JCM Proposed Methodology Form

Cover sheet of the Proposed Methodology Form

Form for submitting the proposed methodology

Host Country	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	3. Energy demand
Title of the proposed methodology, and version number	Energy Saving by Installation of an Evaporator with Mechanical Vapor Recompression, Ver01.0
List of documents to be attached to this form (please check):	☐ The attached draft JCM-PDD: ☒ Additional information
Date of completion	26/12/2019

History of the proposed methodology

Version	Date	Contents revised
01.0	26/12/2019	First edition

A. Title of the methodology

Energy Saving by Installation of an Evaporator with Mechanical Vapor Recompression, Ver.01.0

B. Terms and definitions

Terms	Definitions
Evaporator	An evaporator is a device used in a process turning liquid form in a solution into its vapor to obtain a solution with high concentration.
Mechanical vapor recompression (MVR)	Mechanical vapor recompression is an energy recovery method which boosts low pressure suction vapor generated in an evaporator with a mechanically driven compressor and uses it again as a heating source in an evaporator to heat a liquid such as an inlet solution.
Thermal vapor recompression (TVR)	Thermal vapor recompression is a process which mixes the low-pressure suction vapor generated in an evaporator with a supplied new steam and increases the pressure of the mixed vapor by an ejector to heat a liquid such as an inlet solution.
Suction ratio	Suction ratio is the indicator of the efficiency for an ejector used in TVR. It is defined as the amount of recovered vapor per the amount of new steam.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	Waste heat recovery by installing an evaporator with mechanical vapor recompression.
Calculation of reference emissions	Reference emissions are calculated by steam consumption of reference evaporator, heating value of the steam, efficiencies of the project boiler and CO_2 emission factor of fuel for the boiler.
Calculation of project	Project emissions are calculated by electricity consumption and

emissions	steam consumptions by project evaporator and CO_2 emission factors for electricity and steam consumed.
Monitoring parameters	• Total amount of inlet solution to evaporator • Total amount of evaporation from supplied solution by the project evaporator • Project steam consumption by project evaporator • Electricity consumption of project evaporator

D. Eligibility criteria

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

Criterion 1	The project installs evaporator(s) which applies mechanical vapor recompression.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Consumption of steam supplied from steam generator by reference evaporator	CO_2
Project emissions	
Emission sources	GHG types
Consumption of steam supplied from steam generator by project evaporator	CO_2
Electricity consumption of project evaporator	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Reference emissions are calculated by multiplying reference steam consumption, heating value and CO_2 emission factor of fuel for the boiler. The reference steam consumption is determined by the theoretical formula for the steam consumption of reference evaporator which applies thermal vapor recompression. In order to secure net emission reductions in this methodology, the reference emissions are conservatively calculated in the following manners.

-Setting inlet water temperature for the steam generation at 38.5 degree Celsius which is derived from the highest monthly average atmospheric temperature in Thailand

-Setting the suction ratio at 1.2 by taking the highest value within the range of values applied to the existing evaporator in the market

In addition, possible emissions from auxiliary equipment which cools non-recovered vapor in the reference system are not taken into account for calculating the reference emissions.

F.2. Calculation of reference emissions

$$RE_p = \frac{\sum SC_{RE,i,p} \times (h_{steam,i} - SPH \times T_{inlet})}{1000} \times \frac{1}{\eta_{PJh}} \times EF_{fuel}$$

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

$SC_{RE,i,p}$: *Reference steam consumption by the reference evaporator i during the period p [t/p]*

$h_{steam,i}$: *Specific enthalpy of supplied steam to the project evaporator i [MJ/t]*

SPH : *Specific heat capacity of water[1] [MJ/(t ·K)]*

T_{inlet} : *Inlet water temperature for the steam generation [degree celsius]*

η_{PJh} : *Efficiency of project boiler for steam supply [-]*

EF_{fuel} : *CO_2 emission factor for the fuel consumed by the project boiler for heating energy generation [tCO_2/GJ]*

$$\sum SC_{RE,i,p} = \sum \frac{\left(EV_{tot,i,p} \times LH_{EV,i}\right) - FL_{IN,i,p} \times SPH \times (T_{LS,i} - T_{EV,i})}{LH_{HT,i} \times (SR + 1)}$$

$EV_{tot,i,p}$: *Total amount of evaporation from supplied solution by the project evaporator i during the period p [t/p]*

$LH_{EV,i}$: *Specific latent heat of the evaporation temperature of solution at the project evaporator i [MJ/t]*

SPH : *Specific heat capacity of water[1] [MJ/(t·K)]*

$T_{LS,i}$: *Temperature of the supplied solution to the project evaporator i [degree Celsius]*

$T_{EV,i}$: *Evaporation temperature of the solution at the project evaporator i [degree Celsius]*

$LH_{HT,i}$: *Specific latent heat of the heating temperature of the supplied vapor to the project evaporator i[MJ/t]*

SR	*: Suction ratio of ejector in the reference evaporator with thermal vapor recompression [-]*
$FL_{IN,i,p}$	*: Total amount of inlet solution to the evaporator i during the period p [t/p]*

[1] This methodology may apply the specific heat capacity of water instead of specific heat capacities of solution.

G. Calculation of project emissions

$$PE_p = \sum EC_{PJ,i,p} \times EF_{elec} + \frac{\sum SC_{PJ,i,p} \times (h_{steam,i} - SPH \times T_{inlet})}{1000} \times \frac{1}{\eta_{PJh}} \times EF_{fuel}$$

PE_p	*: Project emissions during the period p [tCO_2/p]*
$EC_{PJ,i,p}$	*: Electricity consumption of the project evaporator i during the period p [MWh/p]*
EF_{elec}	*: CO_2 emission factor for consumed electricity [tCO_2/MWh]*
$SC_{PJ,i,p}$	*: Project steam consumption by the project evaporator i during the period p [t/p]*
$h_{steam,i}$	*: Specific enthalpy of supplied steam to the project evaporator i [MJ/t]*
SPH	*: Specific heat capacity of water [MJ/(t·K)]*
T_{inlet}	*:Inlet water temperature for the steam generation [degree celsius]*
η_{PJh}	*: Efficiency of project boiler for steam supply [-]*
EF_{fuel}	*: CO_2 emission factor for the fuel consumed by the project boiler for heating energy generation [tCO_2/GJ]*

H. Calculation of emissions reductions

Emission reductions are calculated as the difference between the reference emissions and the project emissions, as follows:

$$ER_p = RE_p - PE_p$$

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}	CO_2 emission factor for consumed electricity. When project evaporator consumes only 1) grid electricity or, 2) captive electricity, or 3) electricity directly supplied from power plants outside of the project boundary including cogeneration power plant to the project site through its internal grid (e.g. industrial park), the project participant applies the CO_2 emission factor respectively. When project evaporator may consume both grid electricity and captive electricity more than 2 electric sources, 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 including cogeneration system, it is determined based on the following options: <u>a) Calculated from its power generation efficiency (η_{elec} [%]) 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;	[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] For the option a) Specification of the captive power generation system provided by the manufacturer (η_{elec} [%]). CO_2 emission factor of the fossil fuel type used in the captive power generation system (EF_{fuel} [tCO_2/GJ]) For the option b) Generated and

<table>
<tr><th>Parameter</th><th>Description of data</th><th>Source</th></tr>
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$$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$$

<u>b) Calculated from measured data</u>
The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{PJ,p}$) and the amount of electricity generated ($EG_{PJ,p}$) 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;
$$EF_{elec} = FC_{PJ,p} \times NCV_{fuel} \times EF_{fuel} \times \frac{1}{EG_{PJ,p}}$$
Where:
NCV_{fuel} : Net calorific value of consumed fuel [GJ/mass or volume]

Note:
In case the captive electricity generation system meets all of the following conditions, the value in the following table may be applied to EF_{elec} 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

<table>
<tr><th>fuel type</th><th>Diesel fuel</th><th>Natural gas</th></tr>
<tr><td>EF_{elec}</td><td>0.8 *1</td><td>0.46 *2</td></tr>
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*1 The most recent value at the time of
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supplied electricity by the captive power generation system ($EG_{PJ,p}$ [MWh/p]).
Fuel amount consumed by the captive power generation system ($FC_{PJ,p}$ [mass or volume /p]).
Net calorific value (NCV_{fuel} [GJ/mass or volume]) and CO_2 emission factor of the fuel (EF_{fuel} [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:
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</table>

Parameter	Description of data	Source
	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 (0.0543tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied. For 3) electricity directly supplied from power plants outside of the project boundary including cogeneration power plant, it is determined based on the following options: a) The value provided by the power plants 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 instructed for the option b) of 2) captive electricity as instructed above;	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. [Electricity directly supplied from power plants outside of project boundary] For option a) the evidence may include a quotation of emission factor from the SPP.
η_{PJh}	Efficiency of the project boiler for steam supply. If multiple boilers are installed, the most efficient value is applied.	Specifications of the project boiler from catalogue or prepared for the quotation.

Parameter	Description of data	Source
	In case that the efficiency cannot be identified, one of the following default values is applied according to the fuel used for the boiler. Natural gas: 0.92 Oil: 0.9	[Default value] CDM Methodological tool "Determining the baseline efficiency of thermal or electric energy generation systems version02.0" for the default efficiency of project boiler. The default values should be updated along with the revision of the CDM tool.
EF_{fuel}	CO_2 emission factor for the fuel consumed by the project boiler for heating energy generation [tCO_2/GJ] In case that the efficiency cannot be identified, one of the following default values is applied according to the fuel used for the boiler. Natural gas: 0.0543 [tCO_2/GJ] Oil: 0.0726 [tCO_2/GJ]	In the order of preference: a) values provided by the fuel supplier; b) measurement by the project participants; c) national default values; 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.
$h_{steam,i}$	Specific enthalpy of supplied steam to the project evaporator *i* [MJ/t] In case that the value applied for this	Based on steam table using the values in operating manual or a value

Parameter	Description of data	Source
	parameter has changed, the newly applied value and its date of occurrence is recorded and stored, then start the new monitoring period with the new value as fixed ***ex ante***.	displayed on the control panel at factory
T_{inlet}	Inlet water temperature for the steam generation. The highest monthly average atmospheric temperature in Thailand is applied. Default value is set to 38.5 [℃].	Thai Meteorological Department (2016) "Climatological Data for the Period 1981–2010" unless otherwise instructed by the Joint Committee.
$LH_{HT,i}$	Specific latent heat of the heating temperature of the supplied vapor to the project evaporator *i* [MJ/t] In case that this parameter has changed, the newly applied value and its date of occurrence is recorded and stored, then start the new monitoring period with the new value as fixed ***ex ante***.	Based on steam table using the values in operating manual or a value displayed on the control panel at factory
SR	Suction ratio of ejector in the reference evaporator with thermal vapor recompression. Default value is set to 1.2 [-].	Value derived from the result of survey. Default value, 1.2, should be revised if necessary.
SPH	Specific heat capacity of water Default value is set to 4.18 [*MJ/(t·K)*]	
$T_{LS,i}$	Temperature of the supplied solution to the project evaporator *i* [degree Celsius] In case that this parameter has changed, the newly applied value and its date of occurrence is recorded and stored, then start	Operating manual or a value displayed on the control panel at factory

Parameter	Description of data	Source
	the new monitoring period with the new value as fixed ***ex ante***.	
$T_{EV,i}$	Evaporation temperature of the solution at the project evaporator *i* [degree Celsius] In case that this parameter has changed, the newly applied value and its date of occurrence is recorded and stored, then start the new monitoring period with the new value as fixed ***ex ante***.	Operating manual or a value displayed on the control panel at factory
$LH_{EV,i}$	Specific latent heat of the evaporation temperature of solution at the project evaporator *i* [MJ/t] In case that this parameter has changed, the newly applied value and its date of occurrence is recorded and stored, then start the new monitoring period with the new value as fixed ***ex ante***.	Based on steam table using the values in operating manual or a value displayed on the control panel at factory