Joint Crediting Mechanism Approved Methodology KH_AM005
"Installation of inverters to distribution pumps in water treatment plant"

A. Title of the methodology

Installation of inverters to distribution pumps in water treatment plant, Version 01.0

B. Terms and definitions

Terms	Definitions
inverter	An apparatus to control the motor speed in line with different load demand
electricity consumption ratio (hereinafter referred to as "ECR")	The ratio of actual electricity consumption to rated electricity consumption
operational load	The ratio of actual water flow to rated water flow capacity of pump

C. Summary of the methodology

Items	Summary
GHG emission reduction measures	Introduction of inverter to constant-speed pumps for water distribution in water treatment plant leads to a reduction of electricity consumption by pumps and GHG emissions accordingly.
Calculation of reference emissions	Reference emissions are calculated with the monitored electricity consumption of project pumps, the ratio of ECR of reference and project pumps, and the CO_2 emission factor for consumed electricity.
Calculation of project emissions	Project emissions are calculated with the monitored electricity consumption of project pumps and the CO_2 emission factor for consumed electricity.
Monitoring parameters	● Electricity consumption of project pumps

D. Eligibility criteria

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

Criterion 1	Inverter(s) is installed to the existing constant-speed pump(s) for water distribution in water treatment plant.
Criterion 2	The value of ECR of project pump is always smaller than that of reference pump at the same operational load except when the operational load is equal to one (1), which is demonstrated by equations fixed *ex ante* or may be demonstrated by equations *ex post* at the time of the first verification.

E. Emission Sources and GHG types

Reference emissions	
Emission sources	GHG types
Electricity consumption by reference pumps	CO_2
Project emissions	
Emission sources	GHG types
Electricity consumption by project pumps	CO_2

F. Establishment and calculation of reference emissions

F.1. Establishment of reference emissions

Reference emissions are calculated with the monitored electricity consumption of project pumps, the ratio of ECR of reference and project pumps, and the CO_2 emission factor for consumed electricity.

Net emission reductions are ensured by setting an equation to calculate ECR of reference pump in a conservative manner in this methodology.

1) Electricity consumption and water flow of existing constant-speed pumps are actually measured at major water treatment plants in Cambodia.
2) Monitored data shows that relatively new pumps consume less electricity than old ones at the same operational load.
3) Data of new pumps are selected to determine an approximation formula for ECR of reference pump.

F.2. Calculation of reference emissions

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

Where

RE_p	Reference emissions during the period *p* [t-CO_2/p]
$EC_{PJ,i,p}$	Electricity consumption by project pump *i* during the period *p* [MWh/p]
$ECR_{RE,i,p}$	ECR of reference pump *i* during the period *p* [dimensionless]
$ECR_{PJ,i,p}$	ECR of project pump *i* during the period *p* [dimensionless]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
i	Identification number of pumps [dimensionless]

$ECR_{RE,i,p}$ and $ECR_{PJ,i,p}$ are determined by the following processes.

Step 1: A cubic equation to calculate $ECR_{PJ,i,p}$ for each project pump is fixed *ex ante* or *ex post* with monitored data of the project pump.

Coefficient of determination (R^2) of the equation exceeds 0.95.

Monitored data is adjusted so that the value of ECR is one (1) when the operation load factor is one (1) in the cubic equation.

Step 2: ECR of project pump *i* for the monitoring period ($ECR_{PJ,i,p}$) is calculated from monitored electricity consumption divided by a rated electricity consumption of the pump which is derived by multiplying a rated input power by monitored hours.

When project pump is stopped due to maintenance, breakdown and so on, those hours are excluded from the monitored hours.

Step 3: An average operational load of project pump for the monitoring period (*x*) is derived by applying the value of ECR calculated in Step 2 to the equation fixed in Step 1.

Step 4: $ECR_{RE,i,p}$ is calculated by applying the average operational load of project pump derived in Step 3 to the following equation.

$$ECR_{RE,i,p} = -0.6703x^3 + 0.8734x^2 + 0.3442x + 0.4484$$

Where

x	Operational load of project pump [dimensionless]

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 [t-CO_2/p]
$EC_{PJ,i,p}$	Electricity consumption by project pump i during the period p [MWh/p]
EF_{elec}	CO_2 emission factor for consumed electricity [tCO_2/MWh]
i	Identification number of pumps [dimensionless]

H. Calculation of emissions reductions

$$ER_p = RE_p - PE_p$$

Where

PE_p	Emission reductions during the period p [t-CO_2/p]
RE_p	Reference emissions during the period p [t-CO_2/p]
PE_p	Project emissions during the period p [t-CO_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
$ECR_{PJ,i,p}$	Electricity consumption ratio of project pump i during the period p A cubic equation to calculate $ECR_{PJ,i,p}$ for each project pump is fixed *ex ante* with monitored data of the project pump. Coefficient of determination (R^2) of the equation exceeds 0.95. A cubic equation is adjusted so that the	Monitored data or test data of pump manufacturer

	electricity consumption ratio is one (1) when the operation load factor is one (1). * $ECR_{PJ,i,p}$ may be fixed *ex post*.	
EF_{elec}	CO_2 emission factor for consumed electricity When project pump consumes only grid electricity or captive electricity, the project participant applies the CO_2 emission factor respectively. When project pump may consume both grid and captive electricity, the project participant applies the CO_2 emission factor with lower value. In case the captive electricity is generated by renewable energy source(s) and the amount of the captive electricity generated by the renewable source(s) estimated from its generation capacities is equal to or less than half of the total electricity consumption at the project site, the portion of electricity generated by the renewable source(s) may be neglected in the calculation of the captive CO_2 emission factor. If the amount of captive electricity generated by renewable source(s) is more than half, the captive CO_2 emission factor is determined by the following option (b) of "(2) For captive electricity" using the total amount of captive electricity generated by both fossil fuel and renewable sources for $EG_{PJ,CG,p}$.. [CO_2 emission factor] (1) For grid electricity The most recent value available from the source stated in this table at the time of	[Grid electricity] The most recent published value by the Ministry of Environment of Cambodia at the time of validation. [Captive electricity] For the option (a) Specification of the captive power generation system provided by the manufacturer ($\eta_{elec,CG}$ [%]). CO_2 emission factor of the fossil fuel type used in the captive power generation system ($EF_{fuel,CG}$ [tCO_2/GJ]) For the option (b) Generated and supplied electricity by the captive power generation system ($EG_{PJ,CG,p}$ [MWh/p]). Fuel amount consumed by the captive power generation system ($FC_{PJ,CG,p}$ [mass or volume/p]). Net calorific value ($NCV_{fuel,CG}$ [GJ/mass or volume]) and CO_2 emission factor ($EF_{fuel,CG}$ [tCO_2/GJ]) of the fuel consumed by the captive power generation system in order of preference:

	validation is applied. (2) For captive electricity Option (a) Calculated from its power generation efficiency ($\eta_{elec,CG}$ [%]) 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; $$EF_{elec} = 3.6 \times \frac{100}{\eta_{elec,CG}} \times EF_{fuel,CG}$$ Option (b) Calculated from measured data The power generation efficiency calculated from monitored data of the amount of fuel input for power generation ($FC_{PJ,CG,p}$) and the amount of electricity generated ($EG_{PJ,CG,p}$) 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; $$EF_{elec} = FC_{PJ,CG,p} \times NCV_{fuel,CG} \times EF_{fuel,CG} \times \frac{1}{EG_{PJ,CG,p}}$$ Where: $NCV_{fuel,CG}$: Net calorific value of fuel consumed by the captive power generation system [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.	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 energy generation systems version02.0" for the default efficiency for off-grid power plants.

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- The system is non-renewable generation system
- Electricity generation capacity of the system is less than or equal to 15 MW

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<tr><th>fuel type</th><th>Diesel fuel</th><th>Natural gas</th></tr>
<tr><td>EF_{elec}</td><td>0.8*1</td><td>0.46*2</td></tr>
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*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 (0.0543 tCO_2/GJ), and the most efficient value of default efficiency for off-grid gas turbine systems (42%) are applied.

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History of the document

Version	Date	Contents revised
01.0	21 February 2020	JC5, Annex 6 Initial approval.