Appendix I

Additional Information for the Proposed Methodology

"Introduction of heat recovery system and high efficiency once-through boiler at the beer factory"

1. Market Condition of Boilers in Myanmar

1.1 Number of boilers installed in Myanmar

In Myanmar, there are in total 2,390 boilers in operation[1] in 2016, according to the internal statistics of the Boiler Inspection Department of Ministry of Industry. The situation of introduction of boiler is as follows.

- Largest number of boiler units is installed in food industry, followed by textile industry.
- All boilers are imported and there are no boiler manufacturers in Myanmar.
- About half boilers are second-hand and others are brand-new.
- Approximately, 90-100 units of boilers are newly installed annually.
- The number of boiler suppliers in Myanmar is limited. Factories with import license directly contact with foreign boiler suppliers and import boilers.

1.2 Fuel for boilers in Myanmar

Out of 2,390 units, 65% use biomass (rice husk or agricultural residue) as fuel (Table 1). Locations of biomass boilers installed are limited to areas near rice mills or where agricultural residue is produced, due to constraints in transportation and storage. Therefore, where it is difficult to procure biomass fuel and only fossil fuel fired boilers are already installed, it is assumed that fossil fuel fired boilers are not replaced with biomass boilers due to constraints in transportation and storage, cost and output capacity. In industrial estate, most of the factories apply oil or coal boiler. Dual fuel type (oil and gas) boilers are also applied. Natural gas was once used in industries, but at present natural gas is mainly applied only in power sector or limited government factory and not distributed to private industry due to shortage of domestic gas supply. Small number of LPG boilers are installed in downtown area where space is limited. Those LPG boilers are of small capacities for commercial purpose.

Recently, there are cases in which residents of areas near cities oppose the introduction of coal equipment, and oil boilers are selected in spite of high fuel cost in such areas. In areas far from residential areas, coal boilers still tend to be selected. Accordingly, oil boiler is the majority in recent trend amongst the fossil fuel fired boilers, followed by coal boiler.

Table 1: Number of Boiler Units in operation by Fuel Type

Types	Biomass	Oil	Gas	Coal	Electric	Waste Heat	Total
Number of boiler units	1,547	366	156	153	155	13	2,390
Percentage	65%	15%	7%	6%	6%	1%	100%

[1] Source: Boiler Inspection Department (BID) of Ministry of Industry (MOI). It is necessary for all the boilers installed in Myanmar to be inspected by BID.

Source: Boiler Inspection Department, Ministry of Industry (2016)

1.3 Type of boiler installed in Myanmar

About 60% is water tube type and remaining 40% are fire tube type[2]. Installation of once-through boiler has just been started in Myanmar. Efficiency improvement with economizer or other efficiency improvement attachment is not commonly practiced.

1.4 Share of boiler manufacturers in Myanmar

There is no particular predominant manufacturer in the boiler market of Myanmar. Following table shows the market share of boiler manufacturers in Myanmar.

Table 2: Share of Boiler Manufacturers in Myanmar

Company	Country of origin	Share
A	Germany	16%
B	India	10%
C	UK	7%
Other	-	67%

Source: Industrial Boilers Market-Customization, Marketsandmarkets (June 2017)

2. Reference Boiler Efficiency

2.1 Oil and gas boilers

Apart from biomass, oil and gas boilers are widely installed for industry in Myanmar. The thermal efficiency of oil and gas boilers by major boiler manufacturers in Myanmar is collected from manufacturer's specification in catalogues, which is summarized in the Table 3 below.

Table 3: Efficiency of Boilers (Oil and Gas)

Company	Country of origin	Equivalent evaporation (t/h)	Thermal Efficiency	Type	Fuel
A	Germany	4	84.5%	Water Tube	Oil&Gas
		6	84.5%	Water Tube	Oil&Gas
		8	84.5%	Water Tube	Oil&Gas
B	India	1	89.0%	Fire Tube	Oil&Gas
		2	89.0%	Fire Tube	Oil&Gas
		6	89.0%	Fire Tube	Oil&Gas
C	UK	5	89.0%	Fire Tube	Oil
		6	89.0%	Fire Tube	Oil
		7.26	89.0%	Fire Tube	Oil
		5	88.0%	Fire Tube	Gas

[2] Source: Industrial Boilers Market-Customization, Marketsandmarkets (June 2017)

		6	88.0%	Fire Tube	Gas
		7.26	88.0%	Fire Tube	Gas

Source: Catalogues of manufacturers

From the above table, the highest efficiency of oil and gas boilers in Myanmar is 89%.

2.2 Coal boilers

As shown in Table 1, coal boilers are also used in Myanmar. Coal boilers are mainly from India and China. The efficiency of coal boilers in the catalogues of coal boiler installed in Myanmar is as follows.

Table 4: Efficiency of Coal Boilers

Company	Country of origin	Equivalent evaporation (t/h)	Thermal Efficiency	Type	Fuel
B	India	1.5	82.5%	Fire Tube	Coal
		3	82.5%	Fire Tube	Coal
		4	82.5%	Fire Tube	Coal
		6	82.5%	Fire Tube	Coal
D	China	0.5	76.0%	unknown	Coal
		2	78.0%	unknown	Coal
		4	78.0%	unknown	Coal

Source: Catalogues of manufacturers

As a comparison, the CDM Tool 09 "Methodological tool determining the baseline efficiency of thermal or electric energy generation systems ver. 2.0" sets the default efficiency of old[3] coal fired boiler at 80%. As shown in Table 3 and Table 4, efficiency of coal boiler is lower than that of oil and gas boiler. It is thus conservative to set the default efficiency of coal boiler at 89%, the same as oil and gas boiler. In case of fuel switch from coal to oil or coal to gas, boiler efficiency of 89% is also applied as the default efficiency of reference boiler.

2.3. Setting Reference Boiler Efficiency

Based on the surveys above, reference boiler in Myanmar can be defined as follows in a conservative manner.

- Water tube boiler and fire tube boiler
- Oil-fired, oil and gas-fired (dual fuel), or coal-fired boiler
- Boiler efficiency:89%
- Not equipped with economizer or with other efficiency improvement functions

3. Conservativeness of setting of boiler efficiency

[3] For the purposes of the CDM tool, "old" refers to equipment with an individual age of at least 10 years (Methodological tool "Tool to determine the baseline efficiency of thermal or electric energy generation systems" version 01).

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The advantage of once-through boiler (project boiler) is that its 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 shows the test result conducted by a boiler manufacturer to compare efficiency between once-through boiler and fire tube boiler.

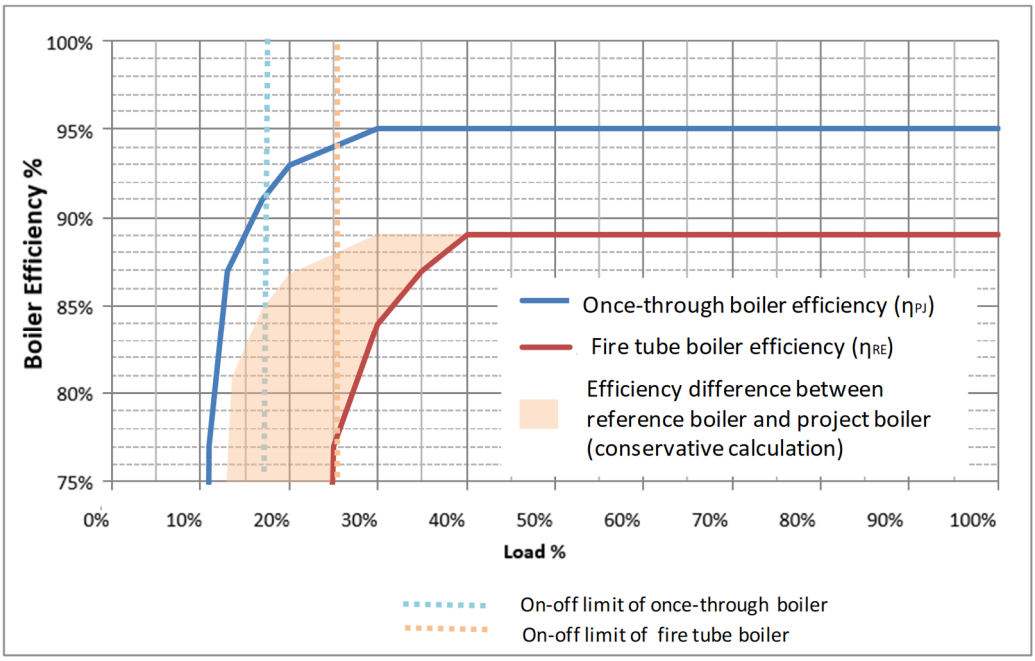

Figure 1: Efficiency comparison between once-through boiler and fire tube boiler at various load range

Source: Based on Japanese boiler manufacturer's test report

As shown in the above figure, when the load rate is at the small range (e.g. 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 (94-95%) at the same range.

When the load is less than 25% (on-off limit), fire tube 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 generally more than 25%, and the efficiency becomes again lower at smaller load range. Meanwhile, the on-off limit of the once-through boiler is 17%, which means that the boiler keeps good efficiency in a 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, consequently CO_2 emission reductions as well. Depending on factory production pattern, it is quite often that boiler load becomes less than 35%. Therefore, the default setting of reference efficiency at 89%, which is higher than the efficiency of fire-tube boiler at a small load rate, is considered to be conservative.

4. Capacity of Once-through Boiler

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Capacity range of once-through boiler in the world is generally equal to or smaller than 7 ton/hour (t/h) in manufacturers' specification. Once-through boilers exceeding 7 t/h are not available in the market in Myanmar, unless custom design order is specially made. Thus, efficiency and other technical data of once-through boiler with the capacity of more than 7 t/h is not available. Therefore, the condition "The project boiler is a once-through boiler with a rated capacity of 7 ton/hour per unit or less (equivalent evaporation)" is set as an eligibility criterion.

5. Emission factor of coal in Myanmar

There are various types of coal with different emission factor, i.e., Anthracite (0.0946 tCO_2/GJ), Coking Coal (0.0873 tCO_2/GJ), Other Bituminous Coal (0.0895 tCO_2/GJ), Sub-Bituminous Coal (0.0928 tCO_2/GJ), and Lignite (0.0909 tCO_2/GJ)[4].

Emission factor of lignite is applied as a default value for emission factor of coal in this methodology for the following reasons:

- Myanmar coal is generally of the low quality lignite and sub-bituminous[5].
- Most of the coal produced in Myanmar is of sub-bituminous coal, although a small percentage (about 7% in the year 2012-2013) of coal produced is lignite[6].
- For example, Tigit 120 MW coal power plant only uses lignite coal.

Since emission factor of lignite is smaller than that of sub-bituminous coal, applying emission factor of lignite as a default emission factor of coal would be conservative.

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[4] The value refers IPCC default value from Table 1.4 of Chapter 1 of Vol. 2 of the "2006 IPCC Guidelines for National GHG Inventories"

[5] According to Myanmar National Energy Policy 2014

[6] Myanmar Energy Master Plan (ADB TA No. 8356-MYA)