**Joint Crediting Mechanism Approved Methodology TH_AM005**
**"Energy Saving by Introduction of High Efficiency Non-Inverter Type Centrifugal Chiller"**

## A. Title of the methodology

| |
|---|
| Energy Saving by Introduction of High Efficiency Non-Inverter Type Centrifugal Chiller, Version 023.0 |

## B. Terms and definitions

| Terms | Definitions |
|---|---|
| Non-inverter type centrifugal chiller | A non-inverter type centrifugal chiller is a chiller including a centrifugal compressor without inverter. It is commonly used for air-conditioning with huge cooling load, e.g., buildings, shopping malls or factories etc. |
| Cooling capacity | Cooling capacity is the capability of individual chiller to remove heat. In this methodology, "cooling capacity" is used to represent a cooling capacity per one chiller unit and not for a system with multiple chiller units. |
| Periodical check | Periodical check is a periodical investigation of chiller done by manufacturer or agent who is authorized by the manufacturer, in order to maintain chiller performance. |
| COP (Coefficient Of Performance) | A ratio of the net refrigerating capacity to the total input power at any given set of rating conditions.<br>Net refrigerating capacity is the capacity of the evaporator available for cooling of the thermal load external to the chiller and it is calculated using only the sensible heat transfer. (AHRI Standard 550/590) |

## C. Summary of the methodology

| Items | Summary |
|---|---|
| *GHG emission reduction* | This methodology applies to the project that aims for saving |

| | |
|---|---|
| *measures* | energy by introducing high efficiency centrifugal chiller for the target factory, commercial facilities etc. in Thailand. |
| *Calculation of reference emissions* | Reference emissions are GHG emissions from using reference chiller, calculated with power consumption of project chiller, ratio of COPs (Coefficient Of Performance) of reference/project chillers and $CO_2$ emission factor for electricity consumed. |
| *Calculation of project emissions* | Project emissions are GHG emissions from using project chiller, calculated with power consumption of project chiller and $CO_2$ emission factor for electricity consumed. |
| *Monitoring parameter* | ● Power consumption of project chiller<br>● 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 | Project chiller is a non-inverter type centrifugal chiller with a capacity which is less than or equals to 1,500 USRt.<br>Note: 1 USRt = 3.52 kW |
| Criterion 2 | COP for project chiller *i* calculated under the standardizing temperature conditions[*1] ($COP_{PJ,tc,i}$) is more than the threshold COP values set in the table below. ("x" in the table represents cooling capacity per unit.) |

| **Cooling capacity per unit [USRt]** | x≤600~~300≤x<500~~ | 600<x≤800~~500≤x<800~~ | 800<x≤1600~~800≤x≤1500~~ |
|---|---|---|---|
| Threshold COP value | 5.90~~67~~ | 6.00~~5.81~~ | 6.08~~5~~ |

$COP_{PJ,tc,i}$ is calculated by altering the temperature conditions of COP of project chiller *i* ($COP_{PJ,i}$) from the project specific conditions to the standardizing conditions. $COP_{PJ,i}$ is derived from specifications prepared for the quotation or factory acceptance test data by manufacturer.

[equation to calculate $COP_{PJ,tc,i}$]

$$\mathbf{COP_{PJ,tc,i}} = \mathbf{COP_{PJ,i}} \times [(\mathbf{T_{cooling-out,i}} - \mathbf{T_{chilled-out,i}} + \mathbf{TD_{chilled}} + \mathbf{TD_{cooling}}) \div (\mathbf{37} - \mathbf{7} + \mathbf{TD_{chilled}} + \mathbf{TD_{cooling}})]$$

| | |
|---|---|
| | $COP_{PJ,tc,i}$ : COP of project chiller *i* calculated under the standardizing temperature conditions* [-]<br>$COP_{PJ,i}$ : COP of project chiller *i* under the project specific conditions [-]<br>$T_{cooling-out,i}$ : Output cooling water temperature of project chiller *i* set under the project specific conditions [degree Celsius]<br>$T_{chilled-out,i}$ : Output chilled water temperature of project chiller *i* set under the project specific conditions [degree Celsius]<br>$TD_{cooling}$ : Temperature difference between condensing temperature of refrigerant and output cooling water temperature<br>1.5 degree Celsius set as a default value [degree Celsius]<br>$TD_{chilled}$ : Temperature difference between evaporating temperature of refrigerant and output chilled water temperature,<br>1.5 degree Celsius set as a default value [degree Celsius]<br><br>*1: The standardizing temperature conditions to calculate $COP_{PJ,tc,i}$<br>Chilled water: output 7 degrees Celsius<br>input 12 degrees Celsius<br>Cooling water: output 37 degrees Celsius<br>input 32 degrees Celsius |
| Criterion 3 | Periodical check is planned at least one (1) time annually. |
| Criterion 4 | Ozone Depletion Potential (ODP) of the refrigerant used for project chiller is zero. |
| Criterion 5 | 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. |

## E. Emission Sources and GHG types

| Reference emissions | |
|---|---|
| Emission sources | GHG types |
| Power consumption by reference chiller | $CO_2$ |
| Project emissions | |
| Emission sources | GHG types |

| | |
|---|---|
| Power consumption by project chiller | $CO_2$ |

## F. Establishment and calculation of reference emissions

### F.1. Establishment of reference emissions

Reference emissions are calculated by multiplying power consumption of project chiller, ratio of COPs for reference/project chillers, and $CO_2$ emission factor for electricity consumed.

The COP of reference chiller is conservatively set as a default value in the following manner to ensure the net emission reductions.

1. The reference COP value varies by its cooling capacity.
2. The maximum values of COP in each cooling capacity range set for this methodology are defined as $COP_{RE,i}$ as described in Section I.

### F.2. Calculation of reference emissions

$$\mathbf{RE_p} = \sum_{\mathbf{i}} \left\{ \mathbf{EC_{PJ,i,p}} \times \left( \mathbf{COP_{PJ,tc,i}} \div \mathbf{COP_{RE,i}} \right) \times \mathbf{EF_{elec}} \right\}$$

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

$EC_{PJ,i,p}$ : Power consumption of project chiller *i* during the period *p* [MWh/p]

$COP_{PJ,tc,i}$ : COP of project chiller *i* calculated under the standardizing temperature conditions [-]

$COP_{RE,i}$ : COP of reference chiller *i* under the standardizing temperature conditions [-]

$EF_{elec}$ : $CO_2$ emission factor for consumed electricity [$tCO_2$/MWh]

## G. Calculation of project emissions

$$\mathbf{PE_p} = \sum_{\mathbf{i}} \left( \mathbf{EC_{PJ,i,p}} \times \mathbf{EF_{elec}} \right)$$

$PE_p$ : Project emissions during the period *p* [$tCO_2$/p]

$EC_{PJ,i,p}$ : Power consumption of project chiller *i* during the period *p* [MWh/p]

$EF_{elec}$ : $CO_2$ emission factor for consumed electricity [$tCO_2$/MWh]

## H. Calculation of emissions reductions

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

$ER_p$ : 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.<br>When project chiller 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.<br><br>When project chiller may consume electricity supplied from more than 1 electric source, the project participant applies the $CO_2$ emission factor with the lowest value.<br><br>[$CO_2$ emission factor]<br>For 1) grid electricity: The most recent value available from the source stated in this table at the time of validation<br><br>For 2) captive electricity including cogeneration system, it is determined based on the following options:<br><br><u>a) Calculated from its power generation efficiency ($\eta_{elec}$ [%]) obtained from manufacturer's specification</u><br>The power generation efficiency based on lower | [Grid electricity]<br>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.<br><br>[Captive electricity]<br><br>For the option a)<br><br>Specification of the captive power generation system provided by the manufacturer ($\eta_{elec}$ [%]).<br>$CO_2$ emission factor of the fossil fuel type used in the captive power generation system ($EF_{fuel}$ [$tCO_2$/GJ])<br><br>For the option b)<br>Generated and supplied electricity by the captive |

<table>
<tr><th>Parameter</th><th>Description of data</th><th>Source</th></tr>
<tr><td></td><td>heating value (LHV) of the captive power generation system from the manufacturer's specification is applied;<br>$$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$$<br><u>b) Calculated from measured data</u><br>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;<br>$$EF_{elec} = FC_{PJ,p} \times NCV_{fuel} \times EF_{fuel} \times \frac{1}{EG_{PJ,p}}$$<br>Where:<br>$NCV_{fuel}$ : Net calorific value of consumed fuel [GJ/mass or volume]<br><br>Note:<br>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.<br>● The system is non-renewable generation system<br>● Electricity generation capacity of the system is less than or equal to 15 MW<br><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></td><td>power generation system ($EG_{PJ,p}$ [MWh/p]).<br>Fuel amount consumed by the captive power generation system ($FC_{PJ,p}$ [mass or volume /p]).<br>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:<br>1) values provided by the fuel supplier;<br>2) measurement by the project participants;<br>3) regional or national default values;<br>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.<br><br>[Captive electricity with diesel fuel]<br>CDM approved small scale methodology: AMS-I.A.<br><br>[Captive electricity with natural gas]<br>2006 IPCC Guidelines on National GHG Inventories for the source of EF of natural gas.<br>CDM Methodological tool "Determining the baseline efficiency of thermal or electric energy generation systems version02.0" for</td></tr>
</table>

<table>
<tr><th>Parameter</th><th>Description of data</th><th>Source</th></tr>
<tr><td></td><td>*1 The most recent value at the time of validation is applied.<br>*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 (0.0543t$CO_2$/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.<br><br>For 3) electricity directly supplied from small power producer (SPP) , it is determined based on the following options:<br>a) The value provided by the SPP with the evidence;<br>b) The value calculated in the same manner for the option a) of 2) captive electricity as instructed above;<br>c) The value calculated in the same manner for the option b) of 2) captive electricity as instructed above;<br>When project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the $CO_2$ emission factor with the lowest value.</td><td>the default efficiency for off-grid power plants.<br><br>[Electricity directly supplied from SPP]<br><br>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.</td></tr>
<tr><td>$COP_{RE,i}$</td><td>The COP of the reference chiller i is selected from the default COP value in the following table in line with cooling capacity of the project chiller i. (“x” in the table represents cooling capacity per unit.)<br><table><tr><th>Cooling capacity /unit (USRt)</th><td>x≤60030 0≤x<500</td><td>600<x≤800500≤x<800</td><td>800<x≤1600800≤x≤1500</td></tr><tr><td>$COP_{RE,i}$</td><td>5.9067</td><td>6.005.81</td><td>6.085</td></tr></table></td><td>The default COP values are derived from the result of survey on COP of chillers from manufacturers that have high market share. The survey should prove the use of clear methodology. The $COP_{RE,i}$ should be revised if necessary from survey result which is conducted by JC or project participants.</td></tr>
<tr><td>$COP_{PJ,i}$</td><td>The COP of project chiller i under the project</td><td>Specifications of project</td></tr>
</table>

| Parameter | Description of data | Source |
|---|---|---|
| | specific conditions. | chiller *i* prepared for the quotation or factory acceptance test data by manufacturer |
| $T_{cooling-out,i}$ | Output cooling water temperature of project chiller *i* set under the project specific conditions. | Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer |
| $T_{chilled-out,i}$ | Output chilled water temperature of project chiller *i* set under the project specific conditions. | Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer |

History of the document

| Version | Date | Contents revised |
|---|---|---|
| 03.0 | 11 October 2023 | JC5<br>Revision to:<br>● Update the threshold COP values in Criterion 2 and the default COP value due to the improved efficiency of chillers currently available in the local market since its initial approval of the methodology<br>● Add the definition of " COP (Coefficient Of Performance)" |
| 02.0 | 14 January 2019 | Electronic decision by the Joint Committee<br>Revision to:<br>● Add option to identify $CO_2$ emission factor for consumed electricity by changing the description of $CO_2$ emission factor for consumed electricity directly supplied from small power producer (SPP)<br>● Change the description of "Measurement methods and procedures", "Source of data", "Description of data" and "Units" in the monitoring spreadsheet |
| 01.0 | 21 August 2017 | JC3, Annex 7<br>Initial approval. |

## Monitoring Plan Sheet (Input Sheet) [Attachment to Project Design Document]

**Table 1: Parameters to be monitored *ex post***

| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) |
|---|---|---|---|---|---|---|---|---|---|
| Monitoring point No. | Parameters | Description of data | Estimated Values | Units | Monitoring option | Source of data | Measurement methods and procedures | Monitoring frequency | Other comments |
| (1) | $EC_{PJ,i,p}$ | Power consumption of project chiller *i* during the period *p* | - | MWh/p | Option C | Monitored data | Data is measured by measuring equipments in the factory.<br>- Measuring and recording:<br>1) Measured data is recorded and stored in the measuring equipments.<br>2) Recorded data is checked its integrity once a month by responsible staff.<br>- Calibration:<br>The measuring equipment is replaced or calibrated at an interval following the regulations in the country in which the measuring equipment is commonly used or according to the manufacturer's recommendation, unless a type approval, manufacturer's specification, or certification issued by an entity accredited under international/national standards for the measuring equipment has been prepared by the time of installation. | Continuously | Input on "MPS (input_separate)" |
| (2) | $FC_{PJ,p}$ | The amount of fuel input for power generation during monitoring period *p* | | mass or volume/p | Option B | Invoice from fuel supply company | Data is collected and recorded from the invoices by the fuel supply company. | Continuously | For option b) of 2) captive electricity; option c) of 3) electricity directly supplied from SPP |
| (3) | $EG_{PJ,p}$ | The amount of electricity generated during the monitoring period *p* | | MWh/p | Option C | Monitored data | Data is measured by measuring equipments in the factory.<br>- Measuring and recording:<br>1) Measured data is recorded and stored in the measuring equipments.<br>2) Recorded data is checked its integrity once a month by responsible staff.<br>- Calibration:<br>The measuring equipment is replaced or calibrated at an interval following the regulations in the country in which the measuring equipment is commonly used or according to the manufacturer's recommendation, unless a type approval, manufacturer's specification, or certification issued by an entity accredited under international/national standards for the measuring equipment has been prepared by the time of installation. | Continuously | For option b) of 2) captive electricity; option c) of 3) electricity directly supplied from SPP |

**Table 2: Project-specific parameters to be fixed *ex ante***

| (a) | (b) | (c) | (d) | (e) | (f) |
|---|---|---|---|---|---|
| **Parameters** | **Description of data** | **Estimated Values** | **Units** | **Source of data** | **Other comments** |
| $EF_{elec}$ | [For 1) grid electricity]<br>$CO_2$ emission factor for consumed electricity | | $tCO_2/MWh$ | 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. | |
| $EF_{elec}$ | [For 2) captive electricity]<br>$CO_2$ emission factor for consumed electricity<br>**Option a)**;<br>[For 3) electricity directly supplied from small power producer (SPP) ]<br>$CO_2$ emission factor for consumed electricity<br>**Option b)** | 0.000 | $tCO_2/MWh$ | Power generation efficiency obtained from manufacturer's specification. | Calculated<br><br>In case of [ 3) Electricity directly supplied from small power producer (SPP) ], when project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the $CO_2$ emission factor with the lowest value. |
| $EF_{elec}$ | [For 2) captive electricity]<br>$CO_2$ emission factor for consumed electricity<br>**Option b)**;<br>[For 3) electricity directly supplied from small power producer (SPP) ]<br>$CO_2$ emission factor for consumed electricity<br>**Option c)** | 0.000 | $tCO_2/MWh$ | The power generation efficiency calculated from monitored data of the amount of fuel input for power generation and the amount of electricity generated. | Calculated<br><br>In case of [ 3) electricity directly supplied from small power producer (SPP) ], when project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the $CO_2$ emission factor with the lowest value. |
| $EF_{elec}$ | [For 2) captive electricity]<br>**In case the captive electricity generation system meets all of the following conditions;**<br>- The system is non-renewable generation system<br>- Electricity generation capacity of the system is less than or equal to 15 MW | | $tCO_2/MWh$ | [Captive electricity with diesel fuel]<br>CDM approved small scale methodology: AMS-I.A.<br><br>[Captive electricity with natural gas]<br>2006 IPCC Guidelines on National GHG Inventories for the source of EF of natural gas.<br>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. | |
| $EF_{elec}$ | [For 3) electricity directly supplied from small power producer (SPP) ]<br>$CO_2$ emission factor for consumed electricity<br>**Option a)** | | $tCO_2/MWh$ | [Electricity directly supplied from SPP]<br>a) The value provided by the SPP with 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. | When project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the $CO_2$ emission factor with the lowest value. |
| $T_{cooling\text{-}out,i}$ | Output cooling water temperature of project chiller *i* set under the project specific condition | - | degree Celsius | Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer | Input on "MPS (input_separate)" |

| | | | | | |
|---|---|---|---|---|---|
| $T_{chilled\text{-}out,i}$ | Output chilled water temperature of project chiller *i* set under the project specific condition | - | degree Celsius | Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer | Input on "MPS (input_separate)" |
| $COP_{RE,i}$ | COP of reference chiller *i* under the standardizing temperature conditions | - | - | Selected from the default values set in the methodology | Input on "MPS (input_separate)" |
| $COP_{PJ,i}$ | COP of project chiller *i* under the project specific conditions | - | - | Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer | Input on "MPS (input_separate)" |
| $COP_{PJ,tc,i}$ | COP of project chiller *i* calculated under the standardizing temperature conditions | - | - | Calculated with the following equation; $COP_{PJ,tc,i} = COP_{PJ,i} \times [(T_{cooling\text{-}out,i} - T_{chilled\text{-}out,i} + TD_{chilled} + TD_{cooling}) \div (37 - 7 + TD_{chilled} + TD_{cooling})]$ | |
| $\eta_{elec}$ | Power generation efficiency | | % | Specification of the captive power generation system provided by the manufacturer | For option a) of 2) captive electricity; option b) of 3) electricity directly supplied from SPP. |
| $NCV_{fuel}$ | Net calorific value of consumed fuel | | GJ/mass or volume | In order of preference:<br>1) values provided by the fuel supplier;<br>2) measurement by the project participants;<br>3) regional or national default values;<br>4) 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. | For option b) of 2) captive electricity; option c) of 3) electricity directly supplied from SPP. |
| $EF_{fuel}$ | $CO_2$ emission factor of consumed fuel | | $tCO_2/GJ$ | In order of preference:<br>1) values provided by the fuel supplier;<br>2) measurement by the project participants;<br>3) regional or national default values;<br>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 options a); b) of 2) captive electricity; options b); c) of 3) electricity directly supplied from SPP. |

**Table3: *Ex-ante* estimation of $CO_2$ emission reductions**

| $CO_2$ emission reductions | Units |
|---|---|
| 0 | $tCO_2/p$ |

**[Monitoring option]**

| | |
|---|---|
| Option A | Based on public data which is measured by entities other than the project participants (Data used: publicly recognized data such as statistical data and specifications) |
| Option B | Based on the amount of transaction which is measured directly using measuring equipment (Data used: commercial evidence such as invoices) |
| Option C | Based on the actual measurement using measuring equipment (Data used: measured values) |

Monitoring Spreadsheet: JCM_TH_AM005_ver02.003.0
Reference Number:

| | | Parameters to be monitored *ex post* | | | Project-specific parameters to be fixed *ex ante* | | | | | | | | | | | | *Ex-ante* estimation of emissions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | Chiller *i* | $EC_{PJ,i,p}$ | $FC_{PJ,p}$ | $EG_{PJ,p}$ | $EF_{elec}$ | $EF_{elec}$ | $EF_{elec}$ | $EF_{elec}$ | $EF_{elec}$ | $T_{cooling\text{-}out,i}$ | $T_{chilled\text{-}out,i}$ | $COP_{RE,i}$ | $COP_{PJ,i}$ | $COP_{PJ,tc,i}$ | $\eta_{elec}$ | $NCV_{fuel}$ | $EF_{fuel}$ | $RE_{i,p}$ | $PE_{i,p}$ | $ER_{i,p}$ |
| Description of data | Project chiller No. | Power consumption of project chiller *i* during the period *p* | The amount of fuel input for power generation during monitoring period *p* | The amount of electricity generated during the monitoring period *p* | [For 1) grid electricity] $CO_2$ emission factor for consumed electricity | [For 2) captive electricity] $CO_2$ emission factor for consumed electricity **Option a)**; [For 3) electricity directly supplied from small power producer (SPP) ] $CO_2$ emission factor for consumed electricity **Option b)** | [For 2) captive electricity] $CO_2$ emission factor for consumed electricity **Option b)**; [For 3) electricity directly supplied from small power producer (SPP) ] CO2 emission factor for consumed electricity **Option c)** | [For 2) captive electricity] **In case the captive electricity generation system meets all of the following conditions**; - The system is non-renewable generation system - Electricity generation capacity of the system is less than or equal to 15 MW | [For 3) electricity directly supplied from small power producer (SPP) ] $CO_2$ emission factor for consumed electricity **Option a)** | Output cooling water temperature of project chiller *i* set under the project specific condition | Output chilled water temperature of project chiller *i* set under the project specific condition | COP of reference chiller *i* under the standardizing temperature conditions | COP of project chiller *i* under the project specific conditions | COP of project chiller *i* calculated under the standardizing temperature conditions | Power generation efficiency | Net calorific value of consumed fuel | $CO_2$ emission factor of consumed fuel | Reference emissions of project chiller *i* during the period *p* | Project emissions of project chiller *i* during the period *p* | Emissions reductions by the project chiller *i* during the period *p* |
| Units | - | MWh/p | mass or volume/p | MWh/p | $tCO_2/MWh$ | $tCO_2/MWh$ | $tCO_2/MWh$ | $tCO_2/MWh$ | $tCO_2/MWh$ | degree Celsius | degree Celsius | - | - | - | % | mass or volume/p | $tCO_2/GJ$ | $tCO_2/p$ | $tCO_2/p$ | $tCO_2/p$ |
| Estimated values | 1 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 2 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 3 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 4 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 5 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 6 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 7 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 8 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 9 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 10 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 11 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 12 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 13 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 14 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 15 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 16 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 17 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 18 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 19 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | 20 | | 0.00 | 0.00 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | | | | | 0.00 | 0.00 | 0.00 | 0.0000 | 0.00 | 0.00 | 0.00 |
| | **Total** | - | | - | - | | | - | - | | | | - | - | - | - | - | 0.00 | 0.00 | 0.00 |

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## Monitoring Plan Sheet (Calculation Process Sheet) [Attachment to Project Design Document]

| 1. Calculations for emission reductions | Fuel type | Value | Units | Parameter |
|---|---|---|---|---|
| Emission reductions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $ER_p$ |
| **2. Calculations for reference emissions** | | | | |
| Reference emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $RE_p$ |
| Reference emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $RE_p$ |
| **3. Calculations of the project emissions** | | | | |
| Project emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $PE_p$ |
| Project emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $PE_p$ |

[List of Default Values]

| | | |
|---|---|---|
| $COP_{RE,i}$ (x≤600USRt) | 5.90 | - |
| $COP_{RE,i}$ (600<x≤800USRt) | 6.00 | - |
| $COP_{RE,i}$ (800<x≤1600USRt) | 6.08 | - |

| | | |
|---|---|---|
| $TD_{cooling}$ | 1.5 | degree Celsius |
| $TD_{chilled}$ | 1.5 | degree Celsius |

## Monitoring Structure Sheet [Attachment to Project Design Document]

| Responsible personnel | Role |
|---|---|
| | |
| | |
| | |
| | |
| | |
| | |
| | |

## Monitoring Report Sheet (Input Sheet) [For Verification]

**Table 1: Parameters monitored *ex post***

| (a) | (b) | (c) | (d) | (e) | (f) | (g) | (h) | (i) | (j) | (k) |
|---|---|---|---|---|---|---|---|---|---|---|
| Monitoring period | Monitoring point No. | Parameters | Description of data | Monitored Values | Units | Monitoring option | Source of data | Measurement methods and procedures | Monitoring frequency | Other comments |
| | (1) | $EC_{PJ,i,p}$ | Power consumption of project chiller *i* during the period *p* | - | MWh/p | Option C | Monitored data | Data is measured by measuring equipments in the factory.<br>- Measuring and recording:<br>1) Measured data is recorded and stored in the measuring equipments.<br>2) Recorded data is checked its integrity once a month by responsible staff.<br>- Calibration:<br>The electrical measuring equipment is replaced or calibrated at an interval following the regulations in the country in which the measuring equipment is commonly used or according to the manufacturer's recommendation, unless a type approval, manufacturer's specification, or certification issued by an entity accredited under international/national standards for the electrical measuring equipment has been prepared by the time of installation. | Continuously | Input on "MRS (input_separate)" |
| | (2) | $FC_{PJ,p}$ | The amount of fuel input for power generation during monitoring period *p* | | mass or volume/p | Option B | Invoice from fuel supply company | Data is collected and recorded from the invoices by the fuel supply company. | Continuously | for option b) of 2) captive electricity; option c) of 3) electricity directly supplied from SPP |
| | (3) | $EG_{PJ,p}$ | The amount of electricity generated during the monitoring period *p* | | MWh/p | Option C | Monitored data | Data is measured by measuring equipments in the factory.<br>- Measuring and recording:<br>1) Measured data is recorded and stored in the measuring equipments.<br>2) Recorded data is checked its integrity once a month by responsible staff.<br>- Calibration:<br>The electrical measuring equipment is replaced or calibrated at an interval following the regulations in the country in which the measuring equipment is commonly used or according to the manufacturer's recommendation, unless a type approval, manufacturer's specification, or certification issued by an entity accredited under international/national standards for the electrical measuring equipment has been prepared by the time of installation. | Continuously | for option b) of 2) captive electricity; option c) of 3) electricity directly supplied from SPP |

**Table 2: Project-specific parameters fixed *ex ante***

| (a) | (b) | (c) | (d) | (e) | (f) |
|---|---|---|---|---|---|
| **Parameters** | **Description of data** | **Estimated Values** | **Units** | **Source of data** | **Other comments** |
| $EF_{elec}$ | [For 1) grid electricity]<br>$CO_2$ emission factor for consumed electricity | | $tCO_2/MWh$ | 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. | |
| $EF_{elec}$ | [For 2) captive electricity]<br>CO2 emission factor for consumed electricity<br>**Option a)**;<br>[For 3) electricity directly supplied from small power producer (SPP) ]<br>CO2 emission factor for consumed electricity<br>**Option b)** | 0.000 | $tCO_2/MWh$ | Power generation efficiency obtained from manufacturer's specification. | Calculated<br><br>In case of [ 3) Electricity directly supplied from small power producer (SPP) ], when project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the CO2 emission factor with the lowest value. |
| $EF_{elec}$ | [For 2) captive electricity]<br>$CO_2$ emission factor for consumed electricity<br>**Option b)**;<br>[For 3) electricity directly supplied from small power producer (SPP) ]<br>CO2 emission factor for consumed electricity<br>**Option c)** | 0.000 | $tCO_2/MWh$ | The power generation efficiency calculated from monitored data of the amount of fuel input for power generation and the amount of electricity generated. | Calculated<br><br>In case of [ 3) electricity directly supplied from small power producer (SPP) ], when project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the CO2 emission factor with the lowest value. |
| $EF_{elec}$ | [For 2) captive electricity]<br>**In case the captive electricity generation system meets all of the following conditions;**<br>- The system is non-renewable generation system<br>- Electricity generation capacity of the system is less than or equal to 15 MW | | $tCO_2/MWh$ | [Captive electricity with diesel fuel]<br>CDM approved small scale methodology: AMS-I.A.<br><br>[Captive electricity with natural gas]<br>2006 IPCC Guidelines on National GHG Inventories for the source of EF of natural gas.<br>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. | |
| $EF_{elec}$ | [For 3) electricity directly supplied from small power producer (SPP) ]<br>$CO_2$ emission factor for consumed electricity<br>**Option a)** | | $tCO_2/MWh$ | [Electricity directly supplied from SPP]<br>a) The value provided by the SPP with 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. | When project chiller may consume electricity supplied from more than 1 SPP, the project participant applies the CO2 emission factor with the lowest value. |
| $T_{cooling\text{-}out,i}$ | Output cooling water temperature of project chiller *i* set under the project specific condition | - | degree Celsius | Specifications of project chiller i prepared for the quotation or factory acceptance test data by manufacturer | Input on "MPS (input_separate)" |

| | | | | | |
|---|---|---|---|---|---|
| $T_{chilled\text{-}out,i}$ | Output chilled water temperature of project chiller *i* set under the project specific condition | - | degree Celsius | Specifications of project chiller i prepared for the quotation or factory acceptance test data by manufacturer | Input on "MPS (input_separate)" |
| $COP_{RE,i}$ | COP of reference chiller *i* under the standardizing temperature conditions | - | - | Selected from the default values set in the methodology | Input on "MPS (input_separate)" |
| $COP_{PJ,i}$ | COP of project chiller *i* under the project specific conditions | - | - | Specifications of project chiller i prepared for the quotation or factory acceptance test data by manufacturer | Input on "MPS (input_separate)" |
| $COP_{PJ,tc,i}$ | COP of project chiller *i* calculated under the standardizing temperature conditions | - | - | Calculated with the following equation;<br>COPPJ,tc,i= COPPJ,i × [(Tcooling-out,i - Tchilled-out,i + TDchilled + TDcooling) ÷ (37 - 7 + TDchilled + TDcooling)] | |
| $\eta_{elec}$ | Power generation efficiency | | % | Specification of the captive power generation system provided by the manufacturer | For option a) of 2) captive electricity; option b) of 3) electricity directly supplied from SPP. |
| $NCV_{fuel}$ | Net calorific value of consumed fuel | | GJ/mass or volume | In order of preference:<br>1) values provided by the fuel supplier;<br>2) measurement by the project participants;<br>3) regional or national default values;<br>4) 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. | For option b) of 2) captive electricity; option c) of 3) electricity directly supplied from SPP. |
| $EF_{fuel}$ | $CO_2$ emission factor of consumed fuel | | $tCO_2/GJ$ | In order of preference:<br>1) values provided by the fuel supplier;<br>2) measurement by the project participants;<br>3) regional or national default values;<br>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 options a); b) of 2) captive electricity; options b); c) of 3) electricity directly supplied from SPP. |

**Table3: *Ex-post* calculation of $CO_2$ emission reductions**

| Monitoring period | $CO_2$ emission reductions | Units |
|---|---|---|
| | 0 | $tCO_2/p$ |

**[Monitoring option]**

| | |
|---|---|
| Option A | Based on public data which is measured by entities other than the project participants (Data used: publicly recognized data such as statistical data and specifications) |
| Option B | Based on the amount of transaction which is measured directly using measuring equipment (Data used: commercial evidence such as invoices) |
| Option C | Based on the actual measurement using measuring equipment (Data used: measured values) |

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| | | Parameters monitored *ex post* | | | Project-specific parameters fixed *ex ante* | | | | | | | | | | | | | *Ex-post* calculation of emissions | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Parameters | Chiller *i* | $EC_{PJ,i,p}$ | $FC_{PJ,p}$ | $EG_{PJ,p}$ | $EF_{elec}$ | $EF_{elec}$ | $EF_{elec}$ | $EF_{elec}$ | $EF_{elec}$ | $T_{cooling\text{-}out,i}$ | $T_{chilled\text{-}out,i}$ | $COP_{RE,i}$ | $COP_{PJ,i}$ | $COP_{PJ,tc,i}$ | $\eta_{elec}$ | $NCV_{fuel}$ | $EF_{fuel}$ | $RE_{i,p}$ | $PE_{i,p}$ | $ER_{i,p}$ |
| Description of data | Project chiller No. | Power consumption of project chiller *i* during the period *p* | The amount of fuel input for power generation during monitoring period *p* | The amount of electricity generated during the monitoring period *p* | [For 1) grid electricity] $CO_2$ emission factor for consumed electricity | [For 2) captive electricity] $CO_2$ emission factor for consumed electricity **Option a)**; [For 3) electricity directly supplied from small power producer (SPP) ] CO2 emission factor for consumed electricity **Option b)** | [For 2) captive electricity] $CO_2$ emission factor for consumed electricity **Option b);** [For 3) electricity directly supplied from small power producer (SPP) ] CO2 emission factor for consumed electricity **Option c)** | [For 2) captive electricity] **In case the captive electricity generation system meets all of the following conditions;** - The system is non-renewable generation system - Electricity generation capacity of the system is less than or equal to 15 MW | [For 3) electricity directly supplied from small power producer (SPP) ] $CO_2$ emission factor for consumed electricity **Option a)** | Output cooling water temperature of project chiller *i* set under the project specific condition | Output chilled water temperature of project chiller *i* set under the project specific condition | COP of reference chiller *i* under the standardizing temperature conditions | COP of project chiller *i* under the project specific conditions | COP of project chiller *i* calculated under the standardizing temperature conditions | Power generation efficiency | Net calorific value of consumed fuel | $CO_2$ emission factor of consumed fuel | Reference emissions of project chiller *i* during the period *p* | Project emissions of project chiller *i* during the period *p* | Emissions reductions by the project chiller *i* during the period *p* |
| Units | - | MWh/p | mass or volume/p | MWh/p | $tCO_2/MWh$ | $tCO_2/MWh$ | $tCO_2/MWh$ | $tCO_2/MWh$ | $tCO_2/MWh$ | degree Celsius | degree Celsius | - | - | - | % | mass or volume/p | $tCO_2/GJ$ | $tCO_2/p$ | $tCO_2/p$ | $tCO_2/p$ |
| Monitored /estimated values | 1 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 2 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 3 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 4 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 5 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 6 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 7 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 8 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 9 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 10 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 11 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 12 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 13 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 14 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 15 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 16 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 17 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 18 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 19 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | 20 | | 0.00 | 0.00 | | 0.000 | 0.000 | | | 0.0 | 0.0 | 0.00 | 0.00 | 0.00 | | | | 0.00 | 0.00 | 0.00 |
| | **Total** | - | | - | - | | | - | | | | | - | - | - | - | - | 0.00 | 0.00 | 0.00 |

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## Monitoring Report Sheet (Calculation Process Sheet) [For Verification]

| 1. Calculations for emission reductions | Fuel type | Value | Units | Parameter |
|---|---|---|---|---|
| Emission reductions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $ER_p$ |
| **2. Calculations for reference emissions** | | | | |
| Reference emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $RE_p$ |
| Reference emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $RE_p$ |
| **3. Calculations of the project emissions** | | | | |
| Project emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $PE_p$ |
| Project emissions during the period *p* | N/A | 0.00 | $tCO_2/p$ | $PE_p$ |

[List of Default Values]

| | | |
|---|---|---|
| $COP_{RE,i}$ (x≤600USRt) | 5.90 | - |
| $COP_{RE,i}$ (600<x≤800USRt) | 6.00 | - |
| $COP_{RE,i}$ (800<x≤1600USRt) | 6.08 | - |

| | | |
|---|---|---|
| $TD_{cooling}$ | 1.5 | degree Celsius |
| $TD_{chilled}$ | 1.5 | degree Celsius |