Joint Crediting Mechanism Approved Methodology ID AM002
"Energy Saving by Introduction of High Efficiency Centrifugal Chiller"

A. Title of the methodology

Energy Saving by Introduction of High Efficiency Centrifugal Chiller, Version ~~2.0~~3.0

B. Terms and definitions

Terms	Definitions
Centrifugal chiller	A centrifugal chiller is a chiller applying a centrifugal compressor. 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 ability 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.

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	This methodology applies to the project that aims for saving energy by introducing high efficiency centrifugal chiller for the target factory, commerce facilities etc. in Indonesia.
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 ● Electricity imported from the grid, where applicable ● Operating time of captive electricity generator, where applicable

D. Eligibility criteria

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

Criterion 1	Project chiller is a centrifugal chiller with a capacity of less than 1,250 USRt. * 1 USRt = 3.52 kW
Criterion 2	COP for project chiller *i* calculated under the standardizing temperature conditions* ($COP_{PJ,tc,i}$) is more than 6.0. $COP_{PJ,tc,i}$ is a recalculation of COP of project chiller i ($COP_{PJ,i}$) adjusting temperature conditions from the project specific condition to the standardizing conditions. $COP_{PJ,i}$ is derived in specifications prepared for the quotation or factory acceptance test data at the time of shipment 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* [-] $COP_{PJ,i}$: COP of project chiller *i* under the project specific conditions [-] $T_{cooling-out,i}$: Output cooling water temperature of project chiller *i* set under the project specific condition [degree Celsius] $T_{chilled-out,i}$: Output chilled water temperature of project chiller *i* set under the project specific condition [degree Celsius] $TD_{cooling}$: Temperature difference between condensing temperature of refrigerant and output cooling water temperature 1.5 degree Celsius set as a default value [degree Celsius] $TD_{chilled}$: Temperature difference between evaporating temperature of refrigerant and output chilled water temperature, 1.5 degree Celsius set as a default value [degree Celsius]

	*The standardizing temperature conditions to calculate $COP_{PJ,tc,i}$ Chilled water: output 7 degree Celsius input 12 degree Celsius Cooling water: output 37 degree Celsius input 32 degree Celsius
Criterion 3	Periodical check is planned more than four (4) times annually.
Criterion 4	Ozone Depletion Potential (ODP) of the refrigerant used for project chiller is zero.
Criterion 5	Plan for not releasing refrigerant used for project chiller is prepared. In the case of replacing the existing chiller with the project chiller, refrigerant used for the existing chiller is not 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, which is a centrifugal chiller, is conservatively set as a default value in the following manner to ensure the net emission reductions.

1. The COP value tends to increase as the cooling capacity becomes larger.
2. The reference COP, which has a certain cooling capacity, is set at a maximum value in corresponding cooling capacity range.
3. The maximum values of COP in each cooling capacity ranges 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

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

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. When project chiller consumes only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively. When project chiller may consume both grid electricity and captive electricity, the project participant applies the CO_2 emission factors for grid and captive electricity proportionately.	[Grid electricity] The most recent value available at the time of validation is applied and fixed for the monitoring period thereafter. The data

<table>
<tr><th>Parameter</th><th>Description of data</th><th>Source</th></tr>
<tr><td></td><td>Proportion of captive electricity is derived from dividing captive electricity generated by total electricity consumed at the project site. The total electricity consumed is a summation of grid electricity imported ($EI_{grid,p}$) and captive electricity generated ($EG_{gen,p}$)* during the monitoring period.

* Captive electricity generated can be derived from metering electricity generated or monitored operating time ($h_{gen,p}$) and rated capacity of generator (RC_{gen}).

[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: 0.8* [tCO_2/MWh]
*The most recent value available from CDM approved small scale methodology AMS-I.A at the time of validation is applied.</td><td>is sourced from “Emission Factors of Electricity Interconnection Systems”, National Committee on Clean Development Mechanism Indonesian DNA for CDM unless otherwise instructed by the Joint Committee.
[Captive electricity]
CDM approved small scale methodology: AMS-I.A</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.

$COP_{RE,i}$
<table><tr><td><u>Cooling capacity per unit (USRt)</u></td><td><u>x≤350</u></td><td><u>350<x ≤550</u></td><td><u>550<x ≤750</u></td><td><u>750<x <1,250</u></td></tr><tr><td><u>$COP_{RE,i}$</u></td><td><u>5.46</u></td><td><u>5.69</u></td><td><u>5.90</u></td><td><u>6.03</u></td></tr></table>
<table><tr><td><s>Cooling capacity /unit (USRt)</s></td><td><s>x<300</s></td><td><s>300≦ x<450</s></td><td><s>450≦ x<500</s></td><td><s>500≦ x<700</s></td><td><s>700≦ x<1,250</s></td></tr><tr><td><s>$COP_{RE,i}$</s></td><td><s>4.92</s></td><td><s>5.33</s></td><td><s>5.59</s></td><td><s>5.85</s></td><td><s>5.94</s></td></tr></table></td><td>Specifications of project chiller i prepared for the quotation or factory acceptance test data by manufacturer.

The default COP value is derived from the result of survey on COP of chillers from manufacturers that has high market share. The survey should prove the use</td></tr>
</table>

Parameter	Description of data	Source
		of clear methodology. The $COP_{RE,i}$ should be revised if necessary from survey result which is conducted by JC or project participants~~ every three years.~~
$COP_{PJ,i}$	The COP of project chiller *i* under the project specific condition.	Specifications of project 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 condition.	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 condition.	Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer
RC_{gen}	Rated capacity of generator, where applicable.	Specification of generator for captive electricity

History of the document

Version	Date	Contents revised
03.0	TBD	TBD

02.0	10 November 2015	Electronic decision by the Joint Committee Revision to the description of "Measurement methods and procedures" for the power consumption of project chillers in the Monitoring Spreadsheet.
01.0	17 September 2014	Electronic decision by the Joint Committee Initial approval.

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

Table 1: Parameters to be monitored *ex post*

(a) Monitoring point No.	(b) Parameters	(c) Description of data	(d) Estimated Values	(e) Units	(f) Monitoring option	(g) Source of data	(h) Measurement methods and procedures	(i) Monitoring frequency	(j) 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. - Specification of measuring equipments: 1) Electrical power meter is applied for measurement of electrical power consumption of project chiller. 2) Meter is certified in compliance with national/international standards on electrical power meter. - Measuring and recording: 1) Measured data is automatically sent to a server where data is recorded and stored. 2) Recorded data is checked its integrity once a month by responsible staff. - Calibration: In case a calibration certificate issued by an entity accredited under national/international standards is not provided, such measuring equipment is required to be calibrated.	Continuously	
(2)	$EI_{grid,p}$	Electricity imported from the grid to the project site during the period *p*		MWh/p	Option B or Option C	Invoice from the power company for Option B or monitored data for Option C	[for Option B] Data is collected and recorded from invoices from the power company. [for Option C] Data is measured by measuring equipments in the factory. - Specification of measuring equipments: 1) Electrical power meter is applied for measurement of power imported from the grid to the project site. 2) Meter is certified in compliance with national/international standards on electrical power meter. - Measuring and recording: 1) Measured data is automatically sent to a server where data is recorded and stored. 2) Recorded data is checked its integrity once a month by responsible staff. - Calibration: In case a calibration certificate issued by an entity accredited under national/international standards is not provided, such measuring equipment is required to be calibrated.	Every month	
(3)	$h_{gen,p}$	Operating time of captive electricity generator during the period *p*		hours/p	Option C	Monitored data	Data is measured by meter equipped to a generator.	Continuously	

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 grid electricity] CO_2 emission factor for consumed electricity	0.000	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 "Emission Factors of Electricity Interconnection Systems", National Committee on Clean Development Mechanism Indonesian DNA for CDM unless otherwise instructed by the Joint Committee.	
EF_{elec}	[For captive electricity] CO_2 emission factor for consumed electricity	0.8	tCO_2/MWh	CDM approved small scale methodology: AMS-I.A	
$T_{cooling-out,i}$	Output cooling water temperature of project chiller *i* set under the project specific condition	0	degree Celsius	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 condition	0	degree Celsius	Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer	
$COP_{RE,i}$	COP of reference chiller *i* under the standardizing temperature conditions	0.00	-	Selected from the default values set in the methodology	
$COP_{PJ,i}$	COP of project chiller *i* under the project specific conditions	0.00	-	Specifications of project chiller *i* prepared for the quotation or factory acceptance test data by manufacturer	
$COP_{PJ,tc,i}$	COP of project chiller *i* calculated under the standardizing temperature conditions	0.00	-	Calculated with the following equation; $COP_{PJ,tc,i} = COP_{PJ,i} \times [(T_{cooling-out,i} - T_{chilled-out,i} + TD_{chilled} + TD_{cooling}) \div (37 - 7 + TD_{chilled} + TD_{cooling})]$	
RC_{gen}	Rated capacity of generator	0.0	kW	Specification of generator for captive electricity	

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

CO_2 emission reductions	Units
#DIV/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 equipments (Data used: commercial evidence such as invoices)
Option C	Based on the actual measurement using measuring equipments (Data used: measured values)

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	#DIV/0!	tCO_2/p	ER_p
2. Selected default values, etc.				
COP of reference chiller i under the standardizing temperature conditions	N/A	0.00	-	$COP_{RE,i}$
3. Calculations for reference emissions				
Reference emissions during the period *p*	N/A	#DIV/0!	tCO_2/p	RE_p
Reference emissions	N/A			
CO_2 emission factor for consumed electricity [grid]	Electricity	0.00	tCO_2/MWh	EF_{elec}
CO_2 emission factor for consumed electricity [captive]	Electricity	0.8	tCO_2/MWh	EF_{elec}
Proportion of grid electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Proportion of captive electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Power consumption of project chiller *i*	Electricity	0.00	MWh/p	$EC_{PJ,i,p}$
COP of reference chiller *i* under the standardizing temperature conditions	N/A	0.00	-	$COP_{RE,i}$
COP of project chiller *i* calculated under the standardizing temperature conditions	N/A	0.00	-	$COP_{PJ,tc,i}$
4. Calculations of the project emissions				
Project emissions during the period *p*	N/A	#DIV/0!	tCO_2/p	PE_p
Project emissions	N/A			
CO_2 emission factor for consumed electricity [grid]	Electricity	0.00	tCO_2/MWh	EF_{elec}
CO_2 emission factor for consumed electricity [captive]	Electricity	0.8	tCO_2/MWh	EF_{elec}
Proportion of grid electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Proportion of captive electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Power consumption of project chiller *i*	Electricity	0.00	MWh/p	$EC_{PJ,i,p}$

[List of Default Values]

$COP_{RE,i}$ (~~x<300USRt~~x≤350USRt)	~~4.92~~5.46	-
$COP_{RE,i}$ (~~300≤x<450USRt~~350<x≤550USRt)	~~5.33~~5.69	-
$COP_{RE,i}$ (~~450≤x<500USRt~~550<x≤750USRt)	~~5.59~~5.90	-
$COP_{RE,i}$ (~~500≤x<700USRt~~750<x<1,250USRt)	~~5.85~~6.03	-
~~$COP_{RE,i}$ (700≤x<1250USRt)~~	~~5.94~~	-

$TD_{cooling}$	1.50	degree Celsius
$TD_{chilled}$	1.50	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. - Specification of measuring equipments: 1) Electrical power meter is applied for measurement of electrical power consumption of project chiller. 2) Meter is certified in compliance with national/international standards on electrical power meter. - Measuring and recording: 1) Measured data is automatically sent to a server where data is recorded and stored. 2) Recorded data is checked its integrity once a month by responsible staff. - Calibration: In case a calibration certificate issued by an entity accredited under national/international standards is not provided, such measuring equipment is required to be calibrated.	Continuously	
	(2)	$EI_{grid,p}$	Electricity imported from the grid to the project site during the period *p*		MWh/p	Option B or Option C	Invoice from the power company for Option B or monitored data for Option C	[for Option B] Data is collected and recorded from invoices from the power company. [for Option C] Data is measured by measuring equipments in the factory. - Specification of measuring equipments: 1) Electrical power meter is applied for measurement of power imported from the grid to the project site. 2) Meter is certified in compliance with national/international standards on electrical power meter. - Measuring and recording: 1) Measured data is automatically sent to a server where data is recorded and stored. 2) Recorded data is checked its integrity once a month by responsible staff. - Calibration: In case a calibration certificate issued by an entity accredited under national/international standards is not provided, such measuring equipment is required to be calibrated.	Every month	
	(3)	$h_{gen,p}$	Operating time of captive electricity generator during the period *p*		hours/p	Option C	Monitored data	Data is measured by meter equipped to a generator.	Continuously	

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 grid electricity] CO_2 emission factor for consumed electricity	0.000	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 "Emission Factors of Electricity Interconnection Systems", National Committee on Clean Development Mechanism Indonesian DNA for CDM unless otherwise instructed by the Joint Committee.	
EF_{elec}	[For captive electricity] CO_2 emission factor for consumed electricity	0.8	tCO_2/MWh	CDM approved small scale methodology: AMS-I.A	
$T_{cooling-out,i}$	Output cooling water temperature of project chiller *i* set under the project specific condition	0	degree Celsius	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 condition	0	degree Celsius	Specifications of project chiller i prepared for the quotation or factory acceptance test data by manufacturer	
$COP_{RE,i}$	COP of reference chiller *i* under the standardizing temperature conditions	0.00	-	Selected from the default values set in the methodology	
$COP_{PJ,i}$	COP of project chiller *i* under the project specific conditions	0.00	-	Specifications of project chiller i prepared for the quotation or factory acceptance test data by manufacturer	
$COP_{PJ,tc,i}$	COP of project chiller *i* calculated under the standardizing temperature conditions	0.00	-	Calculated with the following equation; $COP_{PJ,tc,i}= COP_{PJ,i} \times [(T_{cooling-out,i} - T_{chilled-out,i} + TD_{chilled} + TD_{cooling}) \div (37 - 7 + TD_{chilled} + TD_{cooling})]$	
RC_{gen}	Rated capacity of generator	0.0	kW	Specification of generator for captive electricity	

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

Monitoring Period	CO_2 emission reductions	Units
	#DIV/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 equipments (Data used: commercial evidence such as invoices)
Option C	Based on the actual measurement using measuring equipments (Data used: measured values)

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	#DIV/0!	tCO_2/p	ER_p
2. Selected default values, etc.				
COP of reference chiller i under the standardizing temperature conditions	N/A	0.00	-	$COP_{RE,i}$
3. Calculations for reference emissions				
Reference emissions during the period *p*	N/A	#DIV/0!	tCO_2/p	RE_p
Reference emissions	N/A			
CO_2 emission factor for consumed electricity [grid]	Electricity	0.00	tCO_2/MWh	EF_{elec}
CO_2 emission factor for consumed electricity [captive]	Electricity	0.8	tCO_2/MWh	EF_{elec}
Proportion of grid electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Proportion of captive electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Power consumption of project chiller *i*	Electricity	0.00	MWh/p	$EC_{PJ,i,p}$
COP of reference chiller *i* under the standardizing temperature conditions	N/A	0.00	-	$COP_{RE,i}$
COP of project chiller *i* calculated under the standardizing temperature conditions	N/A	0.00	-	$COP_{PJ,tc,i}$
4. Calculations of the project emissions				
Project emissions during the period *p*	N/A	#DIV/0!	tCO_2/p	PE_p
Project emissions	N/A			
CO_2 emission factor for consumed electricity [grid]	Electricity	0.00	tCO_2/MWh	EF_{elec}
CO_2 emission factor for consumed electricity [captive]	Electricity	0.8	tCO_2/MWh	EF_{elec}
Proportion of grid electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Proportion of captive electricity over total electricity consumed at the project site	N/A	#DIV/0!	-	-
Power consumption of project chiller *i*	Electricity	0.00	MWh/p	$EC_{PJ,i,p}$

[List of Default Values]

$COP_{RE,i}$ (~~x<300USRt~~x≤350USRt)	~~4.92~~5.46	-
$COP_{RE,i}$ (~~300≤x<450USRt~~350<x≤550USRt)	~~5.33~~5.69	-
$COP_{RE,i}$ (~~450≤x<500USRt~~550<x≤750USRt)	~~5.59~~5.90	-
$COP_{RE,i}$ (~~500≤x<700USRt~~750<x<1,250USRt)	~~5.85~~6.03	-
~~$COP_{RE,i}$ (700≤x<1250USRt)~~	~~5.94~~	-

$TD_{cooling}$	1.50	degree Celsius
$TD_{chilled}$	1.50	degree Celsius