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	DENSO CORPORATION Institute for Global Environmental Strategies
Sectoral scope(s) to which the Proposed Methodology applies	3. Energy demand
Title of the proposed methodology, and version number	Installation of gas engine cogeneration system with absorption chiller to supply electricity, heating energy and cooling energy, Version 01.0
List of documents to be attached to this form (please check):	☐The attached draft JCM-PDD: ☒Additional information
Date of completion	04/01/2021

History of the proposed methodology

Version	Date	Contents revised
01.0	04/01/2021	First Edition

A. Title of the methodology

Installation of gas engine cogeneration system with absorption chiller to supply electricity, heating energy and cooling energy, Version 01.0

B. Terms and definitions

Terms	Definitions
Cogeneration System (CGS)	A system that consists of power generator(s) and heat generating equipment (e.g. heat recovery steam generator, exhaust heat exchanger, etc.) and supplies both electricity and heating energy, recovering waste heat exhausted from the power generator(s). The power generator(s) is a gas engine(s) in this methodology.
Absorption chiller	Refrigerating machine using heat source such as heating energy generated by fuel combustion and/or waste heat in the form of hot water, steam or exhaust gas, refrigerant (eg. water) and absorption solution (eg. Lithium bromide, ammonia) to generate chilled water or other chilled liquids by absorption refrigeration cycle.
Recipient Facility	A cluster of buildings and/or plants (or building/plant itself) to which electricity and heating energy generated by CGS are supplied.
Boiler Efficiency	Net quantity of heat generated per quantity of energy contained in fuel fired in the boiler.
Cooling capacity	Capability of individual chiller to remove heat. In this methodology, “cooling capacity” is used to represent a cooling capacity per a single chiller unit and not for a system with multiple chiller units.

C. Summary of the methodology

Items	Summary
GHG emission reduction	Electricity and heating energy generated by a CGS installed in

measures	a project site substitute all or part of grid and/or captive electricity as well as heating energy. Absorption chiller utilizing heating energy generated by a CGS is also introduced to save energy for cooling energy demand. Installation of CGS and absorption chiller leads to efficient energy use of recipient facility(ies) and in turn GHG emission reductions.
Calculation of reference emissions	[Reference emissions for CGS] Reference emissions are CO_2 emissions from the use of grid and/or captive electricity and heating energy (e.g. steam and hot water) generated by a reference boiler, which are calculated with the amount of electricity consumed by the recipient facility(ies) which is generated by the CGS, the amount of heating energy consumed by the recipient facility(ies) which is generated by the CGS, CO_2 emission factors for consumed electricity in the recipient facility(ies), reference boiler efficiency and CO_2 emission factors for fossil fuel consumed by the reference boiler. [Reference emissions for absorption chiller] Reference emissions are GHG emissions from using reference chiller(s) which is determined as centrifugal chiller in this methodology. Reference emissions are calculated with cooling energy generated by project chiller(s), COP of reference chiller, and CO_2 emission factor for consumed electricity. GHG emissions from using chilled water pump, cooling water pump and cooling tower are excluded from calculation since those pumps exist in both reference and project chiller system and they can be canceled each other out.
Calculation of project emissions	[Project emissions from CGS] Project emissions are CO_2 emissions from the use of CGS, which are calculated with the amount of gas fuel consumed by the CGS, net calorific value of gas fuel consumed by the CGS, and CO_2 emission factor of gas fuel consumed by the CGS. [Project emissions from absorption chiller] Project emissions are GHG emissions from using project chiller(s), which are the sum of emissions from electricity

	consumption and fossil fuel consumption. GHG emissions from electricity consumption are calculated with electricity consumption by absorbing solution pumps and refrigerant pumps built in the project chiller(s) and CO_2 emission factor for electricity consumed. GHG emissions from fossil fuel consumption, where applicable, are calculated with fuel consumption of project chiller(s) and CO_2 emission factor for fuel consumed. GHG emissions from using chilled water pump, cooling water pump and cooling tower are excluded from calculation since those pumps exist in both reference and project chiller system and they can be canceled each other out.
Monitoring parameters	● Electricity consumption by the recipient facility(ies) which is generated by the CGS ● Heating energy consumed by the recipient facility(ies) which is generated by the CGS ● Cooling energy generated by the project absorption chiller ● Gas fuel consumption by the CGS ● Electricity consumption by the project absorption chiller ● Gas fuel consumption by the project absorption chiller, where applicable ● The amount of fuel consumed and/or the amount of electricity generated by captive power, where applicable

D. Eligibility criteria

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

Criterion 1	A CGS, whose electricity is generated by a gas engine(s), with absorption chiller(s) utilizing waste heat from CGS is installed and supplies electricity and heating energy (e.g. steam, hot water and chilled water) to recipient facility(ies).
Criterion 2	Electricity and heating energy, each of which is generated in separate systems, are supplied to and consumed by recipient facility(ies) before the installation of a project CGS.
Criterion 3	In the case of replacing the existing chiller with the project chiller, a plan for prevention of releasing refrigerant used in the existing chiller to the air (e.g. re-use of the equipment) is prepared. Execution of this plan is checked at the

	time of verification, in order to confirm that refrigerant used for the existing one replaced by the project is prevented from being released to the air. In the case that the existing chiller is NOT replaced with the project chiller, this criterion is not applied.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Electricity consumption in recipient facility(ies)	CO_2
Fossil fuel consumption for production of steam and hot water consumed in recipient facility(ies)	CO_2
Electricity consumption by reference chiller	CO_2
Project emissions	
Emission sources	GHG types
Gas fuel consumption by CGS	CO_2
Electricity consumption by project chiller	CO_2
Gas fuel consumption by project chiller	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

The following two measures are taken into consideration to ensure the net emission reductions in this methodology.

[Reference boiler efficiency for the CGS]
Reference emissions are calculated with the amount of electricity generated by the CGS and consumed by the recipient facility(ies), the amount of heating energy generated by the CGS and consumed by the recipient facility(ies), reference boiler efficiency, CO_2 emission factors for consumed electricity in the recipient facility(ies) and CO_2 emission factors for fossil fuel consumed by the reference boiler.
A default value for the reference boiler efficiency is conservatively set to 89 [%] taking the highest value among those products sold in Thailand, so as to ensure net emission reductions.

[Reference COP for the absorption chiller]
Reference emissions are calculated with cooling energy of project chiller(s), COP of reference chiller, and CO_2 emission factor for consumed electricity.
GHG emissions from using chilled water pump, cooling water pump and cooling tower are excluded from calculation since those pumps exist in both reference and project chiller system and they can be canceled each other out.
The COP of reference chiller, which is centrifugal chiller, is conservatively set as a default value in the following manner to ensure the net emission reductions.
1. The COP value tends to increase as the cooling capacity becomes larger.
2. The reference COP value varies by its cooling capacity.
3. The maximum values of COP in each cooling capacity range set for this methodology are defined as $COP_{RE,j}$ as described in Section I.

F.2. Calculation of reference emissions

$$\begin{aligned} \boldsymbol{RE_p} &= \sum_i \boldsymbol{RE_{elec,i,p}} + \sum_i \boldsymbol{RE_{heat,i,p}} + \sum_j \boldsymbol{RE_{chiller,j,p}} \\ &= \sum_i \left(\boldsymbol{EC_{i,p}} \times \boldsymbol{EF_{elec,i}}\right) + \sum_i \boldsymbol{HC_{i,p}} \times \frac{\boldsymbol{100}}{\boldsymbol{\eta_{RE}}} \times \boldsymbol{EF_{fuel,RE}} \\ &\quad + \sum_j \left(\frac{\boldsymbol{C_{pj,j,p}}}{\boldsymbol{COP_{RE,j}}} \times \boldsymbol{EF_{elec,j}}\right) \end{aligned}$$

Where

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

$RE_{elec,i,p}$: Reference emissions for electricity consumed by the recipient facility i which is generated by the CGS during the period p [tCO_2/p]

$RE_{heat,i,p}$: Reference emissions for heating energy consumed by the recipient facility i which is generated by the CGS during the period p [tCO_2/p]

$RE_{chiller,j,p}$: Reference emissions by reference chiller j during the period p [tCO_2/p]

$EC_{i,p}$: Electricity consumption by the recipient facility i which is generated by the CGS during the period p [MWh/p]

$EF_{elec,i}$: CO_2 emission factor for consumed electricity in the recipient facility i [tCO_2/MWh]

$HC_{i,p}$: Heating energy consumption by the recipient facility i which is generated by the CGS during the period p [GJ/p][*1]

η_{RE} : Reference boiler efficiency [%]

$EF_{fuel,RE}$	:	CO_2 emission factor for fossil fuel consumed by the reference boiler [tCO_2/GJ]
$C_{PJ,j,p}$	:	Cooling energy generated by the project absorption chiller j during the period p [MWh/p]
$COP_{RE,j}$	:	COP of reference chiller j [dimensionless]
$EF_{elec,j}$	:	CO_2 emission factor for consumed electricity by the project absorption chiller j [tCO_2/MWh]
i	:	Identification number of the recipient facility to which electricity and heating energy generated by the CGS are supplied
j	:	Identification number of the project absorption chiller

*1: Amount of heating energy generated by the CGS and consumed by the project absorption chiller is not included in $HC_{i,p}$

G. Calculation of project emissions

$$\boldsymbol{PE_p} = \boldsymbol{PE_{CGS,p}} + \boldsymbol{PE_{chiller,p}}$$

Where

$$\boldsymbol{PE_{CGS,p}} = \boldsymbol{FC_{PJ,CGS,p}} \times \boldsymbol{NCV_{fuel,CGS}} \times \boldsymbol{EF_{fuel,CGS}}$$

$$\boldsymbol{PE_{chiller,p}} = \sum_j \left(\boldsymbol{EC_{PJ,CL,j,p}} \times \boldsymbol{EF_{elec,j}}\right) + \sum_j \left(\boldsymbol{FC_{PJ,CL,j,p}} \times \boldsymbol{NCV_{fuel,CL,j}} \times \boldsymbol{1,000^{-1}} \times \boldsymbol{EF_{fuel,CL,j}}\right)$$

Where

PE_p	:	Project emissions during the period p [tCO_2/p]
$PE_{CGS,p}$	:	Project emissions from the CGS during the period p [tCO_2/p]
$PE_{chiller,p}$	:	Project emissions from project absorption chiller during the period p [tCO_2/p]
$FC_{PJ,CGS,p}$	:	Gas fuel consumption by the CGS during the period p [mass or volume/p]
$NCV_{fuel,CGS}$	:	Net calorific value of gas fuel consumed by the CGS [GJ/mass or volume]
$EF_{fuel,CGS}$	:	CO_2 emission factor for gas fuel consumed by the CGS [tCO_2/GJ]

$EC_{PJ,CL,j,p}$	: Electricity consumption by project absorption chiller j during the period p [MWh/p]
$EF_{elec,j}$	: CO_2 emission factor for electricity consumed by the project absorption chiller j [tCO_2/MWh]
$FC_{PJ,CL,j,p}$	: Gas fuel consumption by project absorption chiller j during the period p [Nm^3/p]
$NCV_{fuel,CL,j}$	: Net calorific value of gas fuel consumed by project absorption chiller j [MJ/Nm^3]
$EF_{fuel,CL,j}$	: CO_2 emission factor for gas fuel consumed by project absorption chiller j [tCO_2/GJ]
j	: Identification number of the project absorption chiller

H. Calculation of emissions reductions

$$\boldsymbol{ER_p = RE_p - PE_p}$$

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
$EF_{elec,i}$	CO_2 emission factor for consumed electricity in the recipient facility i [tCO_2/MWh] When the recipient facility consumes only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively.	**[Grid electricity]** The most recent value available at the time of validation is

	When both grid electricity and captive electricity may be consumed in the recipient facility, the project participant applies the CO_2 emission factor with lower value. [CO_2 emission factor] For grid electricity: The most recent value available from the source stated in this table at the time of validation For captive electricity including cogeneration system, it is determined based on the following options: a) Calculated from its power generation efficiency ($\eta_{cap,i}$ [%]) 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; $$EF_{elec,i} = 3.6 \times \frac{100}{\eta_{cap,i}} \times EF_{fuel,cap,i}$$ b) Calculated from measured data The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{cap,i,p}$) and the amount of electricity generated ($EG_{cap,i,p}$) 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; $$EF_{elec,i} = FC_{cap,i,p} \times NCV_{fuel,cap,i} \times EF_{fuel,cap,i} \times \frac{1}{EG_{cap,i,p}}$$ Where: $NCV_{fuel,cap,i}$: Net calorific value of the fuel consumed by the captive power generation system connected to the recipient facility i [GJ/mass or volume] Note: In case the captive electricity generation system connected to	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]** For the option a) Specification of the captive power generation system connected to the recipient facility i, provided by the manufacturer

	the recipient facility *i* meets all of the following conditions, the value in the following table may be applied to $EF_{elec,i}$ depending on the consumed fuel type. • The system is non-renewable generation system • Electricity generation capacity of the system is less than or equal to 15 MW *1 The most recent value at the time of validation is applied. *2 The value is calculated with the equation in the option a) above. The lower value of default effective CO_2 emission factor for natural gas (0.0543 tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.	($\eta_{cap,i}$ [%]). CO_2 emission factor of the fuel consumed by the captive power generation system connected to the recipient facility *i* ($EF_{fuel,cap,i}$ [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. Lower value is applied. For the option

fuel type	Diesel fuel	Natural gas
$EF_{elec,i}$	0.8 *1	0.46 *2

		b) Generated and supplied electricity by the captive power generation system connected to the recipient facility *i* ($EG_{cap,i,p}$ [MWh/p]). Fuel amount consumed by the captive power generation system connected to the recipient facility *i* ($FC_{cap,i,p}$ [mass or volume/p]). Net calorific value ($NCV_{fuel,cap,i}$ [GJ/mass or volume]) and CO_2 emission factor of the fuel ($EF_{fuel,cap,i}$ [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 tables 1.2 and 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied. [Captive electricity with diesel fuel] CDM approved small scale methodology: AMS-I.A. [Captive electricity with natural gas] 2006 IPCC Guidelines on National GHG Inventories for

		the source of EF of natural gas. CDM Methodological tool "Determining the baseline efficiency of thermal or electric energy generation systems version02.0" for the default efficiency for off-grid power plants.
η_{RE}	Reference boiler efficiency [%] Default value is set to 89 [%].	Value derived from the result of survey. The default value, 89 [%], should be revised if necessary.
$EF_{fuel,RE}$	CO_2 emission factor for fossil fuel consumed by the reference boiler [tCO_2/GJ] CO_2 emission factor of natural gas is applied in this methodology in a conservative manner.	In the order of preference: a) values provided by fuel supplier; b) measurement by the project participants; c) regional or

<table>
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<td>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.</td>
</tr>
<tr>
<td>$COP_{RE,j}$</td>
<td>COP of reference chiller j [dimensionless]

The COP of the reference chiller j is selected from the default COP value in the following table in line with cooling capacity of the project chiller j. (“x” in the table represents cooling capacity per unit.)

[Default COP values of reference chillers]
<table>
<tr><th>Cooling capacity per unit (USRt)</th><th>300≤x≤350</th><th>350<x≤550</th><th>550<x≤750</th><th>750<x≤1,300</th></tr>
<tr><td>$COP_{RE,i}$</td><td>5.46</td><td>5.69</td><td>5.90</td><td>6.03</td></tr>
</table>
</td>
<td>Specifications of project chiller j prepared for the quotation or factory acceptance test data by manufacturer.

The default COP values are derived from the result of survey on COP of chillers from manufacturers that have high market share. The survey</td>
</tr>
</table>

		should prove the use of clear methodology. The default COP values should be revised if necessary from survey result which is conducted by JC or project participants.
$NCV_{fuel,CGS}$	Net calorific value of gas fuel consumed by the CGS [GJ/mass or volume]	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. Upper value is applied.
$EF_{fuel,CGS}$	CO_2 emission factor for gas fuel consumed by the CGS [tCO_2/GJ]	In 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. Upper value is applied.
$EF_{elec,j}$	CO_2 emission factor for consumed electricity by the project absorption chiller *j* [tCO_2/MWh] When the absorption chiller consumes only grid electricity or	**[Grid electricity]** The most recent value available

	captive electricity, the project participant applies the CO_2 emission factor respectively. When both grid electricity and captive electricity may be consumed in the absorption chiller, the project participant applies the CO_2 emission factor with lower value. [CO_2 emission factor] For grid electricity: The most recent value available from the source stated in this table at the time of validation For captive electricity including cogeneration system, it is determined based on the following options: a) Calculated from its power generation efficiency ($\eta_{cap,j}$ [%]) 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; $$EF_{elec,j} = 3.6 \times \frac{100}{\eta_{cap,j}} \times EF_{fuel,cap,j}$$ b) Calculated from measured data The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{cap,j,p}$) and the amount of electricity generated ($EG_{cap,j,p}$) 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; $$EF_{elec,j} = FC_{cap,j,p} \times NCV_{fuel,cap,j} \times EF_{fuel,cap,j} \times \frac{1}{EG_{cap,j,p}}$$ Where: $NCV_{fuel,cap,j}$: Net calorific value of the fuel consumed by the captive power generation system connected to the absorption chiller j [GJ/mass or volume]	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]** For the option a) Specification of the captive power generation system connected to the absorption chiller j,

	Note: In case the captive electricity generation system connected to the absorption chiller *j* meets all of the following conditions, the value in the following table may be applied to $EF_{elec,j}$ depending on the consumed fuel type. • The system is non-renewable generation system • Electricity generation capacity of the system is less than or equal to 15 MW fuel type / Diesel fuel / Natural gas $EF_{elec,i}$ / 0.8 *1 / 0.46 *2 *1 The most recent value at the time of validation is applied. *2 The value is calculated with the equation in the option a) above. The lower value of default effective CO_2 emission factor for natural gas (0.0543 tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.	provided by the manufacturer ($\eta_{cap,j}$ [%]). CO_2 emission factor of the fuel consumed by the captive power generation system connected to the absorption chiller *j* ($EF_{fuel,cap,j}$ [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. Lower value is applied.

		For the option b) Generated and supplied electricity by the captive power generation system connected to the absorption chiller j ($EG_{cap,j,p}$ [MWh/p]). Fuel amount consumed by the captive power generation system connected to the recipient facility j ($FC_{cap,j,p}$ [mass or volume/p]). Net calorific value ($NCV_{fuel,cap,j}$ [GJ/mass or volume]) and CO_2 emission factor of the fuel ($EF_{fuel,cap,j}$ [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 tables 1.2 and 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied. [Captive electricity with diesel fuel] CDM approved small scale methodology: AMS-I.A. [Captive electricity with natural gas] 2006 IPCC Guidelines on

		National GHG Inventories for the source of EF of natural gas. CDM Methodological tool "Determining the baseline efficiency of thermal or electric energy generation systems version02.0" for the default efficiency for off-grid power plants.
$NCV_{fuel,CL,j}$	Net calorific value of gas fuel consumed by the project absorption chiller *j* [GJ/mass or volume]	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. Upper value is applied.
$EF_{fuel,CL,j}$	CO_2 emission factor for gas fuel consumed by the project absorption chiller j [tCO_2/GJ]	In 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.

		Upper value is applied.