Joint Crediting Mechanism Approved Methodology TH_AM018
"Waste heat recovery and utilization by installing heat exchanger to heat recovery steam generator of gas co-generation system"

A. Title of the methodology

Waste heat recovery and utilization by installing heat exchanger to heat recovery steam generator of gas co-generation system, Ver. 01.0

B. Terms and definitions

Terms	Definitions
Gas co-generation system	Gas co-generation system is a system which is composed of gas turbines and heat recovery steam generators equipped with duct burners. It generates steam by using recovered waste heat of exhaust gas emitted from gas turbines with supplemental use of duct burners.
Heat recovery steam generator (HRSG)	Heat recovery steam generator (HRSG) is a waste heat recovery boiler which utilizes waste heat of exhaust gas emitted by gas turbines as a heat source.
Duct burner	Duct burner is a device which additionally burns fuel gas to supplement the heat source of HRSGs.
Heat exchanger	Heat exchanger is a mechanical device that recovers and transfers the waste heat from HRSGs to feed water of HRSGs, which increases the overall boiler's thermal efficiency.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	By installing heat exchanger(s) in HRSGs of gas co-generation system(s), feed water into the HRSGs is heated up. Consequently, consumption of fuel gas by duct burners is

	reduced, leading to the reduction of GHG emissions.
Calculation of reference emissions	Reference emissions are calculated using the amount of fuel gas consumed by duct burners of HRSGs with project heat exchangers, density of fuel gas consumed by duct burners of HRSGs, net calorific value of fuel gas consumed by duct burners of HRSGs, CO_2 emission factor for the fuel gas consumed by duct burners of HRSGs, the amount of heating energy recovered by project heat exchangers and the amount of heating energy transferred into the feed water of the HRSGs with project heat exchangers.
Calculation of project emissions	(In case that the project additionally consumes electricity) Project emissions are calculated with electricity consumption of heat exchangers, and CO_2 emission factor for electricity consumed.
Monitoring parameters	● Amount of fuel gas consumed by duct burner of HRSGs with project heat exchanger ● Flow rate of feed water into project heat exchanger ● Temperature of water at the outlet of project heat exchanger ● Temperature of water at the inlet of project heat exchanger ● Flow rate of feed water into HRSGs generator with project heat exchanger ● Temperature of feed water into HRSGs with project heat exchanger ● Amount of electricity consumed by heat exchangers

D. Eligibility criteria

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

Criterion 1	Project installs heat exchanger(s) to heat up feed water into HRSGs in a gas co-generation system.
Criterion 2	Heat exchangers have not been installed to the gas co-generation system of the project prior to its implementation.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Fuel gas consumed by duct burner(s) to generate the heating energy equivalent to the energy recovered by project heat exchangers and utilized for heat supply	CO_2
Project emissions	
Emission sources	GHG types
Electricity consumed by heat exchangers	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

By installing heat exchangers, the amount of heating energy supplied to HRSGs is reduced because the temperature of feed water circulated to HRSGs is increased by heat recovered through the heat exchangers. As the amount of waste heat transferred from exhaust gas of gas turbines to HRSGs is not affected by installation of the heat exchangers, heating energy saved by the project is almost only from fuel gas consumed by duct burner. The business-as-usual (BaU) emissions are the emissions occurred when duct burners supply an equivalent amount of all the heating energy recovered by heat exchangers.

The net emission reductions are ensured in the following manner.
Although the reduction of heating energy is mostly achieved in duct burners in practice as mentioned above, this methodology assumes that it is achieved in both duct burners and waste heat from gas turbines in a certain ratio. Under this assumption, only the portion of the reductions for duct burners is considered as the reference emissions. This idea is applied to the equations for calculating reference emissions.

F.2. Calculation of reference emissions

$$RE_p = \sum_i FC_{db,PJ,i,p} \times D_{gas} \times NCV_{gas} \times EF_{gas,fuel} \times \frac{QHR_{he,PJ,i,p}}{QHT_{fw,PJ,i,p}} / 1000$$

$$QHR_{he,PJ,i,p} = F_{he,PJ,i,p} \times (TO_{he,i,p} - TI_{he,i,p}) \times C_p / 1000$$

$$QHT_{fw,PJ,i,p} = F_{fw,i,p} \times (h''_{steam,i} - h'_{fw,PJ,i,p})$$

$$h'_{fw,PJ,i,p} = T_{fw,PJ,i,p} \times C_p/1000$$

Where;

RE_p	:	Reference emissions during the period p [tCO_2/p]
$FC_{db,PJ,i,p}$	:	Amount of fuel gas consumed by duct burners of the HRSG with project heat exchanger i during the period p [Nm^3/p]
D_{gas}	:	Density of fuel gas consumed by duct burners of HRSGs [kg/Nm^3]
NCV_{gas}	:	Net calorific value of fuel gas consumed by duct burners of HRSGs [GJ/t]
$EF_{gas,fuel}$	:	CO_2 emission factor for the fuel gas consumed by duct burners of HRSGs [tCO_2/GJ]
$QHR_{he,PJ,i,p}$	:	Amount of heating energy recovered by project heat exchanger i during the period p [GJ/p]
$F_{he,PJ,i,p}$	:	Flow rate of feed water into project heat exchanger i during the period p [t/p]
$TO_{he,PJ,i,p}$	:	Temperature of water at the outlet of project heat exchanger i during the period p [°C]
$TI_{he,PJ,i,p}$	:	Temperature of water at the inlet of project heat exchanger i during the period p [°C]
C_p	:	Specific heat capacity of water [MJ/(t·Δ°C)]
$QHT_{fw,PJ,i,p}$		Amount of heating energy transferred into the feed water of the HRSG with project heat exchanger i during the period p [GJ/p]
$F_{fw,i,p}$	:	Flow rate of feed water into the HRSG with project heat exchanger i during the period p [t/p]
$h''_{steam,i}$	:	Specific enthalpy of steam supplied by the HRSG with project heat exchanger i [GJ/t]
$h'_{fw,PJ,i,p}$	:	Specific enthalpy of feed water into the HRSG with project heat exchanger i during the period p [GJ/t]
$T_{fw,PJ,i,p}$	:	Temperature of feed water into the HRSG with project heat exchanger i during the period p [°C]
i	:	Identification number of the project heat exchanger

G. Calculation of project emissions

$$PE_p = EC_{PJ,p} \times EF_{elec}$$

Where;

PE_p	:	Project emissions during the period p [tCO_2/p]
$EC_{PJ,p}$	:	Amount of electricity consumed by project heat exchanger(s) during the period p [MWh/p]
EF_{elec}	:	CO_2 emission factor of consumed electricity [tCO_2/MWh]

H. Calculation of emissions reductions

$$ER_p = RE_p - PE_p$$

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
D_{gas}	Density of the fuel gas consumed by duct burner of HRSGs [kg/Nm^3]	In the order of preference: a) values provided by fuel supplier; b) measurement by the project participants; or c) regional or national default values;
NCV_{gas}	Net calorific value of the fuel gas consumed by duct burner of HRSGs [GJ/t]	In the order of preference: a) values provided by fuel supplier; b) measurement by the project participants; c) regional or national default

		values; or 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.
$EF_{gas,fuel}$	CO_2 emission factor for the fuel gas consumed by duct burner of HRSGs [tCO_2/GJ]	In the order of preference: a) values provided by fuel supplier; b) measurement by the project participants; c) regional or national default values; or 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.
C_p	Specific heat capacity of water [MJ/(t·Δ°C)] A default value is set to 4.184 [MJ/(t·Δ°C)]	Theoretical value provided in table 6 of Cabinet Order No. 357 of 1992, Japan
$h''_{steam,i}$	Specific enthalpy of steam supplied by the HRSG with project heat exchanger *i* [GJ/t]	Saturated steam table based on "IAPWS Industrial Formulation" (e.g. steam table published by The Japan Society of Mechanical Engineers), using the values for setting steam pressure according to vendor specification, contract condition by the steam buyer or operation manual on the site.
EF_{elec}	CO_2 emission factor of consumed electricity [tCO_2/MWh]. When project heat exchanger(s) consumes only 1) grid electricity, 2) captive electricity or 3) electricity directly supplied from small power producer (SPP) to the project site through its internal grid (e.g. industrial park), the project participant	**Grid electricity:** The most recent value available at the time of validation is applied and fixed for the monitoring period thereafter. The data is sourced from "Grid Emission Factor (GEF) of Thailand", endorsed by Thailand Greenhouse Gas Management Organization, unless otherwise

	applies the CO_2 emission factor respectively. When project heat exchanger(s) may consume electricity supplied from more than 1 electric source, the project participant applies the CO_2 emission factor with the highest value. [CO_2 emission factor] **For 1) grid electricity:** The most recent value available from the source stated in this table at the time of validation. **For 2) captive electricity:** It is determined based on the following options: **a)** <u>Calculated from its power generation efficiency (η_{cap} [%]) obtained from manufacturer's specification</u> The power generation efficiency based on lower heating value (LHV) of the captive power generation system from the manufacturer's specification is applied; $$EF_{elec} = 3.6 \times \frac{100}{\eta_{cap}} \times EF_{fuel,cap}$$ **b)** <u>Calculated from measured data</u> The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{cap,p}$) and the amount of electricity generated ($EG_{cap,p}$) during the monitoring period p is applied. The measurement is conducted with the monitoring equipment to which calibration certificate is issued by an entity	instructed by the Joint Committee. **Captive electricity:** <u>For the option **a)**</u> Specification of the captive power generation system provided by the manufacturer (η_{cap} [%]). CO_2 emission factor of the fuel consumed by the captive power generation system ($EF_{fuel,cap}$ [tCO_2/GJ]) in order of preference: 1) values provided by the fuel supplier; 2) measurement by the project participants; 3) regional or national default values; 4) IPCC default values provided in table 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Upper value is applied. <u>For the option **b)**</u> Generated and supplied electricity by the captive power generation system ($EG_{cap,}$ [MWh/p]). Fuel amount consumed by the captive power generation system ($FC_{cap,}$ [mass or volume/p]). Net calorific value ($NCV_{fuel,cap}$ [GJ/mass or volume]) and CO_2 emission factor of the fuel ($EF_{fuel,cap}$ [tCO_2/GJ]) in order of preference: 1) values provided by the fuel supplier; 2) measurement by the project participants;

	accredited under national/international standards; $EF_{elec} = FC_{cap,p} \times NCV_{fuel,cap} \times EF_{fuel,cap} \times \frac{1}{EG_{cap,p}}$ Where: $NCV_{fuel,cap}$: Net calorific value of the fuel consumed by the captive power generation system connected to the boiler [GJ/mass or volume] **c)** Conservative default value: A value of 1.3 tCO_2/MWh is applied. **For 3) electricity directly supplied from small power producer (SPP),** It is determined based on the following options: a) The value provided by the SPP with the evidence; b) The value calculated in the same manner for the option a) of 2) captive electricity as instructed above; c) The value calculated in the same manner for the option b) of 2) captive electricity as instructed above. When project heat exchangers may consume electricity supplied from more than 1 SPP, the project participant applies the CO_2 emission factor with the highest value.	3) regional or national default values; 4) IPCC default values provided in tables 1.2 and 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Upper value is applied. For the option **c)** CDM methodological tool "TOOL 05: Baseline, project and/or leakage emissions from electricity consumption and monitoring of electricity generation, version 03.0" **Electricity directly supplied from SPP** For option a) The evidence stating information relevant to the value of emission factor (e.g. data of power generation, type of power plant, type of fossil fuel, period of time).

History of the document

Version	Date	Contents revised
01.0	14/07/2025	Electronic decision by the Joint Committee Initial approval.