JCM Proposed Methodology Form

Cover sheet of the Proposed Methodology Form

Form for submitting the proposed methodology

Host Country	The Kingdom of Thailand
Name of the methodology proponents submitting this form	Institute for Global Environmental Strategies (IGES)
Sectoral scope(s) to which the Proposed Methodology applies	1. Energy industries (renewable- / non-renewable sources)
Title of the proposed methodology, and version number	Waste heat recovery and utilization by installing heat exchanger to heat recovery steam generator of gas co-generation system, Ver. 01.0
List of documents to be attached to this form (please check):	☐The attached draft JCM-PDD: ☒Additional information
Date of completion	28/04/2022

History of the proposed methodology

Version	Date	Contents revised
01.0	28/04/2022	First Edition

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	A system is composed of gas turbine and heat recovery steam generator equipped with duct burner. By recovering waste heat of exhaust gas emitted by gas turbine, steam is generated being supported by duct burner.
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 turbine as heat source.
Duct burner	Duct burner is an equipment which additionally burns fossil gas fuel to support heat source of HRSG
Heat exchanger	Heat exchanger is a mechanical device that recovers and transfers the waste heat from HRSG to the incoming feed water of heat recovery steam generator, which increases the overall boiler's thermal efficiency.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	By installing heat exchanger(s) to heat recovery steam generator of gas co-generation system(s), feed water into heat recovery steam generator is heated up. Consequently, consumption of fossil gas fuel by duct burner is reduced, leading to the reduction of GHG emissions.
Calculation of reference emissions	Reference emissions are calculated using amount of fossil gas fuel consumed by duct burner of heat recovery steam generator with project heat exchanger, density of fossil gas fuel consumed by duct burner of heat recovery steam generator, net calorific

	value of fossil gas fuel consumed by duct burner of heat recovery steam generator, CO_2 emission factor for the fossil gas fuel consumed by duct burner of heat recovery steam generator, amount of heating energy recovered by project heat exchanger and amount of heating energy transferred into the feed water of the heat recovery steam generator with project heat exchanger.
Calculation of project emissions	(In case that project additionally consumes electricity) Project emissions are calculated with electricity consumption of pre-treatment equipment(s) and CO_2 emission factor for electricity consumed.
Monitoring parameters	● Amount of fossil gas fuel consumed by duct burner of heat recovery steam generator 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 heat recovery steam generator with project heat exchanger ● Temperature of feed water into heat recovery steam generator with project heat exchanger ● Amount of electricity consumed by the project

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 heat recovery steam generator in gas co-generation system.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Fossil gas fuel consumed by duct burner(s) to generate the amount of heating energy recovered by project heat exchanger and utilized for heat supply	CO_2
Project emissions	

Emission sources	GHG types
Electricity consumed by project	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

By implementing the project, the amount of fossil gas fuel consumed by duct burner of heat recovery steam generator (HRSG) is reduced because the temperature of feed water into HRSG is increased by heat recovered by project heat exchanger. The amount of waste heat from exhaust gas of gas turbine into heat recovery steam generator is more of the same as the one without in the absence of the project.
Heating energy saved by the project is almost only from fossil gas fuel consumed by duct burner.
However, in this methodology, the total amount of heating energy saved by the project is distributed into the one from fossil gas fuel consumed by duct burner and the one of waste heat from exhaust gas of gas turbine by a certain ratio. That means that the waste heat from the gas turbine is easily transferred to the steam, and the amount of saving fossil gas fuel consumed by duct burner is conservatively identified.
This concept is applied to the equation for calculating reference emissions in order to ensure net emission reductions.

F.2. Calculation of reference emissions

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

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

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

$$h'_{fw,PJ,i,p} = (T_{fw,PJ,i,p} - 0) \times C_p/1000$$

Where;

RE_p : Reference emissions during the period p [tCO_2/p]

$FC_{db,PJ,i,p}$	:	Amount of fossil gas fuel consumed by duct burner of heat recovery steam generator with project heat exchanger *i* during the period *p* [Nm^3/p]
D_{gas}	:	Density of fossil gas fuel consumed by duct burner of heat recovery steam generator [kg/Nm^3]
NCV_{gas}	:	Net calorific value of fossil gas fuel consumed by duct burner of heat recovery steam generator [GJ/t]
$EF_{gas,fuel}$	:	CO_2 emission factor for the fossil gas fuel consumed by duct burner of heat recovery steam generator [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* [degree Celsius]
$TI_{he,PJ,i,p}$	:	Temperature of water at the inlet of project heat exchanger *i* during the period *p* [degree Celsius]
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 heat recovery steam generator with project heat exchanger *i* during the period *p* [GJ/p]
$F_{fw,i,p}$	:	Flow rate of feed water into the heat recovery steam generator with project heat exchanger *i* during the period *p* [t/p]
$h''_{steam,i}$	:	Specific enthalpy of steam supplied by the heat recovery steam generator with project heat exchanger *i* [GJ/t]
$h'_{fw,PJ,i,p}$	:	Specific enthalpy of feed water into heat recovery steam generator with project heat exchanger *i* during the period *p* [GJ/t]
$T_{fw,PJ,i,p}$	:	Temperature of feed water into the heat recovery steam generator with project heat exchanger *i* during the period *p* [degree Celsius]
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 fossil gas fuel consumed by duct burner of heat recovery steam generator [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 fossil gas fuel consumed by duct burner of heat recovery steam generator [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 fossil gas fuel consumed by duct burner of heat recovery steam generator [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 heat recovery steam generator 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 applies the CO_2 emission factor respectively. When project heat exchanger(s) may consume electricity supplied from more	**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 instructed by the Joint Committee. **Captive electricity:** <u>For the option **a)**</u> Specification of the captive power

	than 1 electric source, the project participant applies the CO_2 emission factor with 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)** Calculated from its power generation efficiency (η_{cap} [%]) obtained from manufacturer's specification 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)** Calculated from measured data 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 accredited under national/international standards;	generation system connected to the boiler, provided by the manufacturer (η_{cap} [%]). CO_2 emission factor of the fuel consumed by the captive power generation system connected to the boiler ($EF_{fuel,cap}$ [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. For the option **b)** Generated and supplied electricity by the captive power generation system connected to the biomass boiler(s) ($EG_{cap,}$ [MWh/p]). Fuel amount consumed by the captive power generation system connected to the biomass boiler(s) ($FC_{cap,}$ [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; 3) regional or national default

	$EF_{elec} = FC_{cap,p} \times NCV_{fuel,cap} \times EF_{fuel,cap} \times \frac{1}{EG_{cap,p}}$ 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 exchanger may consume electricity supplied from more than 1 SPP, the project participant applies the CO_2 emission factor with the highest value.	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.