ADDITIONAL INFORMATION FOR REFERENCE EMISSIONS

I. Conservative setting of burner efficiencies

According to the results of the interviews to manufacturers, when holding aluminum melt at the temperature of 600-800 degrees Celsius, furnace atmospheric temperature commonly ranges 750-950 degrees Celsius (see Table 1).

In a furnace with a *conventional* burner, the exhaust gas temperature is the same as the furnace atmospheric temperature because there is no equipment between the furnace and the exhaust duct. Since the furnace atmospheric temperature commonly ranges 750-950 degrees Celsius, the reference exhaust gas temperature is set at the lowest value (750 degrees Celsius) of that range.

In a furnace with a *regenerative* burner, the exhaust gas temperature becomes lower than the furnace atmospheric temperature due to the heat absorber. From the measured test data for regenerative burners, the exhaust gas temperature is below 300 degrees Celsius even when the furnace atmospheric temperature is at 750-950 degrees Celsius (see Table 2). In order to be conservative, the project exhaust gas temperature is set at 300 degrees Celsius which is higher than the possible temperature of the project exhaust gas.

Assuming constant furnace atmospheric temperature, energy efficiency of burner increases as the exhaust gas temperature falls since low exhaust gas temperature means recovery of energy contained in the exhaust gas. This methodology results in a conservative calculation of emission reductions by assuming a low exhaust gas temperature for reference furnace and a high exhaust gas temperature for project burner when calculating the default burner efficiency.

Table 1: Interview results on holding and furnace atmospheric temperature

Interviewee	Summary of comments
Association A	Holding temperature for ADC12 aluminum alloy* typically ranges 660-710 degrees Celsius.
Company B	Holding temperature in the semi-solid aluminum casting ranges 610-630 degrees Celsius.
Association C	Aluminum holding furnace atmospheric temperature typically ranges 850-950 degrees Celsius.
	Aluminum holding furnace atmospheric temperature is commonly 150-degrees higher than holding temperature.

Source: Interviews conducted by the methodology proponents.
Note: * ADC12 aluminum alloy accounts for over-90% share of the entire alloy die casting.

Table 2: Interview results on regenerative burner’s exhaust gas temperature

Interviewee	Summary of comments
Company D (A burner manufacture)	In a common aluminum holding furnace with regenerative burner, the exhaust gas temperature is controlled to maintain at all times below 300 degrees Celsius (usually around 200 degrees Celsius) in order to prevent damage caused by high temperature on switch valves, the apparatus unique to regenerative burners.
Association C	Regenerative burner’s exhaust gas temperature is commonly designed to be around 200 degrees Celsius.

Source: Interviews conducted by the methodology proponents.

Following the above assumption, the default vales of reference furnace energy efficiency is calculated to be 0.682 assuming a value of 1.05 for the air ratio. It is observed that this value is conservative since 0.682 is higher than the measured data reported by one of the manufacturers for the range of furnace atmospheric temperature during normal operating conditions (750-950 degrees Celsius) as shown in Figure 1.

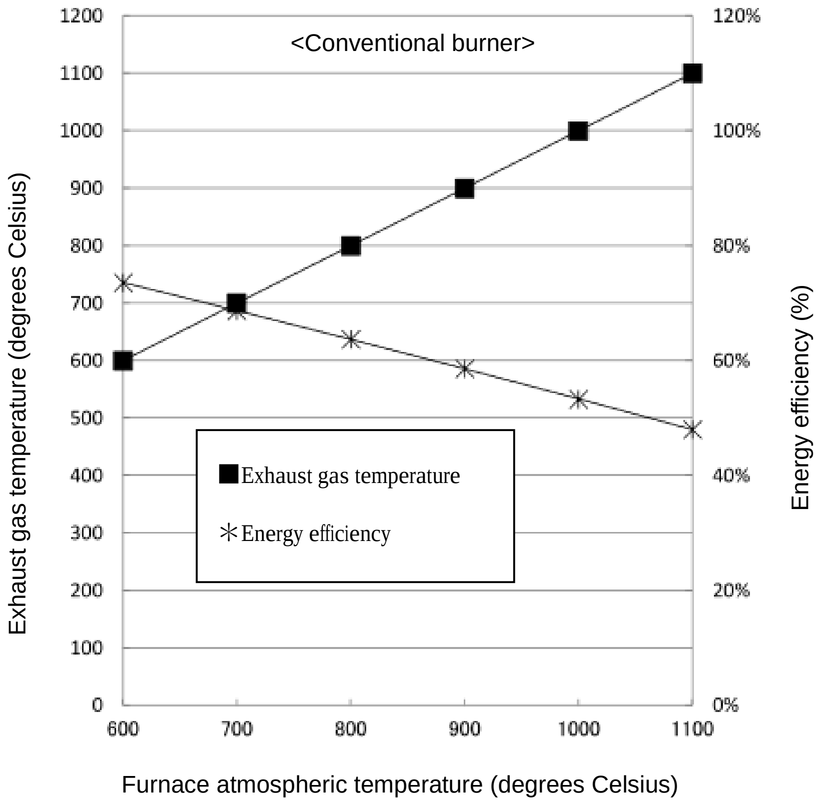

Figure 1: Energy efficiencies with the furnace atmospheric temperature

(Source: Company D)

II. Other parameters for energy efficiency of furnaces

1) Theoretical amount of air necessary for the combustion of fossil fuels

The theoretical amount of air necessary for the combustion of fossil fuels is calculated based on the type and composition of fossil fuel.

Where the combustion reaction formula is:

$$C_mH_n+(m+n/4)O_2 \rightarrow mCO_2+(n/2)H_2O$$

The theoretical amount of air necessary for the combustion of fossil fuels is calculated by the following formula. “0.21” is the composition of O_2 in the air.

$$A_{0,ff} =(m+n/4)/0.21$$

2) Theoretical volume of wet exhaust gas from the combustion of fossil fuels

The theoretical volume of *wet* exhaust gas from the combustion of fossil fuels is calculated based on the theoretical amount of air and the theoretical volume of *dry* exhaust gas.

Under the aforementioned combustion reaction formula, the theoretical volume of *dry* exhaust gas is calculated by the following formula:

Theoretical volume of *dry* exhaust gas = Theoretical amount of air*(1-0.21)+m

Then, the theoretical volume of *wet* exhaust gas is calculated by the following formula:

Theoretical volume of *wet* exhaust gas = Theoretical volume of *dry* exhaust gas+(n/2)

By the formulas explained above, actual parameter values of theoretical amount of air and theoretical volume of gasses for the specific fossil fuel components are calculated as follows:

Table 3: Calculation of the parameters regarding combustion of major fuel components

Unit: Nm^3/Nm^3

Fuel component	Combustion reaction formula	Theoretical amount of air	Theoretical volume of *dry* exhaust gas	Theoretical volume of *wet* exhaust gas
Methane	$CH_4+2O_2 \rightarrow CO_2+2H_2O$	9.5	8.5	10.5
Ethane	$2\ C_2H_6+7O_2 \rightarrow 4CO_2+6H_2O$	16.7	15.2	18.2
Propane	$C_3H_8+5O_2 \rightarrow 3CO_2+4H_2O$	23.8	21.8	25.8
Butane	$2\ C_4H_{10}+13O_2 \rightarrow 8CO_2+10H_2O$	31.0	28.5	33.5

Source: The methodology proponents.

3) Mean specific heat at constant pressure

The mean specific heat at a specific temperature is defined as the mean value between that temperature and 0 degrees Celsius, which is referred to JIS G, Appendix Table 2.

Strictly speaking, the specific heat at constant pressure of wet exhaust gas and of air varies depending on their pressure. On the other hand, the influence of the pressure on the specific heat is considered to be negligible in the methodology because the value increases only by 0.07% even in the condition that the pressure inside furnaces doubles, i.e. to be at around 2 atm, while the pressure inside furnaces commonly remains around 1 atm (101.3kPa) at actual operating condition.

4) Air ratio for the reference burner

The air ratio for the burner is regularly given as a design variable for each equipment and controlled to maintain within a certain range from the perspective of the safety and the efficiency. When substantial and/or frequent deviation occurs, its causes are examined at the periodical check or other investigating opportunities.

While the optimum air ratio is 1.00 which theoretically realizes the most appropriate condition for combustion, in actual operation it is usually recommended to set the ratio at least as 1.05 for the safety reason. As the ratio rises, the energy efficiency of a furnace falls as shown in Table 4. Therefore setting 1.05 as default air-ratio for the reference burner is considered to be conservative.

Table 4: Change of the energy efficiency in response to the air ratio for the burner

Air ratio for the reference burner	1.05	1.15
Energy efficiency of the reference furnace	0.682	0.656

Source: The methodology proponents.

5) Composition and net calorific value of natural gas

Natural gas is the assumed fossil fuel for the calculation of energy efficiencies in this methodology. While composition and net calorific value (NCV) of natural gas may fluctuate daily in the actual situation, in this methodology these values in calculating reference and project burner efficiencies are set as the conservative default value referring to *IPCC Special Report on Carbon dioxide Capture and Storage,* Annex I, Table AI.10.

Table 5 compares the value of default NCV derived from its composition to the actual highest and lowest values of NCV derived from their compositions which are reported by an Indonesian natural gas provider as the data in March 2014 as well as their effect on the burner efficiencies.

The NCV (Typical) falls between those of the actual highest and lowest values of NCV, thus it is considered to be appropriate to set it as the default value in the calculation of emission reductions. In addition, it is observed that possible fluctuation of the natural gas composition has marginal effect on the calculation of emission reductions since based on the actual reported highest and lowest values mentioned above whose fluctuation is calculated to be 3.3%, its effect on the efficiency ratio of the project burner to the reference burner is 0.6%.

Table 5: Change of the energy efficiency in response to the net calorific value and composition of natural gas

		Typical	High	Low
Net calorific value [kJ/Nm^3]		36,659	38,597	36,133
Composition [%]	Methane CH_4	94.4	86.0	89.4
	Ethane C_2H_6	3.1	4.4	3.7
	Propane C_3H_8	0.5	2.5	0.9
	Isobutan/N-butan C_4H_{10}	0.2	1.1	0.4
	Carbon dioxide CO_2	0.5	4.0	4.8
	Nitrogen N_2	1.1	1.2	0.6
Energy efficiency of the project furnace η_{PJ} [-]		0.865	0.872	0.863
Energy efficiency of the reference furnace η_{RE} [-]		0.682	0.698	0.678
Efficiency ratio η_{PJ}/η_{RE} [-]		1.268	1.249	1.274

Source: *IPCC Special Report on Carbon dioxide Capture and Storage*, Annex I, Table AI.10;

III. Mechanism of the regenerative burner

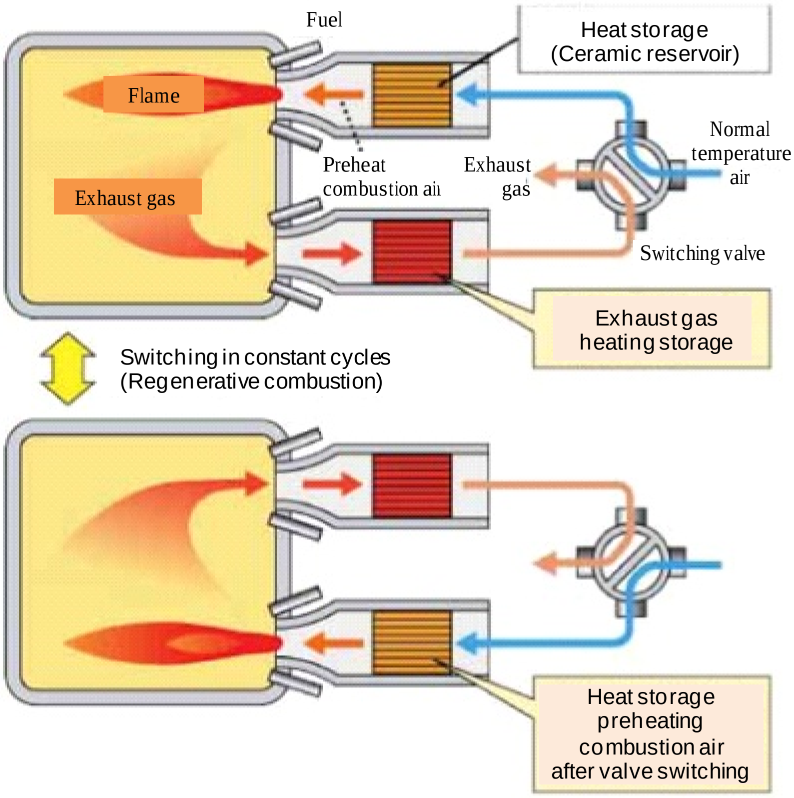

Figure 2: Schematic diagram of the regenerative burner
(Source: Japan Industrial Furnace Manufactures Association)