Joint Crediting Mechanism Approved Methodology TH_AM002

"Energy Saving by Introduction of Multi-stage Oil-Free Air Compressor"

A. Title of the methodology

Energy Saving by Introduction of Multi-stage Oil-Free Air Compressor, Version 02.0

B. Terms and definitions

Terms	Definitions
Multi-stage oil-free air compressor	A device with more than one compression stage without using lubricating oil to compress air, nitrogen or inert gases to make the pressure of gas higher than that of the inlet.
Specific conditions	The specific conditions for this methodology are defined as below, following ISO 1217:2009. Ambient temperature = 20 degrees Celsius, Ambient pressure = 0 MPa (Gauge pressure), Relative humidity = 0%, Cooling water/air = 20 degrees Celsius, Effective working pressure at discharge valve = 0.7 MPa (Gauge pressure).
Free air delivery (FAD)	The actual quantity of compressed air converted to the inlet conditions of the compressor. The unit is m^3/min.
Periodical check	A periodical investigation of air compressor conducted by manufacturer or agent who is authorized by the manufacturer, in order to maintain air compressor performance.
Specific power (SP)	An indicator of efficiency of air compressor, calculated with electric motor power (nominal output power) [kW] and free air delivery [m^3/min] $$\mathbf{SP} = \frac{\mathbf{Motor\ power\ [kW]}}{\mathbf{FAD\ [m^3/min]}}$$

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	This methodology applies to the project that aims at saving energy by introducing multi-stage oil-free air compressor in manufacturing process of semiconductors.
Calculation of reference emissions	Reference emissions are GHG emissions from using reference air compressor, calculated with power consumption of project air compressor, specific power (SP) of reference/project air compressors and CO_2 emission factor for electricity consumed.
Calculation of project emissions	Project emissions are GHG emissions from using project air compressor, calculated with power consumption of project air compressor and CO_2 emission factor for electricity consumed.
Monitoring parameters	● Power consumption of project air compressor ● The amount of fuel consumed and the amount of electricity generated by captive power, where applicable.

D. Eligibility criteria

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

Criterion 1	Project air compressor is a non-inverter type multi-stage oil-free air compressor with an electric motor power of 55kW, 75kW, 110kW, 132kW, 145kW, 160kW, or 200kW installed in manufacturing process of semiconductors.
Criterion 2	Periodical check is planned more than one (1) time annually.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Electricity consumption by air compressor	CO_2
Project emissions	
Emission sources	GHG types
Electricity consumption by air compressor	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 air compressor, specific power (SP) for reference/project air compressors, and CO_2 emission factor for electricity consumed.

SP of reference air compressor is conservatively set as a default value in the following manner to ensure the net emission reductions.

1. The most efficient value is selected for each motor power of air compressors from the collected SP values available in Thai market and determined as the reference SP.
2. The value of SP is defined as $SP_{RE,sc,i}$ described in Section I.

F.2. Calculation of reference emissions

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

RE_p : Reference emissions during the period *p* [tCO_2/p]
$EC_{PJ,i,p}$: Power consumption of project air compressor *i* during the period *p* [MWh/p]
$SP_{PJ,sc,i}$: SP of project air compressor *i* calculated under the specific conditions [kW·min/m^3]
$SP_{RE,sc,i}$: SP of reference air compressor *i* under the specific conditions [kW·min/m^3]
EF_{elec} : CO_2 emission factor for consumed electricity [tCO_2/MWh]

G. Calculation of project emissions

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

PE_p : Project emissions during the period *p* [tCO_2/p]
$EC_{PJ,i,p}$: Power consumption of project air compressor *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 air compressor consumes only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively. When project air compressor may consume both grid electricity and captive electricity, the project participant applies the CO_2 emission factor with 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 validation For captive electricity, 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;	[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] 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

	$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec}} \times EF_{fuel}$ 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 weight] 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 fuel type / Diesel fuel / Natural gas EF_{elec} / 0.8 *1 / 0.46 *2 *1 The most recent value at the time of validation is applied.	generation system ($EG_{PJ,p}$ [MWh/p]). Fuel amount consumed by the captive power generation system ($FC_{PJ,p}$ [mass or weight/p]). Net calorific value (NCV_{fuel} [GJ/mass or weight]) 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] 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

<table>
<tr><td></td><td>*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 (0.0543 tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.</td><td>energy generation systems version02.0" for the default efficiency for off-grid power plants.</td></tr>
<tr><td>$SP_{RE,sc,i}$</td><td>The SP of the reference air compressor i for each motor power is set as a default value in this methodology as shown in the table below.

<table><tr><th>Motor Power [kW]</th><th>Reference SP</th></tr><tr><td>55</td><td>5.73</td></tr><tr><td>75</td><td>6.00</td></tr><tr><td>110</td><td>5.67</td></tr><tr><td>132</td><td>5.84</td></tr><tr><td>145</td><td>6.14</td></tr><tr><td>160</td><td>5.65</td></tr><tr><td>200</td><td>5.49</td></tr></table>
It is noted that the SP value is calculated under the specific conditions</td><td>Specifications of project air compressor i prepared for the quotation or factory acceptance test data by manufacturer.

The default SP value is derived from the result of survey on SP of non-inverter oil-free air compressors from manufacturers that have high market share in Thailand.

The $SP_{RE,sc,i}$ is revised if necessary from survey result which is conducted by JC or project participants every three years.</td></tr>
<tr><td>$SP_{PJ,i}$</td><td>SP of project air compressor i under the project specific conditions.</td><td>Specifications of project air compressor i prepared for the quotation or factory acceptance test data by manufacturer.</td></tr>
<tr><td>$SP_{PJ,sc,i}$</td><td>SP of project air compressor i under the specific conditions is calculated by the following equation:

$$SP_{PJ,sc,i} = SP_{PJ,i} \times \frac{T_{s,PJ,sc,i}}{T_{s,PJ,i}} \times \left[\left(\frac{P_{d,PJ,sc,i}}{P_{s,PJ,sc,i}}\right)^{\frac{k-1}{m_i k}} - 1\right] \div \left[\left(\frac{P_{d,PJ,i} + 0.101}{P_{s,PJ,i}}\right)^{\frac{k-1}{m_i k}} - 1\right]$$
k: Heat capacity ratio (Dried Air) = 1.4</td><td>Specifications of project air compressor i prepared for the quotation or factory acceptance test data by manufacturer.</td></tr>
</table>

	m_i: Number of compression stages of project air compressor *i* $P_{s,PJ,i}$: Suction pressure of project air compressor *i* under the project specific conditions [MPa(abs)] (Default value is set at atmospheric pressure = 0.101[MPa(abs)]) $P_{s,PJ,sc,i}$: Suction pressure of project air compressor *i* under the specific conditions [MPa(abs)] (Default value is set at atmospheric pressure = 0.101[MPa(abs)]) $T_{s,PJ,i}$: Suction temperature of project air compressor *i* under the project specific conditions [K] (Value from the product catalogue or manufacturer's specification) $T_{s,PJ,sc,i}$: Suction temperature of project air compressor *i* under the specific conditions [K] (Default value is set at 293.0[K]) $P_{d,PJ,i}$: Discharge pressure of project air compressor *i* under the project specific conditions [MPa(Gauge pressure)] (Value from the product catalogue or manufacturer's specification) $P_{d,PJ,sc,i}$: Discharge pressure of project air compressor *i* under the specific conditions [MPa(abs)] (= 0.101[MPa(abs)] + 0.7 [MPa(Gauge pressure)] = 0.801[MPa(abs)])	

History of the document

Version	Date	Contents revised
02.0	21 August 2017	JC3, Annex 10 Revision to: ● Add conditions to apply 0.80 or 0.46 as a CO_2 emission factor for captive electricity
01.0	23 August 2016	Decision by the Joint Committee. Initial approval.