Joint Crediting Mechanism Approved Methodology TH_AM008
"Introducing heat recovery heat pumps with natural refrigerants for the food manufacturing industries"

A. Title of the methodology

Introducing heat recovery heat pumps with natural refrigerants for the food manufacturing industries, version01.0

B. Terms and definitions

Terms	Definitions
Heat recovery electric heat pump (HP)	A heat recovery electric heat pump is a heat pump system where hot and chilled water is simultaneously generated through reutilizing waste heat.
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).
Compressor	In this methodology, a compressor signifies positive displacement refrigeration compressors (e.g. screw and reciprocating types) for industrial applications and excludes compressors used in a chiller.
Coefficient of Performance (COP)	For the purpose of this methodology, COP is defined as a ratio of rated cooling capacity to the rated electricity consumption by a compressor, and it is calculated using following formula COP=Q/W Where: Q: Rated cooling capacity of a compressor W: Rated electricity consumption by a compressor The temperature conditions at which COPs are calculated in this methodology are shown below: ・ Condensing temperature: 38 degree Celsius ・ Evaporating temperature: -5 degree Celsius

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	This methodology applies to the project that aims at saving energy by introducing (a) heat recovery electric HP(s) in a food manufacturing process.
Calculation of reference emissions	Reference emissions are GHG emissions from using reference equipment for the generation of hot and chilled water. They are calculated by the ratio of efficiency between reference equipment and project HPs and CO_2 emission factors of electricity and fossil fuel consumed by the reference equipment.
Calculation of project emissions	Project emissions are GHG emissions from using the project HPs and their auxiliary electric equipment, and they are calculated with their electricity consumption and the CO_2 emission factor of electricity consumed by the project HPs.
Monitoring parameters	● Electricity consumption of the project HPs ● Electricity consumption of the auxiliary electric equipment of the HPs

D. Eligibility criteria

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

Criterion 1	A project newly introduces (a) high efficiency HP(s) using natural refrigerants to a food manufacturing plant and it does not replace (an) existing HP(s). In case of HPs supplying chilled water, the water is fed into a refrigeration system of the plant which uses either screw or reciprocating compressors.
Criterion 2	The cooling capacity of a HP unit is more than or equal to 50kW and less than 1600kW.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Electricity consumption by reference equipment for generating chilled	CO_2

water	
Fuel consumption by reference equipment for generating hot water	CO_2
Project emissions	
Emission sources	GHG types
Electricity consumption by HPs	CO_2
Electricity consumption by auxiliary electric equipment of HPs (e.g. pump)	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

This methodology only applies to a food manufacturing plant which uses hot and chilled water for the industrial process.
Reference emissions are calculated by multiplying electricity consumption of the project by the ratio of efficiency between a reference equipment and project HPs, and emission factors of electricity and fossil fuel consumed.

The reference equipment is identified as a boiler for the hot water generation and a compressor (*1) for the chilled water generation as their loads are partially replaced by the project HPs. The methodology ensures a net emission reduction by conservatively setting default efficiency values for both reference boiler and compressor respectively as specified below:

<Boiler>
This methodology applies a conservative default value of the reference boiler efficiency as 89 [%], which is the highest value among the products sold in Thailand, so as to ensure net emission reductions.

<Compressor>
This methodology doubly ensures the conservativeness of the default efficiency values of compressors, expressed in COPs, in the following manner:

1) The highest design efficiencies of screw- and reciprocating-type models—two main displacement compressor types used in the food manufacturing industries—are selected from dominant compressor manufacturers' lineups available in Thailand; and
2) The methodology applies COPs for the compressors instead of the one for the whole refrigeration system whose efficiency is lower than that of the compressors due to some heat loss in the system.

The default COP value for the calculation of the reference emission can be selected based on the rated cooling capacity of the existing compressor at the time of validation.

(*1) The water is fed into a refrigeration system of the plant, which consists of individual components of compressors, evaporators, condensers and other relevant parts mounted together to form a custom-made system to meet specific needs of the operation. By using the HPs to lower the inlet water temperature of the refrigeration system, the electricity consumption of the compressor is reduced.

F.2. Calculation of reference emissions

$$\mathbf{RE_p} = \sum_i \frac{\boldsymbol{EC_{PJ,i,p}} \times \mathbf{3.6}}{\boldsymbol{ECR_i}} \times \frac{\boldsymbol{H_i}}{\boldsymbol{\eta_{REh}}} \times \boldsymbol{EF_{REh}} + \sum_i \frac{\boldsymbol{EC_{PJ,i,p}}}{\boldsymbol{ECR_i}} \times \frac{\boldsymbol{CH_i}}{\boldsymbol{COP_{RE}}} \times \boldsymbol{EF_{elec}}$$

RE_p	:	Reference emissions during the period p [tCO_2/p]
$EC_{PJ,i,p}$	:	Electricity consumed by the project HP *i* during the period *p* [MWh/p]
ECR_i	:	Rated electricity consumption of the project HP *i* [kW]
H_i	:	Rated heating capacity of the project HP *i* [kW]
η_{REh}	:	Efficiency of the reference boiler for heating energy generation [-]
EF_{REh}	:	CO_2 emission factor for the fuel consumed by the reference boiler for heating energy generation [tCO_2/GJ]
CH_i	:	Rated cooling capacity of the project HP *i* [kW]
COP_{RE}	:	Efficiency of the reference compressor for cooling energy generation [-]
EF_{elec}	:	CO_2 emission factor for consumed electricity [tCO_2/MWh]
i	:	Identification number of the project HP

G. Calculation of project emissions

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

$EC_{PJ,i,p}$	:	Electricity consumed by the project HP *i* during the period *p* [MWh/p]
$EC_{PJ\_AUX,j,p}$	:	Electricity consumed by the auxiliary electric equipment *j* for the project HP(s) during the period *p* [MWh/p]
EF_{elec}	:	CO_2 emission factor for consumed electricity [tCO_2/MWh]
j	:	Identification number of the auxiliary electric equipment for the project HP(s)

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
ECR_i	Rated electricity consumption of the project HP *i* [kW]	Provided by the technology supplier
H_i	Rated heating capacity of the project HP *i* [kW]	Provided by the technology supplier
η_{REh}	Efficiency of the reference boiler for heating energy generation Default value is set to 89.0 [%].	Value derived from the result of survey. The default value, 89.0 [%], should be revised if necessary.
EF_{REh}	CO_2 emission factor for the fuel consumed by the reference boiler for heating energy generation [tCO_2/GJ] If there is an oil-fired boiler at the project site, the fuel used for the boiler is applied.	In the order of preference: a) values provided by the fuel supplier; b) measurement by the project participants; c) national default values;

<table>
<tr><td></td><td>In case there is a biomass boiler at the project site, 0 tCO_2/GJ is applied.
Otherwise, the CO_2 emission factor of natural gas is applied in a conservative manner.</td><td>d) 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.</td></tr>
<tr><td>CH_i</td><td>Rated cooling capacity of the project HP i [kW]</td><td>Provided by the technology supplier</td></tr>
<tr><td>COP_{RE}</td><td>Efficiency of reference compressor for cooling energy generation

Default efficiency value for the compressor to which the project HP i supplies the water:

<table><tr><th>Cooling Capacity/unit (kW)</th><th>50kW≤x <400kW</th><th>400kW≤x <800kW</th><th>800kW≤x <1600kW</th></tr><tr><td>COPs</td><td>4.01</td><td>4.09</td><td>4.21</td></tr></table>Conditions:
- Condensing temperature = 38 degree Celsius
- Evaporating temperature = -5 degree Celsius</td><td>The default value is derived from the result of survey of compressors used for in the food manufacturing sector for the production process. The survey is comprised of manufacturers with a high market share in Thailand.</td></tr>
<tr><td>EF_{elec}</td><td>CO_2 emission factor for consumed electricity.

When the project HPs consume only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively.

When the project HPs may consume both grid electricity and captive electricity, the project participant applies the CO_2 emission factor of lower value.

[CO_2 emission factor]
For grid electricity: The most recent value available from the source stated in this table at the time of</td><td>[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 unless otherwise instructed by the Joint Committee.

[Captive electricity]</td></tr>
</table>

	validation. For captive electricity including cogeneration system, it is determined based on the following options: a) Calculated from its power generation efficiency (η_{elec} [%]) obtained from manufacturer's specification The power generation efficiency based on lower heating value (LHV) of the captive power generation system from the manufacturer's specification is applied; $$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$$ b) Calculated from measured data The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{PJ,p}$) and the amount of electricity generated ($EG_{PJ,p}$) during the monitoring period p is applied. The measurement is conducted with the monitoring equipment to which calibration certificate is issued by an entity accredited under national/international standards; $$EF_{elec} = FC_{PJ,p} \times NCV_{fuel} \times EF_{fuel} \times \frac{1}{EG_{PJ,p}}$$ Where: NCV_{fuel} : Net calorific value of consumed fuel [GJ/mass or 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.	For the option a) Specification of the captive power generation system provided by the manufacturer (η_{elec} [%]). CO_2 emission factor of the fossil fuel type used in the captive power generation system (EF_{fuel} [tCO_2/GJ]) For the option b) Generated and supplied electricity by the captive power generation system ($EG_{PJ,p}$ [MWh/p]). Fuel amount consumed by the captive power generation system ($FC_{PJ,p}$ [mass or 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.

<table>
<tr>
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<td>
・ The system is non-renewable generation system
・ Electricity generation capacity of the system is less than or equal to 15 MW

<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.
</td>
<td>
[Captive electricity with diesel fuel]
CDM approved small scale methodology: AMS-I.A.

[Captive electricity with natural gas]
2006 IPCC Guidelines on National GHG Inventories for the source of EF of natural gas.
CDM Methodological tool "Determining the baseline efficiency of thermal or electric energy generation systems version02.0" for the default efficiency for off-grid power plants.
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History of the document

Version	Date	Contents revised
01.0	14 January 2019	Electronic decision by the Joint Committee Initial approval.