Draft approved baseline and monitoring methodology AM00XX

"Power saving through replacement by energy efficient chillers"

I. SOURCE, DEFINITIONS AND APPLICABILITY

Source

This methodology is based on the project activity "India – Accelerated Chiller Replacement Program", whose baseline and monitoring methodology and project design document were prepared by Decan Corporation, USA and The World Bank.

For more information regarding the proposal and its consideration by the Executive Board please refer to case NM0197-rev: "Power saving through accelerated replacement of chillers" on http://cdm.unfccc.int/goto/MPappmeth

This methodology also refers to the latest approved version of the following tools[1]:

- "Combined tool to identify the baseline scenario and demonstrate additionality"; and
- "Tool to calculate the emission factor for an electricity system".

Selected approach from paragraph 48 of the CDM modalities and procedures

"Emissions from a technology that represents an economically attractive course of action, taking into account barriers to investment"

Definitions

For the purpose of this methodology, the following definitions apply:

Chiller. The term chiller is used to describe large-scale cooling equipment used in large commercial and industrial buildings and facilities. Chillers get their name because they work by cooling or "chilling" water, or a water/antifreeze mixture, that is circulated around the space or process to be cooled. For purposes of the present methodology, chillers are defined as system where the refrigerant is compressed and evaporated in a refrigeration cycle. Such chillers are electrically powered and include a condenser unit and an evaporator unit (as defined below). Chiller using absorption to force condensation of the refrigerant gas are not included under this definition.

Condenser unit.[2] The condenser unit is the component of a chiller where the refrigerant gas is compressed to cause condensation.

Evaporator unit. The evaporator unit is the component where the condensed refrigerant is evaporated by causing its rapid expansion into a low-pressure chamber through a nozzle.

Chill water. Chill water is the water or watermixture[3] that circulates through the evaporator unit, where it is cooled by the refrigerant as the latter evaporates. The chill water in turn circulates to the

[1] Please refer to: http://cdm.unfccc.int/goto/MPappmeth
[2] For the purpose of this methodology and for ease of understanding, the definitions of condenser unit and evaporator unit are given, avoiding unnecessary elaboration of all components of a chiller system. These definitions may not match with theoretical definition of condenser and evaporator.
[3] Water mixture is used in place of plain water when very low temperatures are needed at application point, which cannot be delivered by water as at those temperatures, water is likely to freeze.

applications that need to be cooled (e.g. space in buildings), where it exchanges heat, and is re-circulated back to the evaporator unit.

Condensing water and **cooling tower.** The condensing water is the water that circulates through the condenser unit, where it cools and thereby causes the condensation of the compressed refrigerant, and itself is warmed. Note that this is the key variable determining the condensation temperature U_0 of the refrigerant. The condensing water leaving the condenser unit is circulated back to a *cooling tower* where it is cooled through evaporation to the atmosphere, and re-circulated (with make-up water added to compensate for the evaporative loss) to the condenser unit.

Cooling system. A cooling system comprises all components needed to provide the cooling services. It comprises one or several chillers, plus ancillary equipment such as pumps for circulating the chill water and the condensing water, and associated piping, and the fans used to facilitate cooling at the cooling tower.

Electricity consumption of a chiller. The electricity consumption of a chiller, as referred to in this methodology, includes the electricity used to operate the chiller. This mainly includes the electricity needed to power the compressor. Electricity consumption from ancillary equipment, such as pumps for circulating the chill water and the condensing water or fans used to facilitate cooling at the cooling tower, is not included.

Existing chiller. Existing chiller refers to the chiller that is operated at the project site prior to the implementation of the project activity and is replaced under the project activity.

New chiller. New chiller refers to the new chiller that is installed under the project activity and replaces the existing chiller.

Chiller output. The chiller output of a given chiller is the average rate of cooling provided by the chiller during a certain time interval (in tons refrigeration).

Tons refrigeration (TR). The unit for the chiller output defined as 12000 BTU/hr where BTU means British thermal units or 3.51685 kW.

Rated output capacity. The rated output capacity of a chiller is the maximum chiller output (in TR) that the chiller is designed to deliver.

Power consumption function. The power consumption function determines the specific electricity consumption of a chiller (Kilowatt of power used per tons refrigeration provided) as a function of (a) the chiller output, (b) the inlet temperature of the condensing water and (c) the outlet temperature of the chill water. [Does this cover the ambient conditions?]

Applicability

The methodology is applicable to project activities that replace an existing chiller by a new chiller which is more energy efficient than the existing chiller. The methodology is applicable to the following two configurations:

- Prior to the implementation of the project activity, the cooling system was only served by one single existing chiller. This existing chiller is replaced by one single new chiller. The rated output capacity of the new chiller is not significantly larger (maximum +5%) than the rated output capacity of the existing chiller.

- Prior to the implementation of the project activity, the cooling system was served by several chillers. One or several of the existing chillers are replaced by corresponding new chiller(s). For each chiller replacement, the rated output capacity of the new chiller is not significantly larger or smaller (maximum ±5%) than the rated output capacity of the existing chiller. In this case, all procedures described in this methodology should be applied for each chiller separately.

The following conditions apply to the methodology:

- The existing chiller and the new chiller are used to generate chilled water or a water/antifreeze mixture (e.g., water with addition of glycol) for process cooling or air conditioning.
- The existing chiller is functioning and fully operational (i.e. not broken down, as documented by performance and maintenance logs for at least one year of operation preceding the start of crediting period) and can continue to operate for several years if usual maintenance is undertaken.
- The existing chiller and the new chiller are non-system integrated chillers, i.e. the replacement of the chiller does not impact any production processes or other level of service provided.
- The existing chiller and the new chiller are driven by electrical energy.
- The replacement of chillers is not required directly or indirectly by laws or regulations (e.g. to comply with safety or pollution standards), except for situations where non-compliance with the law or regulation is widespread and occurs in more than 50% of the cases.
- For the existing chiller the following data are available:
    - The production year/age of the chiller;
    - Data to obtain the power consumption function;
    - Historical data on physical leakage of refrigerant.
- The existing chiller, which is replaced under the project activity, is destroyed and destruction will be monitored and certified according to an established monitoring and certification protocol.
- The refrigerant contained in the existing chiller will be recovered and destroyed, or stored in suitable containers within suitable premises to ensure that the recovered, stored refrigerant gases can be monitored and tracked. Stored refrigerant gases may be withdrawn from storage for re-use, or for destruction by a method approved under regulations by the host country and/or pursuant to international treaties signed by the host country under Montreal, Kyoto or other Protocol that may in the future apply.
- The manufacturer of the new chiller confirms in a letter that he will not claim CERs for producing and selling the new chiller.

This methodology is <u>not</u> applicable to existing or new chillers that use the refrigerant directly for process cooling or air conditioning, e.g., direct expansion systems.[4]

This methodology is not applicable if the identified baseline scenario is not the continuation of use of the existing chiller.

II. BASELINE METHODOLOGY PROCEDURE

Project boundary

The project boundary includes the physical, geographical location of site where the chiller is replaced under the project activity. The project boundary includes also the electricity systems (grid) and, if

[4] The power output function of such system has to be established using a procedure different from those provided in this methodology.

applicable, any captive power plant(s) to which the project activity is connected (electricity system as defined in "tool to calculate the emission factor for an electricity system"). CO_2 emissions from power generation are included in the project boundary.

Table 1: Summary of gases and sources included in the project boundary, and justification / explanation where gases and sources are not included.

	Source	Gas	Included?	Justification / Explanation
Baseline	Power plants servicing the electricity grid and/or captive power plants	CO_2	Yes	Major emission source.
		CH_4	No	Minor source.
		N_2O	No	Minor source.
	Leakage of refrigerant from chillers.	Refrigerants that are GHGs	Yes	Only those refrigerants, that are GHGs and listed Annex A of the Kyoto Protocol, as per CDM Modalities and Procedures.
Project Activity	Power plants servicing the electricity grid and/or captive power plants	CO_2	Yes	Major emission source.
		CH_4	No	Minor source.
		N_2O	No	Minor source.
	Leakage of refrigerant from new chillers.	Refrigerants that are GHGs	Yes	Emissions from this source are measured when the refrigerant used in project chiller is a GHG as defined by Article 1, paragraph 5 of the Convention.[5]
	Leakage of refrigerants contained in the existing chiller	Refrigerants that are GHGs	No	Sale of refrigerants is likely to offset refrigerants newly manufactured, therefore its effects are neutral.

Procedure for estimating the remaining lifetime of the existing chiller

Project participants should determine the remaining lifetime of the existing chiller that is replaced under the project activity. The remaining lifetime of the existing chiller is determined as the difference between the technical lifetime and the age of the chiller.
The following approaches should be used to estimate the average technical lifetime of the existing chiller:

(a) Use documented data on common practices in the sector, e.g., based on industry surveys, statistics, technical literature, etc. in the relevant geographical area.
(b) Evaluate practices regarding replacement schedules e.g. based on historical replacement records of similar equipment.

In doing so, the availability of refrigerant used in the existing chiller, which may be affected by international agreements on phase-outs or national laws for phase-out of production and consumption of refrigerant types should be taken into account.
The average lifetime of the existing chiller should be chosen in a conservative manner, i.e., the lowest value for the remaining lifetime should be chosen in cases where the lifetime is estimated as a time

[5] This includes GHGs listed in Annex A of the Kyoto Protocol as well as GHGs controlled under the Montreal Protocol.

range rather than a single value. Document the age of the existing chiller and the remaining technical lifetime in the CDM-PDD and provide appropriate documentation and evidence. The remaining lifetime, as estimated, shall be subject to change if a regulation is enforced during the crediting period that results in an earlier date for replacement.

Identification of the baseline scenario and demonstration of additionality

Project participants shall apply the latest version of the "Combined tool to identify the baseline scenario and demonstrate additionality", agreed by the CDM Executive Board.
In applying step 1 of the tool, the following alternatives should, inter alia, be considered:

- Project implementation (chiller replacement) not undertaken as a CDM project activity;
- Continuation of the current situation, defined as continued use of the existing chiller without any retrofitting;
- Retrofitting of the existing chiller (e.g. driven by the availability of a new technology);
- Implementation of a fundamental process change which results in no further use of the existing chiller.

In identifying alternative scenarios ensure that all scenarios can provide the same cooling service (quantity and temperature of cooling provided) as the proposed CDM project activity. For example, the continuation of the current situation should be excluded from consideration if the existing chiller cannot provide the same flow and outlet temperature of the chill water as the new chiller.

This methodology is applicable only if the identified baseline scenario is the continued use of the existing chiller without any retrofitting.

Baseline emissions

Baseline emissions are determined as the product of the baseline electricity consumption of the existing chiller and the emission factor for electricity generation, as follows:

$$BE_y = EF_{ELEC,y} \times EC_{BL,y} \qquad \textbf{(1)}$$

Where:

BE_y	=	Baseline emissions in year *y* (t CO_2/yr)
$EF_{ELEC,y}$	=	Emission factor for electricity generation in year *y* (t CO_2/MWh)
$EC_{BL,y}$	=	Quantity of electricity that would be consumed by the existing chiller in the absence of the project activity in year *y* (MWh)

Determination of electricity consumption of the existing chiller ($EC_{BL,y}$)

The electricity consumption of the existing chiller in the absence of the project activity ($EC_{BL,y}$) is determined with the help of a power output function. The power output function correlates the key operating parameters of the cooling system which significantly affect the energy efficiency of the chiller – the quantity of cooling provided (OUP), the outlet temperature of the chill water (T_1) and the inlet temperature of the condensing water (V_0) – with the power consumption of the chiller. The power output function is established prior to the replacement of the chiller based on measurements or manufacturer's data, as outlined below.

During the crediting period, the three above-mentioned operating parameters are monitored. The electricity consumption of the existing chiller is estimated by applying the power output function to the three monitored parameters. As the operating parameters vary over time, this procedure is applied for many distinct time intervals *t* (1 hour). Annual baseline electricity consumption is then calculated as the summation over all time intervals *t*.

The baseline electricity consumption of the existing chiller is calculated as follows:

$$EC_{BL,y} = \sum_{t=1}^{t=p} EC_{BL,t} \tag{2}$$

with:

$$EC_{BL,t} = PF\left(OUP_t; V_{0,t}; T_{1,t}\right) \times OUP_t \tag{3}$$

$$OUP_t = m_t \times c_p \times \left(T_{0,t} - T_{1,t}\right) / 3025 \tag{4}$$

Where:

$EC_{BL,y}$	=	Quantity of electricity that would be consumed by the existing chiller in the absence of the project activity in year *y* (MWh)
$EC_{BL,t}$	=	Quantity of electricity that would be consumed by the existing chiller in the absence of the project activity in the time period *t* (MWh)
PF(...)	=	Power consumption function of the existing chiller (MW/TR)
OUP_t	=	Average chiller output of the new chiller during the period *t* (TR)[6]
m_t	=	Average flow rate of the chill water during the period *t* (kg/h)
c_p	=	Specific heat of the chill water (kcal / kg °C)
$V_{0,t}$	=	Average inlet temperature of the condensing water as it enters the condenser unit during the period *t* (°C)
$T_{0,t}$	=	Average inlet temperature of the chill water as it enters the evaporator unit during period *t* (°C)
$T_{1,t}$	=	Average outlet temperature of the chill water as it leaves the evaporator unit during period *t* (°C)
t	=	Time periods during the year *y*
T	=	Length of the time period *t* used to parameterise the power consumption function (default: 1 hour)
p	=	Number of time periods *t* during year *y* (= 8760/T)
3025	=	Conversion factor to convert kcal/hr to TR

For the purpose of establishing the power consumption function, project participants should determine and document in the CDM-PDD the maximum range over which the three key operating parameters (OUP, V_0, T_1) can vary in the cooling system. Preferably, historical data records for at least one year should be used for this purpose. The range should reflect the range of year-round ambient temperature and humidity conditions and cooling demand variations. Different ambient conditions (temperature and humidity) are reflected through different inlet temperature of the condensing water (as the operation of the cooling tower depends on ambient temperature and humidity) and different chiller output loads (as the cooling demand usually depends on the ambient temperature). The range of the inlet temperature of the condensing water can be determined based on data of the wet bulb and dry bulb temperatures specific to the location of chiller and information on the variation of humidity and ambient temperature, covering each season in the year and variations during days and nights. In the absence of more precise data, it may be assumed that the inlet temperature of the condensing water is 4 °C higher than the average ambient wet bulb temperature. The range of the outlet temperature of the chill water should be varied according to the cooling process or air conditioning requirements. However, in some

[6] The output of each new chiller should be accurately measured and estimated separately.

applications the outlet temperature of the chill water may be kept relatively constant, making the variation of this parameter unnecessary.

The power consumption function can then be estimated using one of the following three options:

Option A: Determination of the power consumption function based on measurements, following the procedure provided in the Annex to this methodology.

Option B: Determination of the power consumption function based on manufacturer's data. For this purposes, either a mathematical function or a look-up table may be produced, following the guidance provided in step 5 of the Annex to this methodology.

Option C: The power consumption function is assumed to be constant (and not dependent on the quantity of cooling provided, the outlet temperature of the chill water and the inlet temperature of the condensing water). In this case, the value for the power consumption function (PF) should be chosen as the most conservative value, i.e. the lowest power consumption that is observed over the maximum range of the three operating parameters. This value can either be determined based on measurements or manufacturer's data, following the guidance provided under Option A or Option B.

Note**:** If the rated output capacity of the new chillers (CAP_{PJ}) is less than 95% of the rated output capacity of existing chiller (CAP_{BL}), then option C shall be used.

Determination of the emission factor for electricity generation ($EF_{ELEC,y}$)

In the case electricity for the operation of the chillers is purchased from the grid and no captive power plant operates at the project site, the emission factor for electricity generation should be determined as the combined margin emission factor, using the latest approved version of the "Tool to calculate the emission factor for an electricity system".

In the case that electricity for the operation of the chillers is fully or partly provided by an on-site fossil fuel fired captive power plant, the lower emission factor between the grid emission factor and the emission factor of the captive power plant should be used as a conservative simplification[7], as follows:

$$EF_{ELEC,y} = MIN\left(EF_{grid,y}; EF_{EL,captive,y}\right) \quad \textbf{(5)}$$

Where:

$EF_{ELEC,y}$	=	Emission factor for electricity generation in year *y* (tCO_2/MWh)
$EF_{grid,y}$	=	Grid emission factor in year *y* (tCO_2/MWh)
$EF_{EL,captive,y}$	=	Emission factor for electricity generation in the captive power plant in year *y* (tCO_2/MWh)

[7] This conservative simplification has been made because it is depends on the exact configuration of the project activity to which extent electricity is displaced in the captive fossil fuel fired power plant and/or the grid. For example:

- The captive power plant at the project site may be dispatched independently of the electricity savings of the project activity. In this case, the project activity displaces grid power.
- The captive power plant may operate less as a result of the project activity during certain periods (e.g. day / night / summer / winter) but may operate at the same rate as in the absence of the project activity during other periods.

Project participants may request for a revision of this methodology to cover their specific project configuration in a more appropriate manner. This may require developing more detailed scenarios (see, for example, ACM0006).

The emission factor of the captive power plant ($EF_{EL,captive,y}$) may be determined one of the following options:

- In case of diesel generators: use the default value the default emission factor for a diesel generator with a capacity of more than 200 kW for small-scale project activities (0.8 tCO_2/MWh, see AMS 1.D.1 in the simplified baseline and monitoring methodologies for selected small-scale CDM project activity categories);
- Calculate $EF_{EL,captive,y}$ as follows:

$$EF_{EL,captive,y} = \frac{EF_{CO2,FF,captive,y}}{\eta_{EL,captive}} \times \frac{3.6}{1000} \qquad \textbf{(6)}$$

Where:

$EF_{EL,captive,y}$	=	Emission factor for electricity generation in the captive power plant (tCO_2/MWh)
$EF_{CO2,FF,captive}$	=	CO_2 emission factor of the fossil fuel type used in year *y* in the captive power plant (tCO_2/TJ)
$\eta_{EL,captive}$	=	Efficiency of electricity generation of the fossil fuel fired captive power plant

Project emissions

Project emissions are calculated as follows:

$$PE_y = PE_{ref,y} + PE_{EC,y} \qquad \textbf{(7)}$$

Where:

PE_y	=	Project emissions in year *y* (t CO_2/yr)
$PE_{ref,y}$	=	Project emissions from physical leakage of refrigerant from the new chiller(s) in year *y* (t CO_2e/yr)
$PE_{EC,y}$	=	Project emissions from electricity consumption in year *y* (t CO_2yr)

Emissions from physical leakage of the refrigerant

The use of refrigerant in the new chiller includes the initial charge of refrigerant before starting the operation of the new chiller and refrigerant used during the lifetime of the new chiller to replace refrigerant that has leaked. As a conservative simplification, it is assumed that all refrigerant used in the new chiller is released to the atmosphere. Moreover, the initial charge of refrigerant of the new chiller is accounted in the first year of the first crediting period.[8] All GHGs as defined per Article 1, paragraph 5, of the Convention should be considered, as per the guidance by the Board[9]. The emissions are determined as follows:

$$PE_{ref,y} = \left(Q_{ref,PJ,start} + Q_{ref,PJ,y}\right) \times GWP_{ref,PJ} - Q_{ref,BL} \times GWP_{ref,BL} \qquad \textbf{(8)}$$

Where:

$PE_{ref,y}$	=	Project emissions from physical leakage of refrigerant from the new chiller in year *y*

[8] In some countries, systems to recover and destroy or re-utilize refrigerants may be common practice. In this case, project participants may develop approaches to consider this and request for a revision of this methodology.

[9] Paragraph 17 of report of EB34.

		($t\ CO_2e/yr$)
$Q_{ref,PJ,start}$	=	Quantity of refrigerant charge in the new chiller at its start of operation (only accounted in the first year of the first crediting period) (tonnes/year)
$Q_{ref,PJ,y}$	=	Average annual quantity of refrigerant used in year *y* to replace refrigerant that has leaked in year *y* (tonnes/year).
$GWP_{ref,PJ}$	=	Global Warming Potential valid for the commitment period of the refrigerant that is used in new chiller (only to be accounted if the refrigerant is classified as a GHG) ($t\ CO_2e/t$ refrigerant)
$Q_{ref,BL}$	=	In case the refrigerant used in the existing chiller is listed in Annex A of KP, three year average quantity of refrigerant used by existing chiller in baseline, prior to implementation of project activity (tonnes/yr).
$GWP_{ref,BL}$	=	Global Warming Potential valid for the commitment period of the refrigerant that is used in new chiller (only to be accounted if the refrigerant is classified as a GHG listed in Annex A of Kyoto protocol) ($t\ CO_2e/t$ refrigerant)

Emissions from electricity consumption

Emissions from electricity consumption of the new chiller installed under the project activity are calculated based on the monitored electricity consumption by the new chiller and the emission factor for electricity generation, as follows:

$$PE_{EC,y} = EF_{ELEC,y} \times EC_{PJ,y} \tag{9}$$

Where:

$PE_{EC,y}$	=	Project emissions from electricity consumption in year *y* ($t\ CO_2/yr$)
$EC_{PJ,y}$	=	Quantity of electricity consumed in year *y* by the new chiller installed under the project activity (MWh/yr)
$EF_{ELEC,y}$	=	Emission factor for electricity generation in year *y* ($t\ CO_2/yr$)

Leakage Emissions

Leakage emissions from energy used in production of refrigerants is ignored, as they occur both in the baseline and the project activity and are expected to be of the same order of magnitude.

If HCFC-22 is used as refrigerant under the project activity and/or in the baseline, then HFC-23 emissions occurring as a by-product from the production of HCFC-22 shall be accounted as leakage emissions, as follows:

$$LE_{HFC23,y} = \left(Q_{HCFC22,PJ,start} + Q_{HCFC22,PJ,y} - Q_{HCFC22,BL}\right) \times 0.03 \times GWP_{HFC23} \tag{10}$$

Where:

$LE_{HFC23,y}$	=	Leakage emissions due to production of HFC-23 during manufacturing of HCFC-22 in year *y* (tCO_2e/yr)
$Q_{HCFC22PJ,start}$	=	Quantity of HCFC-22 charge in the new chiller at its start of operation (only accounted in the first year of the first crediting period) (tonnes/year)
$Q_{HCFC22,PJ,y}$	=	Average annual quantity of HCFC-22 used in year *y* to replace refrigerant that has leaked in year *y* (tonnes/year)
GWP_{HFC23}	=	Global Warming Potential of HFC-23 valid for the commitment period ($t\ CO_2/t$ HFC23)
$Q_{HCFC22,BL}$	=	In case the existing chiller also uses the HCFC-22 as refrigerant,$Q_{HCFC22,BL}$ should be estimated as three year average quantity of HCFC-22 used in the existing chiller

(tonnes/year)

Emissions Reductions

Emission reductions are calculated as follows:

$$ER_y = BE_y - PE_y - LE_{HFC23,y} \quad \textbf{(11)}$$

Where:

ER_y = Emission reductions in year *y* (t CO_2/yr)
BE_y = Baseline emissions in year *y* (t CO_2/yr)
PE_y = Project emissions in year *y* (t CO_2/yr)
$LE_{HFC23,y}$ = Leakage emissions due to production of HFC-23 during manufacturing of HCFC-22 in year *y* (tCO_2e/yr)

ER_y = 0 if the year *y* of the crediting period is larger than the remaining life time of the replaced existing chiller, as determined per the procedure provided above.

Changes required for methodology implementation in 2nd and 3rd crediting periods

At the start of the second and third crediting period for a project activity, two issues are to be addressed: (i) assessing the continued validity of the baseline scenario, and (ii) updating the baseline.
The continued validity of the baseline scenario shall be assessed by applying the procedure to identify the baseline scenario, as outlined above. Updating the baseline includes to reassess the remaining lifetime of each chiller that was replaced by applying the "procedure for estimating the remaining lifetime of the existing chiller" as outlined above.
All parameters included under "data and parameters not monitored" shall be updated at the renewal of the crediting period. Finally, the provisions in the latest approved versions of the tools used by this methodology apply.

Data and parameters not monitored

Data / parameter:	T
Data unit:	hour
Description:	Length of the time period *t* used to parameterise the power consumption function
Source of data:	1 hour should be used as a default value. A shorter time period should be chosen if there are typically significant load variations within 1 hour.
Measurement procedures (if any):	
Any comment:	If load fluctuations are high, project proponents can use the value of T below 1 hour. A proper justification should be provided for this.

Data / parameter:	c_p
Data unit:	kcal / kg °C
Description:	Specific heat of the chill water
Source of data:	Use references in standard engineering books or appropriate thermodynamic models
Value to be applied:	Apply a value of 1.000 for water
Any comment:	-

Data / parameter:	$\eta_{EL,captive}$
Data unit:	-
Description:	Efficiency of electricity generation of the fossil fuel fired captive power plant
Source of data:	
Measurement procedures (if any):	
Any comment:	Only applicable if the electricity to operate the new chiller is fully or partly provided by an on-site fossil fuel fired captive power plant and if the default value for diesel generators is not used

Data / parameter:	CAP_{BL}
Data unit:	Tons refrigeration (TR)
Description:	Rated output capacity of the existing chiller that is replaced under the project activity
Source of data:	Manufacturer's data or measurements by project participants
Measurement procedures (if any):	
Any comment:	

Data / parameter:	CAP_{PJ}
Data unit:	Tons refrigeration (TR)
Description:	Rated output capacity of the new chiller installed under the project activity
Source of data:	Manufacturer's data
Measurement procedures (if any):	
Any comment:	

Data / parameter:	$Q_{ref,PJ,start}$ and $Q_{HCFC22,PJ,start}$
Data unit:	tonnes
Description:	Quantity of refrigerant charge in the new chiller at its start of operation
Source of data:	Manufacturer's data
Measurement procedures (if any):	-
Any comment:	Note that this emissions source is only accounted in the first year of the first crediting period

Data / parameter:	$Q_{ref,BL}$ and $Q_{HCFC22,BL}$
Data unit:	tonnes
Description:	Three year average quantity of refrigerant used in the existing chiller (tonnes/year)
Source of data:	Baseline data of existing chiller
Measurement procedures (if any):	The refrigerant used in each baseline year to replace the physically leaked refrigerant.
Any comment:	If the refrigerant used in existing chiller is not HCFC-22, it should be listed in Annex A of Kyoto Protocol, for the necessary accounting under this monitoring procedure.

Data / parameter:	$GWP_{ref,PJ}$
Data unit:	t CO_2e/t refrigerant
Description:	Global Warming Potential, valid for the commitment period, of the refrigerant that is used in the new chiller
Source of data:	If the refrigerant used is listed in Annex A of the Protocol, then values listed in IPCC's second assessment report shall be used, else values listed in the IPCC's third assessment report shall be used.
Measurement procedures (if any):	-
Any comment:	Only to be accounted if the refrigerant is classified as a GHG as per Article 1, paragraph 5, of the Convention

Data / parameter:	GWP_{HFC23}
Data unit:	t CO_2e/t refrigerant
Description:	Global Warming Potential of HFC-23 valid for the commitment period
Source of data:	Relevant COP/MOP decisions
Value to be applied:	11,700 for the first commitment period
Any comment:	-

III. MONITORING METHODOLOGY

Monitoring procedures

The key variables to be monitored are the electricity consumption of the chiller and the operation parameters of the chiller required to apply the power consumption function. In addition, the quantity of refrigerants used in the project activity should be used.

An electronic database (e.g., spreadsheets) shall be established for the purpose of the project activity. This database should contain the measurement results of the relevant parameters for each period *t* and may serve to calculate the emission reductions based on the measurement results. The database should be part of monitoring reports.

Moreover, monitoring shall comprise the following:

Destruction certification. The existing chiller must be destructed after replacement to ensure that the existing chiller is not sold and reutilized but taken out of service permanently. The destruction must be witnessed, photographed (still and video), and certified by an independent third party, using a standard form of certification that shall make provisions for the unique identification of the existing chiller destroyed.

Metering equipment (data logger) calibration. The data logger used to continuously monitor the operation of the new chiller must be calibrated and certified before being put into use. For this purpose the certification of the manufacturer will be considered sufficient. Thereafter, the meters must be re-calibrated on a schedule to be determined; say, annually. A small random sample may be checked after the first year, and the results of that, together with experience gained of the statistical behaviour of the data downloads, will determine how frequently subsequent recalibration should be carried out.

Continuous metering. The meters (data-loggers) should generate automatically a stream of data pertaining to power consumption and the operating parameters specified in the tables below. Given that carbon credits earned will depend critically on the data generated and reported by these meters, it will be necessary to evolve means to ensure that they are not tampered with, that is, the meters will have to be sealed, and measures will need to be taken to ensure that they are reasonably hack-proof.

Describe and specify in the CDM-PDD all monitoring procedures, including the type of measurement instrumentation used, the responsibilities for monitoring and QA/QC procedures that will be applied. Where the methodology provides different options (e.g. use of default values or on-site measurements), specify which option will be used. Meters should be installed, maintained and calibrated according to equipment manufacturer instructions and be in line with national standards, or, if these are not available, international standards (e.g. IEC, ISO).

All data collected as part of monitoring should be archived electronically and be kept at least for two years after the end of the last crediting period. 100% of the data should be monitored if not indicated differently in the comments in the tables below.

Finally, the monitoring provisions in the tools referred to by this methodology apply.

Data and parameters monitored

Data / parameter:	m_t
Data unit:	kg / hour
Description:	Average flow rate of the chill water during the period *t*
Source of data:	Measurements by project participants
Measurement procedures (if any):	The flow rate cannot be measured directly, but may be calculated using one of the following approaches, for which the new chiller shall be equipped, and the relevant data logged automatically to the data logging device: • Measurement of pump Head, where a meter attached to the pump is available for this purpose, and look-up of the pump characteristic curves to determine corresponding flow rate; • Measurement of pressure drop across the evaporator, and calculation of flow from this data; and • Measurement of pressure drop across the balancing valve, and calculation of flow rate from this data.
Monitoring frequency:	Continuously, average values to be determined for each time period *t* of length *T*
QA/QC procedures:	
Any comment:	

Data / parameter:	$V_{0,t}$
Data unit:	°C
Description:	Average inlet temperature of the condensing water as it enters the condenser unit during the period *t*
Source of data:	Measurements by project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuously, average values to be determined for each time period *t* of length *T*
QA/QC procedures:	
Any comment:	

Data / parameter:	$T_{0,t}$
Data unit:	°C
Description:	Average inlet temperature of the chill water as it enters the evaporator unit during period *t*
Source of data:	Measurements by project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuously, average values to be determined for each time period *t* of length *T*
QA/QC procedures:	
Any comment:	

Data / parameter:	$T_{1,t}$
Data unit:	°C
Description:	Average outlet temperature of the chill water as it leaves the evaporator unit during period *t*
Source of data:	Measurements by project participants
Measurement procedures (if any):	
Monitoring frequency:	Continuously, average values to be determined for each time period *t* of length *T*
QA/QC procedures:	
Any comment:	

Data / parameter:	$EF_{grid,y}$
Data unit:	tCO_2/MWh
Description:	Grid emission factor in year *y*
Source of data:	As per the latest version of the “Tool to calculate the emission factor for an electricity system”
Measurement procedures (if any):	As per the latest version of the “Tool to calculate the emission factor for an electricity system”
Monitoring frequency:	As per the latest version of the “Tool to calculate the emission factor for an electricity system”
QA/QC procedures:	As per the latest version of the “Tool to calculate the emission factor for an electricity system”
Any comment:	-

Data / parameter:	$EF_{CO2,FF,captive}$
Data unit:	tCO_2/TJ
Description:	CO_2 emission factor of the fossil fuel type used in year *y* in the captive power plant
Source of data:	The following data sources may be used if the relevant conditions apply: (see table below)
Measurement procedures (if any):	For a) and b): Measurements should be undertaken in line with national or international fuel standards.
Monitoring frequency:	For a) and b): The CO_2 emission factor should be obtained for each fuel delivery, from which weighted average annual values should be calculated For c): Review appropriateness of the values annually For d): Any future revision of the IPCC Guidelines should be taken into account
QA/QC procedures:	-
Any comment:	Only applicable if the electricity to operate the new chiller is fully or partly provided by an on-site fossil fuel fired captive power plant and if the default value for diesel generators is not used

Data source	**Conditions for using the data source**
a) Values provided by the fuel supplier in invoices	This is the preferred source.
b) Measurements by the project participants	If a) is not available
c) Regional or national default values	If a) is not available These sources can only be used for liquid fuels and should be based on well documented, reliable sources (such as national energy balances).
d) IPCC default values at the lower limit of the uncertainty at a 95% confidence interval as provided in table 1.4 of Chapter 1 of Vol. 2 (Energy) of the 2006 IPCC Guidelines on National GHG Inventories	If a) is not available

Data / parameter:	$Q_{ref,PJ,y}$ and $Q_{HCFC22,PJ,y}$
Data unit:	Tonnes/year
Description:	Average annual quantity of refrigerant used in year *y* to replace refrigerant that has leaked in year *y*
Source of data:	Inventory data by the project participants of refrigerant cylinders consumed in year *y*
Measurement procedures (if any):	-
Monitoring frequency:	Annually
QA/QC procedures:	Cross-check the quantities of refrigerants consumed with typical leakage rates of the refrigerators
Any comment:	-

Annex: Procedure to determine the power consumption function based on measurements

The power consumption function (or baseline efficiency profile) of chiller is established under different chiller outputs (OUP), inlet temperatures of the condensing water (V_0) and outlet temperatures of the chill water (T_1) to reflect the representative range of year-round ambient temperature and humidity conditions. The power consumption function is should be measured through the steps outlined below. The measurement results and the derivation of the power consumption function should be documented transparently in the CDM-PDD or the first monitoring report.

Step 1: Ensure chiller is maintained properly before experiment

Ensure that the chiller is filled with the correct quantity of refrigerant and the scaling in the condenser unit and evaporator unit is removed. In addition, preventive maintenance of the chiller should be done prior to carrying out the measurements.

Step 2: Define the operating conditions for which measurements are carried out

The measurements should be carried out for the maximum range of variation of the chiller output (OUP), the inlet temperatures of the condensing water (V_0) and the outlet temperatures of the chill water (T_1), as identified in the baseline procedure above. For this purpose, project participants should identify discrete operation points for which steady-state measurements are carried out. For example, if the chiller output varies from 0 to 100 TR, discrete measurement points may cover chiller outputs of 20, 40, 60, 80 and 100 TR. The discrete measurement points should cover applicable combinations of the three parameters (OUP, V_0 and T_1).

Step 3: Install the necessary measurement equipment

Install the necessary measurement equipment to measure the following parameters:

- Electricity consumption of the chiller;
- Inlet temperatures of the condensing water (V_0);
- Inlet temperature of the chill water (T_0);
- Outlet temperatures of the chill water (T_1);
- Flow of the chill water (m).

The guidance provided in the monitoring methodology should be followed when measuring these parameters.

Step 4: Carry out measurements

Measure the parameters identified in step 3 for each discrete operation point identified in step 2, by operating the chiller at the discrete operating conditions. The discrete operating points can, inter alia, be generated by the following means:

- The chill water flow may be varied with the help of a valve or variable speed drive or starting or stopping the number of pumps distributing the chill water to consumers.

- The different inlet temperatures of the condensing water (V_0) can be generated by installing a water conditioning device (including chiller/ heater) at the inlet of the condenser unit to produce the desired cooling water temperature. This conditioning device may, inter alia, work on following principles:

    - Electric heaters (or hot water) and chilled water pipes are installed;

    - The device can also be a type of mixer, which can facilitate addition of small amount of chilled water in the inlet condensing water.

In the case that several chillers operate in parallel, having a common condensing water and/or chilled water circuit, isolating one chiller for the purpose of the experiment can influence the operation of other chillers. In such cases, either the chiller under experiment will require a separate water circuit or will have to be isolated from the other chillers for the time of experiment.

Step 5: Establish the power consumption function

Calculate the chiller output as per equation # in the baseline methodology for each discrete operation point. Establish for each discrete operation point all four parameters (EC, OUP, V_0 and T_1) of the power consumption function in a table. An example is provided in table 2 below.

Table 2: Example of data collected to establish the power consumption function

Specific electricity consumption (MW/TR)	Chiller output (TR)	Inlet temperature of the condenser water (V_0)	Outlet temperature of the chill water (T_1)
0.00088	100 TR	40 °C	6 °C
0.00078	100 TR	40 °C	8 °C
0.00073	100 TR	40 °C	10 °C
0.00070	100 TR	40 °C	12 °C
0.00075	100 TR	30 °C	6 °C
0.00073	100 TR	30 °C	8 °C
0.00070	100 TR	30 °C	10 °C
0.00066	100 TR	30 °C	12 °C
0.00069	100 TR	20 °C	6 °C
0.00066	100 TR	20 °C	8 °C
0.00063	100 TR	20 °C	10 °C
0.00062	100TR	20 °C	12 °C
0.00088	80 TR	40 °C	6 °C
0.00080	80 TR	40 °C	8 °C
	...	...	...

The power consumption function may be established by the following two ways:

- Use a look-up table, as the one provided in Table 2, as the power consumption function. To ensure a conservative approach, for each period *t* the more conservative should be selected if the monitored data operating parameters (OUP_t, $V_{0,t}$, $T_{1,t}$) are between the discrete operation points provided in the look-up table. For example: If the monitored chiller output is 90 TR, the inlet temperature of the condenser water is 35°C and the outlet temperature of the chill water is 7°C, the lowest value for the specific electricity consumption among the following eight data sets should be used:

    - OUP = 100 TR; V_0 = 40°C; T_1 = 6°C

- $OUP = 100$ TR; $V_0 = 40°C$; $T_1 = 8°C$
- $OUP = 100$ TR; $V_0 = 30°C$; $T_1 = 6°C$
- $OUP = 100$ TR; $V_0 = 30°C$; $T_1 = 8°C$
- $OUP = 80$ TR; $V_0 = 40°C$; $T_1 = 6°C$
- $OUP = 80$ TR; $V_0 = 40°C$; $T_1 = 8°C$
- $OUP = 80$ TR; $V_0 = 30°C$; $T_1 = 6°C$
- $OUP = 80$ TR; $V_0 = 30°C$; $T_1 = 8°C$

- Develop a mathematical expression that correlates the three operating parameters (OUP_t, $V_{0,t}$, $T_{1,t}$) with the electricity consumption. In doing so, conservativeness should be ensured by requiring that the result of the function, when applied to the discrete operation points, is on average the same or lower than the specific electricity consumption measured.

- - - - -