JCM Proposed Methodology Form

Cover sheet of the Proposed Methodology Form

Form for submitting the proposed methodology

Host Country	Republic of the Union of Myanmar
Name of the methodology proponents submitting this form	Kirin Holdings Company, Limited.
Sectoral scope(s) to which the Proposed Methodology applies	3. Energy demand
Title of the proposed methodology, and version number	Introduction of cascade cooling system and/or temperature stratification tank at the beer factory, Version.01.0
List of documents to be attached to this form (please check):	☐The attached draft JCM-PDD: ☒Additional information
Date of completion	15/07/2020

History of the proposed methodology

Version	Date	Contents revised
01.0	15/07/2020	First Edition

A. Title of the methodology

Introduction of cascade cooling system and/or temperature stratification tank at the beer factory
Version.01.0

B. Terms and definitions

Terms	Definitions
Cascade cooling system (CCS)	A system that arranges multiple cooling equipment (e.g. chillers) connected in series to cool refrigerant in a multistage manner from higher to lower temperature.
Brine	A secondary refrigerant which exchanges heat with the primary refrigerant and circulates through the manufacturing process.
Brine chiller	A chiller used for low temperature refrigeration utilizing brine as the secondary refrigerant.
Temperature stratification tank	A kind of brine tank, with a head set higher than all the heads in the product cooling process, in which temperature stratification is formed.
Process pump	A brine pump which sends brine from brine tank to demand side (e.g. heat exchanger with products to be cooled).
Chiller pump	A brine pump which sends brine from brine tank to chiller (including cascade cooling system).
Total efficiency of pump	An efficiency which is calculated by the efficiency of motor multiplied by the efficiency of pump. The efficiency of pump is calculated by the rated water power output divided by rated shaft power output.
Coefficient of Performance (COP)	Coefficient of Performance (COP) is defined as a value calculated by dividing rated cooling capacity by rated electricity consumption of chiller.

C. Summary of the methodology

Items	Summary

<table>
<tr>
<td>GHG emission reduction measures</td>
<td>
This methodology is applied to one of the following cases.
<u>Case 1) Installation of both CCS and temperature stratification tank</u>
<u>Case 2) Installation of only CCS</u>
<u>Case 3) Installation of only temperature stratification tank</u>

GHG emission reduction measures ([A], [B], [C], [D]) are realized for each equipment in the following cases.
<table>
<tr><th rowspan="2"></th><th colspan="3">Where GHG emission reductions are realized.</th></tr>
<tr><th>Chiller</th><th>Process pump</th><th>Chiller pump</th></tr>
<tr><td>Case 1 (2&3)</td><td>[A]</td><td>[B]*[C]</td><td>[B]*[D]</td></tr>
<tr><td>Case 2</td><td>[A]</td><td>[B]</td><td>[B]</td></tr>
<tr><td>Case 3</td><td>-</td><td>[C]</td><td>[D]</td></tr>
</table>

[A] A cascade cooling system, in which multiple refrigerators are arranged in cascade to step down the temperature, improves the efficiency of total cooling system compared to a system where brine chillers are used in parallel to achieve the same cooling output. It leads to reduction of power consumption and consequently GHG emissions.

[B] The amount of cold heat required on the demand side is the same for the project condition and the reference condition. Since a large temperature difference is needed in order to install CCS, a larger heat exchanger than reference system is installed on the demand side. As a result, the brine temperature difference becomes larger than reference refrigeration system, and the same amount of cold heat can be given with a small flow rate of brine. It leads to reduction of electricity consumption of process pump and chiller pump connected to CCS and consequently GHG emissions.

[C] By setting the head of the stratification tank higher than the head of the whole cooling process, the pressure of brine is not released, which results in the reduction of energy consumption of process pump for the temperature stratification tank and consequently GHG emissions.
</td>
</tr>
</table>

	[D] Since a volume of brine stored in temperature stratification tank is more than that stored in reference small brine tank, the operation of chiller pump can be controlled intermittently. Under the reference condition (small brine tank), chiller pump is usually operated 24 hours a day. Therefore, it leads to reduction of electricity consumption of chiller pump and consequently GHG emissions.
Calculation of reference emissions	Reference emissions are calculated with the following manners for each equipment in each case. **Case 1) Installation of both CCS and temperature stratification tank** **- Brine chiller [A]** Reference emissions are calculated with the cold heat amount produced by CCS, COP of the reference brine chiller and the emission factor for consumed electricity. **- Process pump [B]*[C]** Reference emissions are calculated with monitored electricity consumption of the project process pump, the ratio of total head which is needed for the process pump in the project system and the reference system, the ratio of the brine temperature difference under the project condition and the reference condition, the total efficiency of the project process pump and reference pump, and the emission factor for consumed electricity. **- Chiller pump [B]*[D]** Reference emissions are calculated with monitored average flow rate of brine, the ratio of the brine temperature difference under the reference condition and project condition, the density of brine, gravitational acceleration, total head under the reference condition, operation time (24 hours a day), the total efficiency of reference chiller pump, and the emission factor for consumed electricity. **Case 2) Installation of only CCS** **- Brine Chiller [A]** Reference emissions are calculated with the cold heat amount

	produced by CCS, COP of the reference brine chiller and the emission factor for consumed electricity. **- Process pump [B]** Reference emissions are calculated with monitored electricity consumption of the project process pump, the ratio of the brine temperature difference under the project condition and the reference condition, the total efficiency of the project process pump and reference pump, and the emission factor for consumed electricity. **- Chiller pump [B]** Reference emissions are calculated with monitored electricity consumption of the project chiller pump, the ratio of the brine temperature difference under the project condition and the reference condition, the total efficiency of the project chiller pump and reference pump, and the emission factor for consumed electricity. **Case 3) Installation of only temperature stratification tank** **- Process pump [C]** Reference emissions are calculated with monitored electricity consumption of the project process pump for the temperature stratification tank, total head which is needed for the process pump in the project system and the reference system, and the emission factor for consumed electricity. **- Chiller pump [D]** Reference emissions are calculated with monitored average flow rate of brine, the density of brine, gravitational acceleration, total head under the reference condition, operation time (24 hours a day), the total efficiency of reference chiller pump, and the emission factor for consumed electricity.
Calculation of project emissions	Project emissions are calculated with the following manners for each equipment in each case. **Case 1, 2, 3)** **- CCS** Project emissions are calculated with the monitored electricity consumption of all the chillers of CCS and the emission factor

	for consumed electricity. **- Process pump** Project emissions are calculated with the monitored electricity consumption of process pump connected to demand side and/or temperature stratification tank, and the emission factor for consumed electricity. **- Chiller pump** Project emissions are calculated with the monitored electricity consumption of chiller pump connected to CCS and/or temperature stratification tank, and the emission factor for consumed electricity.
Monitoring parameters	**Case 1) Installation of both CCS and temperature stratification tank** ● Electricity consumption of CCS ● Electricity consumption of process pump ● Electricity consumption of chiller pump ● Total flow of brine entering CCS ● Average flow rate of brine which is sent by chiller pump ● Operation days of cooling process **Case 2) Installation of only CCS** ● Electricity consumption of CCS ● Electricity consumption of process pump ● Electricity consumption of chiller pump ● Total flow of brine entering CCS **Case 3) Installation of only temperature stratification tank** ● Electricity consumption of process pump ● Electricity consumption of chiller pump ● Average flow rate of brine which is sent by chiller pump ● Operation days of cooling process

D. Eligibility criteria

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

Criterion 1	The project to which this methodology is applied implements one of the following cases at the beer factory.

	Case 1) Installation of both cascade cooling system and temperature stratification tank Case 2) Installation of only cascade cooling system Case 3) Installation of only temperature stratification tank In either case, the applicable technology is shown in Table 1 below. Table 1: Applicable Technologies <table><tr><td>No.</td><td>Technology</td><td>Applicable technology and criteria</td></tr><tr><td>1</td><td>Cascade cooling system</td><td>Newly installed or replace the existing multiple brine chillers.</td></tr><tr><td>2</td><td>Temperature stratification tank</td><td>Replace the existing small brine tank.</td></tr></table>
Criterion 2	Ozone Depletion Potential (ODP) of the refrigerant used for project chiller is zero. *Criterion 2 is only applied to Case 1 or Case 2
Criterion 3	A plan for prevention of releasing refrigerant used for project chiller is prepared. 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. *Criterion 3 is only applied to Case 1 or Case 2

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Electricity consumption by reference brine chiller *Either Case 1 or Case 2	CO_2
Electricity consumption by reference pump (process pump and chiller pump) *Either Case 1 or Case 2 or Case 3	CO_2
Project emissions	
Emission sources	GHG types

Electricity consumption by project cascade cooling system * Either Case 1 or Case 2	CO_2
Electricity consumption by project pump (process pump and chiller pump) *Either Case 1 or Case 2 or Case 3	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Net emission reductions are ensured for each equipment in the following manner.

Case 1) Installation of both CCS and temperature stratification tank

- Brine chiller

Reference emissions from cascade cooling system are calculated with the cold heat amount produced by CCS, COP of the reference brine chiller and the emission factor for consumed electricity.

The COP of reference brine chiller is conservatively set as a default value from collected data to ensure the net emission reductions.

In the reference scenario, the appropriate number of multiple brine chillers are installed depending on the situation so that the total cooling capacity is the same as the project CCS. Therefore, the COP of reference brine chiller is conservatively set high as a default value, which is described in Section I, to ensure the net emission reductions.

- Process pump

Reference emissions are calculated with monitored electricity consumption of the project process pump, the ratio of total head which is needed for the process pump in the project system and the reference system, the ratio of the brine temperature difference under the project condition and the reference condition, the total efficiency of the project process pump and reference pump, and the emission factor for consumed electricity.

The total efficiency of reference process pump is conservatively set high as a default value, which is described in Section I, to ensure the net emission reductions.

- Chiller pump

Reference emissions are calculated with monitored average flow rate of brine, the ratio of the brine temperature difference under the reference condition and project condition, the density of brine, gravitational acceleration, total head under the reference condition, operation time (24 hours a day), the total efficiency of reference chiller pump, and the emission factor for consumed electricity.

The total efficiency of reference chiller pump is conservatively set high as a default value, which is described in Section I, to ensure the net emission reductions.

<u>**Case 2) Installation of only CCS**</u>

- Brine chiller

The same manner as Case 1 to ensure the net emission reductions is applied.

- Process pump

Reference emissions are calculated with monitored electricity consumption of the project process pump, the ratio of the brine temperature difference under the project condition and the reference condition, the total efficiency of the project process pump and reference pump, and the emission factor for consumed electricity.

The total efficiency of reference process pump is conservatively set high as a default value, which is described in Section I, to ensure the net emission reductions.

- Chiller pump

Reference emissions are calculated with monitored electricity consumption of the project chiller pump, the ratio of the brine temperature difference under the project condition and the reference condition, the total efficiency of the project chiller pump and reference pump, and the emission factor for consumed electricity.

The total efficiency of reference chiller pump is conservatively set high as a default value, which is described in Section I, to ensure the net emission reductions.

<u>**Case 3) Installation of only temperature stratification tank**</u>

- Process pump

Reference emissions are calculated with monitored electricity consumption of the project process pump, the ratio of total head which is needed for the process pump in the project system and the reference system, and the emission factor for consumed electricity.

- Chiller pump

Reference emissions are calculated with monitored average flow rate of brine, the density of brine, gravitational acceleration, total head under the reference condition, operation time (24 hours a day), the total efficiency of reference chiller pump, and the emission factor for consumed electricity.

The total efficiency of reference chiller pump is conservatively set high as a default value, which is described in Section I, to ensure the net emission reductions.

F.2. Calculation of reference emissions

<u>Case 1) Installation of both CCS and temperature stratification tank</u>

$$RE_p = RE_{CCS,p} + RE_{proc-pump,p} + RE_{chiller-pump,p}$$

Where

RE_p	Reference emissions during the period *p* [tCO_2/p]
$RE_{CCS,p}$	Reference emissions from reference brine chiller during the period *p* [tCO_2/p]
$RE_{proc-pump,p}$	Reference emissions from reference process pumps during the period *p* [tCO_2/p]
$RE_{chiller-pump,p}$	Reference emissions from reference chiller pumps during the period *p* [tCO_2/p]

Measure 1: CCS [A]

$$RE_{CCS,p} = \sum_i \left(CH_{PJ,i,p} \div COP_{RE,i} \times EF_{elec}\right)$$

$$CH_{PJ,i,p} = \left(T_{cooling-in,i} - T_{chilled-out,i}\right) \times Q_{PJ,i,p} \times SG_{PJ,i} \times SH_{PJ,i}$$

Where

$RE_{CCS,p}$	Reference emissions from reference brine chiller during the period *p* [tCO_2/p]
$CH_{PJ,i,p}$	Cold heat produced by the cascade cooling system *i* during the period *p* [MWh/p]
$COP_{RE,i}$	COP of reference chiller *i* [dimensionless]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
$T_{cooling-in,i}$	Input cooling brine temperature of project cascade cooling system *i* [degree Celsius]
$T_{chilled-out,i}$	Output chilled brine temperature of project cascade cooling system *i* [degree Celsius]
$Q_{PJ,i,p}$	Total flow of brine entering into project cascade cooling system *i* during the period *p* [m^3/p]
$SG_{PJ,i}$	Specific gravity of brine into project cascade system *i* [kg/m^3]
$SH_{PJ,i}$	Specific heat of brine into project cascade system *i* [MWh/kg/degree Celsius]
i	Identification number of project cascade cooling system and corresponding reference chiller

Measure 2: process pump [B]*[C]

$$RE_{proc-pump,p} = \sum_{j} \left(EC_{PJ,proc-pump,j,p} \times \frac{TH_{RE,j}}{TH_{PJ,j}} \times \frac{\Delta \mathrm{T}_{PJ}}{\Delta \mathrm{T}_{RE}} \times \frac{\eta_{PJ,proc-pump,j}}{\eta_{RE,pump}} \times EF_{elec} \right)$$

Where

$RE_{proc-pump,p}$	Reference emissions from reference process pumps during the period *p* [tCO_2/p]
$EC_{PJ,proc-pump,j,p}$	Electricity consumption by project process pump *j* during the period *p* [MWh/p]
$TH_{RE,j}$	Total head of reference process pump *j* under the same conditions as the project [m]
$TH_{PJ,j}$	Total head of project process pump *j* under the project conditions [m]
$\Delta \mathrm{T}_{PJ}$	Temperature difference between brine which is sent to demand side from project temperature stratification tank and brine which is return from demand side to project temperature stratification tank [degree Celsius]
$\Delta \mathrm{T}_{RE}$	Temperature difference between brine which is sent to demand side from reference brine tank and brine which is return from demand side to reference brine tank [degree Celsius]
$\eta_{PJ,proc-pump,j}$	Total efficiency of project process pump *j* [dimensionless]
$\eta_{RE,pump}$	Total efficiency of reference pump [dimensionless]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
j	Identification number of process pumps to circulate brine

Measure 3: chiller pump [B]*[D]

$$RE_{chiller-pump,p} = \sum_{k} \left(EC_{RE,ciller-pump,k,p} \times EF_{elec} \right)$$

$$EC_{RE,chiller-pump,k,p} = WP_{RE,chiller-pump,k,p} \div \eta_{RE,pump} \times 24 \times OD_{PJ,p}$$

$$WP_{RE,chiller-pump,k,p} = Q_{PJ,chiller-pump,k,p} \times \frac{\Delta \mathrm{T}_{PJ}}{\Delta \mathrm{T}_{RE}} \times SG_{PJ,k} \times g \times TH_{RE,k} \div 3600 \div 10^{6}$$

Where

$RE_{chiller-pump,p}$	Reference emissions from reference chiller pumps during the period *p* [tCO_2/p]
$EC_{RE,chiller-pump,k,p}$	Electricity consumption by reference chiller pump *k* during the period *p* [MWh/p]
$WP_{RE,chiller-pump,k,p}$	Water power output of reference chiller pump *k* [MW]
$\eta_{RE,pump}$	Total efficiency of reference pump *k* [dimensionless]

$OD_{PJ,p}$	Operation days of the project process during the period *p* [day/p]
$Q_{PJ,chiller-pump,k,p}$	Average flow rate of brine which is sent by project chiller pump *k* during the period *p* [m^3/s]
ΔT_{PJ}	Temperature difference between brine which is sent to demand side from project temperature stratification tank and brine which is return from demand side to project temperature stratification tank [degree Celsius]
ΔT_{RE}	Temperature difference between brine which is sent to demand side from reference brine tank and brine which is return from demand side to reference brine tank [degree Celsius]
$SG_{PJ,k}$	Specific gravity of brine which is sent by project chiller pump *k* [kg/m^3]
g	Gravitational acceleration[m/s^2]
$TH_{RE,k}$	Total head of reference chiller pump *k* under the same conditions as the project [m]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
k	Identification number of chiller pump to circulate brine

Case 2) Installation of only CCS

$$RE_p = RE_{CCS,p} + RE_{proc-pump,p} + RE_{chiller-pump,p}$$

Where

RE_p	Reference emissions during the period *p* [tCO_2/p]
$RE_{CCS,p}$	Reference emissions from reference brine chiller during the period *p* [tCO_2/p]
$RE_{proc-pump,p}$	Reference emissions from reference process pumps during the period *p* [tCO_2/p]
$RE_{chiller-pump,p}$	Reference emissions from reference chiller pumps during the period *p* [tCO_2/p]

Measure 1: CCS [A]

The same equation as Case 1 to calculate $\mathrm{RE_{CCS,p}}$ is applied.

Measure 2: Process pump [B]

$$RE_{proc-pump,p} = \sum_j \left(EC_{PJ,proc-pump,j,p} \times \frac{\Delta T_{PJ}}{\Delta T_{RE}} \times \frac{\eta_{PJ,proc-pump,j}}{\eta_{RE,pump}} \times EF_{elec} \right)$$

Where

$RE_{proc-pump,p}$	Reference emissions from reference process pumps during the period *p* [tCO_2/p]
$EC_{PJ,proc-pump,j,p}$	Electricity consumption by project process pump *j* during the period *p* [MWh/p]
ΔT_{PJ}	Temperature difference between brine which is sent to demand side from project temperature stratification tank and brine which is return from demand side to project temperature stratification tank [degree Celsius]
ΔT_{RE}	Temperature difference between brine which is sent to demand side from reference brine tank and brine which is return from demand side to reference brine tank [degree Celsius]
$\eta_{PJ,proc-pump,j}$	Total efficiency of project process pump *j* [dimensionless]
$\eta_{RE,pump}$	Total efficiency of reference pump [dimensionless]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
j	Identification number of process pumps to circulate brine

Measure 3: Chiller pump [B]

$$RE_{chiller-pump,p} = \sum_{k}\left(EC_{PJ,chiller-pump,k,p} \times \frac{\Delta T_{PJ}}{\Delta T_{RE}} \times \frac{\eta_{PJ,chiller-pump,k}}{\eta_{RE,pump}} \times EF_{elec}\right)$$

Where

$RE_{chiller-pump,p}$	Reference emissions from reference chiller pumps during the period *p* [tCO_2/p]
$EC_{PJ,chiller-pump,k,p}$	Electricity consumption by project chiller pump *k* during the period *p* [MWh/p]
ΔT_{PJ}	Temperature difference between brine which is sent to demand side from project temperature stratification tank and brine which is return from demand side to project temperature stratification tank [degree Celsius]
ΔT_{RE}	Temperature difference between brine which is sent to demand side from reference brine tank and brine which is return from demand side to reference brine tank [degree Celsius]
$\eta_{PJ,chiller-pump,k}$	Total efficiency of project chiller pump *k* [dimensionless]
$\eta_{RE,pump}$	Total efficiency of reference pump [dimensionless]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
k	Identification number of chiller pumps to circulate brine

Case 3) Installation of only temperature stratification tank

$$RE_p = RE_{proc-pump,p} + RE_{chiller-pump,p}$$

Where

RE_p	Reference emissions during the period *p* [tCO_2/p]
$RE_{proc-pump,p}$	Reference emissions from reference process pumps during the period *p* [tCO_2/p]
$RE_{chiller-pump,p}$	Reference emissions from reference chiller pumps during the period *p* [tCO_2/p]

Measure 1: Process pump [C]

$$RE_{proc-pump,p} = \sum_j \left(EC_{PJ,proc-pump,j,p} \times \frac{TH_{RE,j}}{TH_{PJ,j}} \times EF_{elec} \right)$$

Where

$RE_{proc-pump,p}$	Reference emissions from reference process pumps during the period *p* [tCO_2/p]
$EC_{PJ,proc-pump,j,p}$	Electricity consumption by project process pump *j* during the period *p* [MWh/p]
$TH_{RE,j}$	Total head of project process pump *j* under the same conditions as the project [m]
$TH_{PJ,j}$	Total head of project process pump *j* under the project conditions [m]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
j	Identification number of process pumps to circulate brine

Measure 2: Chiller pump [D]

$$RE_{chiller-pump,p} = \sum_k \left(EC_{RE,chiller-pump,k,p} \times EF_{elec} \right)$$

$$EC_{RE,chiller-pump,k,p} = WP_{RE,chiller-pump,k,p} \div \eta_{RE,pump} \times 24 \times OD_{PJ,p}$$

$$WP_{RE,chiller-pump,k,p} = Q_{PJ,chiller-pump,k,p} \times SG_{PJ,k} \times g \times TH_{RE,k} \div 3600 \div 10^6$$

Where

$RE_{chiller-pump,p}$	Reference emissions from reference chiller pumps during the period *p* [tCO_2/p]
$EC_{RE,chiller-pump,k,p}$	Electricity consumption by reference chiller pump *k* during the period *p* [MWh/p]

$WP_{RE,chiller-pump,k,p}$	Water power output of reference chiller pump *k* [MW]
$\eta_{RE,pump}$	Total efficiency of reference pump *k* [dimensionless]
$OD_{PJ,p}$	Operation days of the project process during the period *p* [day/p]
$Q_{PJ,chiller-pump,k,p}$	Average flow rate of brine which is sent by project chiller pump *k* during the period *p* [m^3/s]
$SG_{PJ,k}$	Specific gravity of brine which is sent by project chiller pump *k* [kg/m^3]
g	Gravitational acceleration[m/s^2]
$TH_{RE,k}$	Total head of reference chiller pump *k* under the same conditions as the project [m]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
k	Identification number of chiller pump to circulate brine

G. Calculation of project emissions

<u>Case 1) Installation of both CCS and temperature stratification tank</u>

$$PE_p = PE_{CCS,p} + PE_{proc-pump,p} + PE_{chiller-pump,p}$$

Where

PE_p	Project emissions during the period *p* [tCO_2/p]
$PE_{CCS,p}$	Project emissions from cascade cooling system during the period *p* [tCO_2/p]
$PE_{proc-pump,p}$	Project emissions from project process pumps during the period *p* [tCO_2/p]
$PE_{chiller-pump,p}$	Project emissions from project chiller pumps during the period *p* [tCO_2/p]

Measure 1: CCS

$$PE_{CCS,p} = \sum_i \left(EC_{PJ,CCS,i,p} \times EF_{elec}\right)$$

Where

$PE_{CCS,p}$	Project emissions from cascade cooling system during the period *p* [tCO_2/p]
$EC_{PJ,CCS,i,p}$	Electricity consumption by project cascade cooling system *i* during the period *p* [MWh/p]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]

Measure 2: Process pump

$$PE_{proc-pump,p} = \sum_j \left(EC_{PJ,proc-pump,j,p} \times EF_{elec}\right)$$

Where

$PE_{proc-pump,p}$	Project emissions from project process pumps during the period *p* [tCO_2/p]
$EC_{PJ,proc-pump,j,p}$	Electricity consumption by project process pump *j* during the period *p* [MWh/p]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]

Measure 3: Chiller pump

$$PE_{chiller-pump,p} = \sum_{k}\left(EC_{PJ,chiller-pump,k,p} \times EF_{elec}\right)$$

Where

$PE_{pump,p}$	Project emissions from project chiller pumps during the period *p* [tCO_2/p]
$EC_{PJ,chiller-pump,k,p}$	Electricity consumption by project chiller pump *k* during the period *p* [MWh/p]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]

Case 2) Installation of only CCS

$$PE_p = PE_{CCS,p} + PE_{proc-pump,p} + PE_{chiller-pump,p}$$

Where

PE_p	Project emissions during the period *p* [tCO_2/p]
$PE_{CCS,p}$	Project emissions from cascade cooling system during the period *p* [tCO_2/p]
$PE_{proc-pump,p}$	Project emissions from project process pumps during the period *p* [tCO_2/p]
$PE_{chiller-pump,p}$	Project emissions from project chiller pumps during the period *p* [tCO_2/p]

Measure 1: CCS

The same equation as Case 1 to calculate $\mathrm{PE_{CCS,p}}$ is applied.

Measure 2: Process pump

The same equation as Case 1 to calculate $\mathrm{PE_{proc-pump,p}}$ is applied.

Measure 3: Chiller pump

The same equation as Case 1 to calculate $\mathrm{PE_{chiller-pump,p}}$ is applied.

Case 3) Installation of only temperature stratification tank

$$PE_p = PE_{proc-pump,p} + PE_{chiller-pump,p}$$

Where

PE_p	Project emissions during the period *p* [tCO_2/p]
$PE_{proc-pump,p}$	Project emissions from project process pumps during the period *p* [tCO_2/p]
$PE_{chiller-pump,p}$	Project emissions from project chiller pumps during the period *p* [tCO_2/p]

Measure 1: Process pump

The same equation as Case 1 to calculate $\mathrm{PE_{proc-pump,p}}$ is applied.

Measure 2: Chiller pump

The same equation as Case 1 to calculate $\mathrm{PE_{chiller-pump,p}}$ is applied.

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
$\mathrm{EF_{elec}}$	CO_2 emission factor for consumed electricity [tCO_2/MWh] When project cascade cooling system and/or project pumps consume only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively. When project cascade cooling system and/or project pumps may consume both grid electricity and captive electricity, the project participant applies the CO_2 emission factor	[Grid electricity] PDD of the most recently registered CDM project hosted in Myanmar or the latest version of the “Tool to calculate the emission factor for an electricity system” under the CDM at the time of validation.

	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, it is determined based on the following options: a) Calculated from its power generation efficiency (η_{elec} [%]) 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; $$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$$ b) Calculated from measured data 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 weight] Note:	[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 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 weight/p]). Net calorific value (NCV_{fuel} [GJ/mass or weight]) 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;

	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></table> *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 (0.0543tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.	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 version 02.0" for the default efficiency for off-grid power plants.
$COP_{RE,i}$	COP of reference brine chiller *i* [dimensionless] The COP of the reference brine chiller *i* is set as the default value in the following table. [Default COP value for reference brine chiller]	The default COP values are derived from the result of survey on COP of brine chillers from manufacturers. The default COP values should be revised if

	$COP_{RE,i}$ [-] : 4.34	necessary from survey result which is conducted by JC or project participants.
$T_{cooling-in,i}$	Input cooling brine temperature of project cascade cooling system *i* [degree Celsius]	Specifications of project cascade cooling system *i* provided by manufacturer
$T_{chilled-out,i}$	Output chilled brine temperature of project cascade cooling system *i* [degree Celsius]	Specifications of project cascade cooling system *i* provided by manufacturer
$SG_{PJ,i}$	Specific gravity of brine into project cascade system *i* [kg/m^3]	Specific value provided by the manufacturer
$SG_{PJ,k}$	Specific gravity of brine which is sent by project chiller pump *k* [kg/m^3]	Specific value provided by the manufacturer
$SH_{PJ,i}$	Specific heat of brine into project cascade system *i* [MWh/kg /degree Celsius]	Specific value provided by the manufacturer
$TH_{RE,j}$	Total head of reference process pump *j* under the same conditions as the project [m]	Specific value provided by the manufacturer
$TH_{RE,k}$	Total head of reference chiller pump *k* under the same conditions as the project [m]	Specific value provided by the manufacturer
$TH_{PJ,j}$	Total head of project process pump *j* under the same conditions as the project [m]	Specific value provided by the manufacturer
ΔT_{PJ}	Temperature difference between brine which is sent to demand side from project temperature stratification tank and brine which is return from demand side to project temperature stratification tank [degree Celsius]	Specific value provided by the manufacturer
ΔT_{RE}	Temperature difference between brine which is sent to demand side from reference brine tank and brine which is return from demand side to reference brine tank [degree Celsius] The default value is set conservatively as in the following table.	The default value is derived from the interview of manufacturer and the result of survey on specification of brine chillers from

	[Default ΔT_{RE}] <table><tr><td>ΔT_{RE} [degC]</td><td>5</td></tr></table>	manufacturers. In the brine chiller introduced in the cooling process in beverage production, the brine temperature difference between the inlet and outlet is usually from 0 degC to 5 degC. Therefore ΔT_{RE} is conservatively set to 5 degC.
$\eta_{PJ,proc-pump,j}$	Total efficiency of project process pump *j* [dimensionless]	Specifications of project process pump *j* prepared for the quotation or factory acceptance test data by manufacturer.
$\eta_{PJ,chiller-pump,k}$	Total efficiency of project chiller pump *k* [dimensionless]	Specifications of project chiller pump *k* prepared for the quotation or factory acceptance test data by manufacturer.
$\eta_{RE,pump}$	Total efficiency of reference pump [dimensionless] The default value is set conservatively as in the following table. [Default $\eta_{RE,pump}$] <table><tr><td>$\eta_{RE,pump}$ [-]</td><td>0.736</td></tr></table> * $\eta_{RE,pump}$ is calculated by the following equation.	The default $\eta_{RE,pump}$ values are derived from the following document; Efficiency of pump: Japanese Industrial Standard JIS B 8313 “End suction centrifugal pumps”, in which the highest value is 0.765. Efficiency of motor: Final Reports on the Top Runner Target Product

	$$\eta_{RE,pump} = efficiency\ of\ pump \times efficiency\ of\ motor$$ $$efficiency\ of\ pump = 0.765$$ $$efficiency\ of\ motor = 0.962$$	Standards (Final Report by Three-phase Induction Motor Evaluation Standards Subcommittee, Energy Efficiency Standards Subcommittee of the Advisory Committee for Natural Resources and Energy), in which the highest value is 0.962.
g	Gravitational acceleration[m/s^2] [Default value of gravitational acceleration] g [m/s^2] | 9.8	Theoretical value.