Joint Crediting Mechanism Approved Methodology TH_AM011
"Installation of Energy-efficient Refrigerators Using Natural Refrigerant at Cold Storage"

A. Title of the methodology

Installation of Energy-efficient Refrigerators Using Natural Refrigerant at Cold Storage, Version 01.0

B. Terms and definitions

Terms	Definitions
Secondary loop cooling system	A secondary loop cooling system is an indirect cooling system that cools the object with a secondary refrigerant (e.g., brine) which is cooled by a primary refrigerant (e.g., HFC). The secondary loop cooling system primarily consists of the refrigerator which is mainly composed of the compressor and heat exchangers as the primary refrigeration cycle and pumps, heat exchangers and fans as the secondary refrigeration cycle. The secondary loop cooling system is described as "primary refrigerant/secondary refrigerant" (e.g., "HFC/brine").
Coefficient of Performance (COP)	COP is defined as a value calculated by dividing refrigeration capacity by electricity consumption of a refrigerator under a full load condition. Electricity consumption of a refrigerator is defined in this methodology as the electricity used to operate the compressor. Electricity consumption of pumps for circulating the secondary refrigerant, and other ancillary equipment are not included in the COP calculation. The room temperature conditions at which COPs are calculated in this methodology are shown below: • *Room temperature condition: - 25 deg. C, 0 deg. C, 5 deg. C* • *Cooling water fed to condenser: inlet 32 deg. C*
Natural refrigerant	Natural refrigerant refers to naturally occurring substances

	with refrigeration capacity and with zero ozone depletion potential (ODP) (e.g. CO_2 and NH_3).
Periodical check	Periodical check is a periodical maintenance operation done by the manufacturer or an agent who is authorized by the manufacturer to maintain refrigerator performance (not including part replacement or overhaul).

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	Energy-efficient refrigerators using natural refrigerant is introduced for energy saving at the cold storage.
Calculation of reference emissions	Reference emissions are GHG emissions from reference refrigerators, calculated by using data of power consumption of project refrigerator, ratio of COPs of reference/project refrigerators and CO_2 emission factor for consumed electricity.
Calculation of project emissions	Project emissions are GHG emissions from project refrigerator, calculated with power consumption of project refrigerator and CO_2 emission factor for consumed electricity.
Monitoring parameters	Power consumption of project refrigerator

D. Eligibility criteria

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

<table>
<tr><td>Criterion 1</td><td>Refrigerator(s) with a secondary loop cooling system using CO₂ as a refrigerant and equipped with inverter is installed at cold storage.</td></tr>
<tr><td>Criterion 2</td><td>COP of project refrigerator(s) installed in the project cooling system is more than the threshold COP values set in the tables below. (“x” in the table represents cooling capacity per unit.)
<table>
<tr><th>Room temperature condition</th><th>Cooling capacity (kW)</th><th>Threshold COP value</th></tr>
<tr><td>- 25 deg. C</td><td>42.4 ≤ x ≤ 340.0</td><td>1.71</td></tr>
<tr><td>0 deg. C</td><td>73.6 ≤ x ≤ 516.4</td><td>2.79</td></tr>
<tr><td>5 deg. C</td><td>86.2 ≤ x ≤ 612.6</td><td>3.20</td></tr>
</table>
</td></tr>
</table>

	COP for the project refrigerator(s) are calculated with the following conditions: • *Room temperature condition: - 25 deg. C or 0 deg. C or 5 deg. C* • *Cooling water fed to condenser: inlet 32 deg. C*
Criterion 3	Periodical check is planned at least one (1) time annually.
Criterion 4	In the case of replacing the existing refrigerator with the project refrigerator, a plan for prevention of releasing refrigerant used in the existing refrigerator 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 the reference refrigerator	CO_2
Project emissions	
Emission sources	GHG types
Power consumption by the project refrigerator	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Reference emissions are calculated by multiplying the power consumption of project refrigerator, ratio of COPs for reference/project refrigerators and CO_2 emission factor for consumed electricity.

The following types of cooling system are identified as possible cooling systems other than the project system to be installed at cold storage:

- For room temperature condition of -25 deg. C: HFC dry expansion (single loop), NH_3 flooded, pump system (single loop), HFC/brine (secondary loop) and NH_3/brine (secondary loop)
- For room temperature condition of 0 deg. C and 5 deg. C: HFC dry expansion (single loop)

This methodology ensures that net emission reductions are achieved by applying the following conservative assumptions:

- Determination of default values for COP_{RE}:

The maximum COP values of refrigerators among the data of possible type cooling systems available in Thai market within the range specified by Criterion 2 is defined as the default values of COP_{RE} (1.71 for temperature condition of - 25 deg. C, 2.79 for temperature condition of 0 deg. C and 3.20 for 5 deg. C) to ensure the net emission reductions.

- Emissions associated with leakage of refrigerant in operation:

Among the possible types of cooling systems, two cooling systems use HFCs (R404A, GWP: 3,000-4,000) as refrigerant. The project cooling system uses a natural refrigerant that has a very small GWP (CO_2: 1, NH_3: less than 1). However, emissions associated with leakage of refrigerant are not counted in the emission reduction calculation.

- Project refrigerator equipped with inverter:

The project refrigerator is controlled by inverter technology. In this methodology, COP is defined under the condition of full load although in reality a cold storage is often operated under the condition of partial load where the efficiency of the refrigerator without inverter tends to decrease because of its intermittent operation. Calculating emissions based on the COPs of full load conditions is deemed conservative since the efficiency of the project refrigerator is likely to be maintained either at the full load or at partial load condition as it is equipped with inverter.

F.2. Calculation of reference emissions

$$RE_p = \sum_i \left(EC_{PJ,i,p} \times \frac{COP_{PJ,i}}{COP_{RE,i}} \times EF_{elec} \right)$$

Where

RE_p	Reference emissions during the period p [tCO_2/p]
$EC_{PJ,i,p}$	Power consumption of project refrigerator i during the period p [MWh/p]
$COP_{PJ,i}$	COP of project refrigerator i [-]
$COP_{RE,i}$	COP of reference refrigerator i [-]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
i	Identification number of refrigerators

G. Calculation of project emissions

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

Where

PE_p	Project emissions during the period p [tCO_2/p]
$EC_{PJ,i,p}$	Power consumption of project refrigerator i during the period p [MWh/p]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
i	Identification number of refrigerators

H. Calculation of emissions reductions

$$ER_p = RE_p - PE_p$$

Where

ER_p	Emission reductions during the period p [tCO_2/p]
RE_p	Reference emissions during the period p [tCO_2/p]
PE_p	Project emissions during the period p [tCO_2/p]

I. Data and parameters fixed *ex ante*

The source of each data and parameter fixed *ex ante* is listed as below.

Parameter	Description of data	Source
$COP_{PJ,i}$	COP of project refrigerator i [-]. The room temperature conditions at which COPs are calculated in this methodology are shown below: • *Room temperature condition: - 25 deg. C, 0 deg. C, 5 deg. C* • *Cooling water fed to condenser: inlet 32 deg. C*	Specifications of project refrigerator i prepared for the quotation or factory acceptance test data at the time of shipment by manufacturer.

<table>
<tr>
<td>$COP_{RE,i}$</td>
<td>COP of reference refrigerator i [-]

The default values for $COP_{RE,i}$ is applied depending on the room temperature condition set for the project refrigerator i:
<table>
<tr><th>Temperature condition</th><th>Cooling capacity</th><th>Default values</th></tr>
<tr><td>- 25 deg. C</td><td>$42.4 \leq x \leq$ 340.0kW</td><td>1.71</td></tr>
<tr><td>0 deg. C</td><td>$73.6 \leq x \leq$ 516.4kW</td><td>2.79</td></tr>
<tr><td>5 deg. C</td><td>$86.2 \leq x \leq$ 612.6kW</td><td>3.20</td></tr>
</table>
* “x” in the table represents cooling capacity per unit.</td>
<td>The default COP values are derived from the maximum value of COP among the available data of the possible types of refrigerators except project within the range specified by Criterion 2.
The survey should prove the use of clear methodology.
Default values of $COP_{RE,i}$ should be revised if necessary from survey result which is conducted by JC or project participants.</td>
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<tr>
<td>EF_{elec}</td>
<td>CO_2 emission factor for consumed electricity [tCO_2/MWh].
When the project refrigerator consumes only 1) grid electricity, 2) captive electricity or 3) electricity directly supplied from other sources (e.g. independent power producer (IPP), small power producer (SPP) and very small power producer (VSPP)) to the project site, the project participant applies the CO_2 emission factor respectively.
When the project refrigerator may consume electricity supplied from more than 1 electric source, the project participant applies the CO_2 emission factor with the lowest value.

[CO_2 emission factor]
Case 1) Grid electricity
The most recent value available from the source stated in this table at the time of validation

Case 2) Captive electricity including cogeneration system</td>
<td>Case 1)
[Grid electricity]
The most recent value available at the time of validation is applied and fixed for the monitoring period thereafter. The data is sourced from “Grid Emission Factor (GEF) of Thailand”, endorsed by Thailand Greenhouse Gas Management Organization (TGO) unless otherwise instructed by the Joint Committee.

Case 2)
[Captive electricity]
<u>For Option a)</u>
Specification of the captive power generation system provided by the manufacturer (η_{elec} [%]). CO_2 emission</td>
</tr>
</table>

	EF_{elec} is determined based on the following options: a) Calculated from its power generation efficiency (η_{elec} [%]) obtained from manufacturer's specification. The power generation efficiency based on lower heating value (LHV) of the captive power generation system from the manufacturer's specification is applied; $$EF_{gen} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$$ b) Calculated from measured data The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{PJ,p}$) and the amount of electricity generated ($EG_{PJ,p}$) during the period p is applied. The measurement is conducted with the monitoring equipment to which calibration certificate is issued by an entity accredited under national/international standards; $$EF_{elec} = FC_{PJ,p} \times NCV_{fuel} \times EF_{fuel} \times \frac{1}{EG_{PJ,p}}$$ Where: NCV_{fuel} : Net calorific value of consumed fuel [GJ/mass or volume] Note: In case the captive electricity generation system meets all of the following conditions, the value in the following table may be applied to EF_{elec} depending on the consumed fuel type. ● The system is non-renewable generation system ● Electricity generation capacity of the system is less than or equal to 15 MW	factor of the fossil fuel type used in the captive power generation system (EF_{fuel} [tCO_2/GJ]) For Option b) Generated and supplied electricity by the captive power generation system ($EG_{PJ,p}$ [MWh/p]). Fuel amount consumed by the captive power generation system ($FC_{PJ,p}$ [mass or volume/p]). Net calorific value (NCV_{fuel} [GJ/mass or volume]) and CO_2 emission factor of the fuel (EF_{fuel} [tCO_2/GJ]) in order of preference: 1) values provided by the fuel supplier; 2) measurement by the project participants; 3) regional or national default values; 4) IPCC default values provided in tables 1.2 and 1.4 of Ch.1 Vol.2 of 2006 IPCC Guidelines on National GHG Inventories. Lower value is applied. [Captive electricity with diesel fuel] CDM approved small scale methodology: AMS-I.A. [Captive electricity with natural gas]

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<table>
<tr><td>fuel type</td><td>Diesel fuel</td><td>Natural gas</td></tr>
<tr><td>EF_{elec}</td><td>0.8 *1</td><td>0.46 *2</td></tr>
</table>
*1 The most recent value at the time of validation is applied.
*2 The value is calculated with the equation in the option a) above. The lower value of default effective CO_2 emission factor for natural gas (0.0543tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.

Case 3) Electricity directly supplied from other sources including cogeneration system
EF_{elec} is determined based on the following options:
a) The value provided by the electricity supplier with the evidence;
b) The value calculated in the same manner for the option a) of 2) captive electricity as instructed above;
c) The value calculated in the same manner for the option b) of 2) captive electricity as instructed above;
When the project refrigerator may consume electricity supplied from more than 1 electric source, the project participant applies the CO_2 emission factor with the lowest value.
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<td>
2006 IPCC Guidelines on National GHG Inventories for the source of EF of natural gas.
CDM Methodological tool "Determining the baseline efficiency of thermal or electric energy generation systems version 02.0" for the default efficiency for off-grid power plants.

Case 3)
[Electricity directly supplied from other sources including cogeneration system]
<u>For Option a)</u>
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).
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History of the document

Version	Date	Contents revised
01.0	20 September 2021	Electronic decision by the Joint Committee Initial approval.