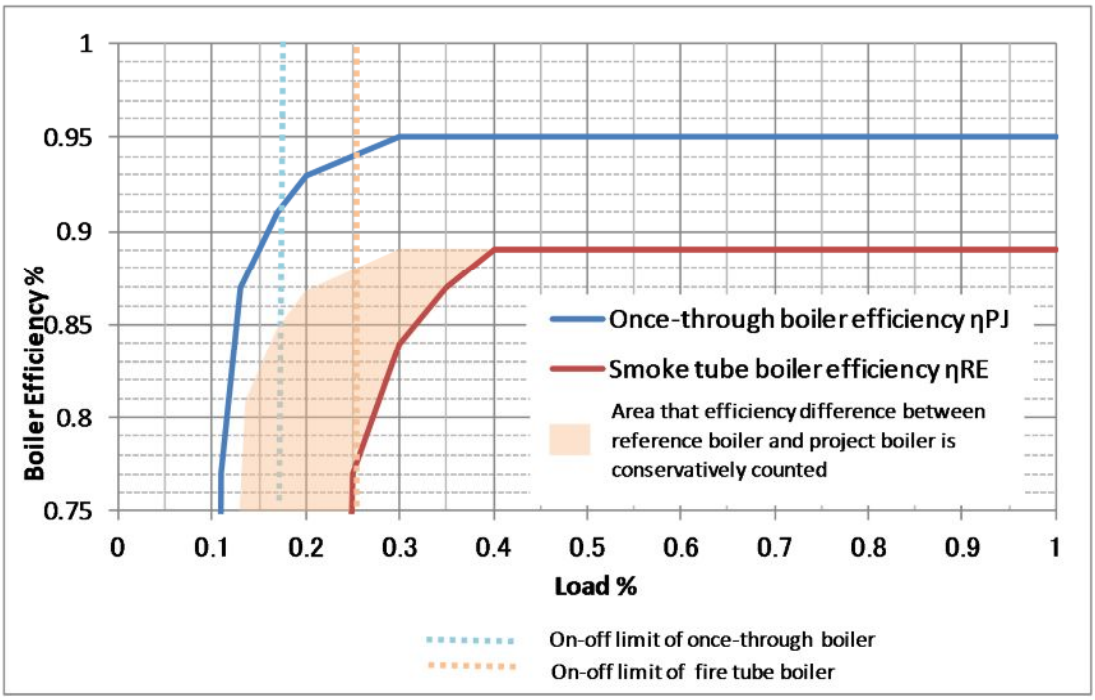

Figure 1: Efficiency comparison between once-through boiler and fire tube boiler at various load range

Source: Based on Japanese boiler manufacture's test report

As shown in the above figure, when the load rate is small range (ex. 25-35%), the efficiency of fire tube boiler becomes low (η_{RE}＝77-87%) while efficiency of once-through boiler can be maintained relatively high (95-94%) at the same range.

When the load is less than 25% (on-off limit), boiler starts switching on and off. At this time, the efficiency decreases rapidly, which cannot be theoretically calculated. The on-off limit of fire tube boiler is reportedly 40% and the efficiency becomes again lower at smaller load range. Meanwhile, the on-off limit of the project boiler is 17%, which means that the boiler keeps good efficiency up

in smaller load range up to 17%.

This means when the boiler is operated at smaller load range, the efficiency difference between project boiler and reference boiler becomes large, and thus CO_2 emission reduction amount becomes larger. Depending on factory production pattern, it is quite often that boiler load becomes less than 35%. (In the actual operation record of a factory to which this JCM methodology will be applied, the average load was 37% in July 2016)
Therefore, the default setting of reference efficiency at 89% is considered to be conservative.

In terms of coal fired reference boiler (chain grate and fluidized bed type commonly used in Indonesia), there is no on-off limits as the oil and gas fired boilers and the manufactures of boilers mentioned that combustion control is more difficult and slower compared with oil and gas burners. Thus, difference of operating efficiency and boiler catalogue efficiency is bigger in the case of coal fired boilers than the case of oil and gas fired boilers.
Furthermore, with fluidized bed, efficiency of coal boiler can be increased while N_2O emissions become much higher. In Japan, Ministry of Environment sets the emission factor of N_2O of fluidized bed (solid fuel) is 54 kg N_2O / TJ while chain grate (solid fuel) is 0.85 kg N_2O / TJ. Thus, in fluidized bed boiler system, actual GHG emissions will be higher than the catalogue efficiency. It can be concluded that it is conservative to set the reference efficiency of coal boiler as the same as the fire tube boiler of 89% efficiency.

Thus, reference boiler can be defined as follows.

- Fire tube boiler
- Gas, oil or coal fired
- Boiler efficiency 89%
- No economizer or other efficiency improvement functions

2 . Emission reduction through the application of water purification and demineralization to reduce boiler blow flow rate

From interview with boiler suppliers in Indonesia, boiler water is treated by water softener in almost all cases in Indonesia, which replace minerals such as Calcium (Ca) and Magnesium (Mg) with Natrium (Na). That water is then treated with chemicals so that boiler can run properly. However, such water having chemicals should be blown off periodically before it gets concentrated. On the other hand, water deionizer such as Reverse Osmosis (RO) system can produce water with less substances including Na, which can reduce the application of chemicals and boiler water blow.

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Constant boiler blow flow rate is set in actual boiler operation to prevent water condensation, which is variable according to the quality of the source of boiler water. Boiler blow flow may waste significant heat.

Boiler efficiency is defined as the net quantity of heat used to generate steam per quantity of energy contained in the fuel fired in the boiler. However, heat is actually wasted in proportion to the boiler blow flow rate in the actual boiler operation. When the reference boiler uses water softener and the project boiler applies RO, the boiler blow flow rate can be reduced in the project boiler and thus fuel consumption can be reduced accordingly, as indicated in the following formula.

$$\frac{FC_{PJ}}{FC_{RE}} = \frac{(100-BF_{PJ})}{(100-BF_{RE})} \ ,$$

Where,

FC_{PJ}: Fuel consumption of project boiler with RO [mass or volume unit]
FC_{RE}: Fuel consumption of reference boiler with water softener [mass or volume unit]
BF_{PJ}: Blow flow rate of project boiler [%]
BF_{RE}: Blow flow rate of reference boiler [%]

The boiler blow flow rate is determined respectively for the case of water softener (reference case) and water deionizer such as RO (project case) with the same source of the boiler water applied at the site. The boiler flow rate can be confirmed in the manufacturer's instruction based on test result on the water treatment requirement of boiler, both for the reference case and the project case.

The boiler user may set actual blow flow rate higher than the specified value in a water treatment program with a safety factor to protect the boiler. At that case, it is considered that actual blow flow rate of reference boiler will be higher than the value of blow flow rate of reference boiler in water treatment program multiplied by the same safety margin as project boiler. Accordingly, applying the difference of blow flow rate specified in water treatment programs of project boiler and reference boiler is considered to be more conservative than applying the difference of actual setting by the users.

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Example Case