15. Renewable Energy / Solar, Wind and Others

1. Typical Project

· A new development, capacity addition, retrofit and replacement of renewable energy generation units such as hydro, wind, photovoltaic, geothermal, and solar water heating system (hereinafter "renewable energy").

2. Applicability

(1) Projects of newly development, capacity addition, retrofit and replacement of renewable energy generation units such as hydro, wind, photovoltaic, geothermal, and solar water heating system.

(2) Grid connected or standalone off-grid systems.

(3) Standalone solar water heater systems.

3. Methodology of Emission Reduction Calculation

The emission reduction from the project activity is determined as the differences between the GHG emission of baseline scenario (the electricity that replaced by the project would have been generated by existing power plants etc.) and project scenario (electricity generation by the renewable energy generation units)[1].

Details of sources of each data in the following formulae are provided in "4. Data and Parameters for the Estimation".

$$ER_y = BE_y - PE_y$$

ER_y : GHG emission reduction through the project in year y (t-CO_2e/y)

BE_y : GHG emission from the baseline scenario in year y (t-CO_2e/y)

PE_y : GHG emission from the project scenario in year y (t-CO_2e/y)

(1) Calculation of Baseline Emission

1) Grid connected system

Baseline GHG emission is calculated as the following equation based on the annual electricity consumption that replaced by the project and CO_2 emission factor of the electricity. In the case of a retrofit project, the generation efficiency will be improved and the electricity supply from the existing power plants will be changed, therefore, baseline GHG emission can be estimated based on the electricity generated by the project.

2) Standalone or Mini-grid system

A standalone or mini-grid system will be located in an off-grid area or at a site where no grid electricity is used. The baseline scenario is assumed that a diesel generator supplies electricity in need. In the case of a retrofit project, the baseline GHG emission can be estimated based on the increased amount of electricity.

$$BE_y = EG_y \times EF_{elec}$$

EG_y : Power generation by the renewable energy system in year y (MWh/y)

EF_{elec} : CO_2 emission factor of the electricity (t-CO_2/MWh)

---

[1] The target year shall be a representative year under average operation or an annual average of multiple years.

3) Solar water system

Baseline scenario is assumed to be the continuation of supply of hot water with equipment using fossil fuels. In the case of a retrofit project, the efficiency will be improved and the fossil fuel consumption at the existing equipment will be reduced, therefore, baseline GHG emission can be estimated based on the difference of energy consumption before and after the retrofit.

$$BE_y = Q_{heat,y} \times EF_{fuel,i} \div 10^6 = \frac{F_y \times \Delta T \times C \times \rho}{\varepsilon_{BL}} \times EF_{fuel,i} \div 10^6$$

$Q_{heat,y}$: Energy supply by the solar water heating system (GJ/y)

$EF_{fuel,i}$: CO$_2$ emission factor of fossil fuel i (kg-CO$_2$/TJ)

ε_{BL} : Efficiency of baseline heating system

F_y : Amount of hot water supplied by the solar water heating system in year y (m^3)

ΔT : Temperature rise of water (or hear carrier) by the solar water heating system (K)

C   : Specific heat of water (or hear carrier) (GJ/t·K)

ρ : Density of water (or heat carrier) (t/m^3)

(2)   Calculation of Project Emission

Basically, GHG emission associated with the operation of the renewable energy systems is assumed to be zero.

If CH$_4$ emission from reservoirs of hydro power plants is significant, the emission is calculated as follows:

$$PE_y = \frac{EF_{res} \times EG_y}{1000}$$

EF_{res} : Default emission factor for emissions from reservoirs of hydro power plants (90kg-CO$_2$e/MWh (CDM EB23))

EG_y : Total electricity produced by the project activity in year y (MWh/y)

GHG emissions from geothermal power plants are calculated as follows:

$$PE_y = PES_y + PEEF_y$$

PES_y : CO$_2$ and CH$_4$ emissions associated with steam production (t-CO$_2$/y)

$PEFF_y$: CO$_2$ emission associated with fuel consumption at the power plant (t-CO$_2$/y)

Calculation of PES$_y$

CO$_2$ and CH$_4$ emissions associated with steam production are calculated as follows:

$$PES_y = \left(w_{Main,CO2} + w_{Main,CH4} \times GWP_{CH4}\right) \times M_{S,y}$$

$w_{Main,CO2}$: Average mass fraction of carbon dioxide in the produced steam (t-CO$_2$/t)

$w_{Main,CH4}$: Average mass fraction of methane in the produced steam (t-CH$_4$/t)

GWP_{CH4} : Global warming potential of methane

$M_{S,y}$: Quantity of steam produced in year y (t)

15. Renewable Energy / Solar, Wind and Others

Calculation of PEFF$_y$

CO_2 emission associated with fossil fuel consumption at the power plant is calculated as follows:

$$PEFF_y = \sum_i \left(FC_{i,y} \times NCV_i \times EF_{fuel,i} \div 10^6 \right)$$

FC$_{i,y}$: Consumption of fossil fuel i at the power plant in year y (t/y)

NCV$_i$: Net calorific value of the fossil fuel i (TJ/Gg = TJ/kt)

EF$_{fuel,i}$: CO_2 emission factor of the fossil fuel i (kg-CO_2/TJ)

4. Data and Parameters for the Estimation

Data	Description	Data Sources	
		For baseline emission calculation	For project emission calculation
EG$_y$	Total electricity produced by the project activity in year y (MWh/y)	A planned value	N/A
EF$_{elec}$	In the case of the grid connection: CO_2 emission factor of the grid electricity (t-CO_2/MWh)	A default value (Table 3, Appendix) • For hydro, geothermal power projects: apply a value of "Firm Energy". • For solar, wind, tidal power projects: apply a value of "Intermittent Energy". If there is no default value applied or if there is another appropriate value, that value may be used.	
	In the case of the captive power generation or mini-grid: CO_2 emission factor of the diesel power generation (t-CO_2/MWh)	A Default value (Table 4, Appendix) If there is no default value applied or if there is another appropriate value, that value may be used.	
ε$_{BL}$	Efficiency of baseline heating system	A catalog value or a conservative value 1.0	
F$_y$	Amount of hot water supplied by the solar water heating system in year y (m^3)	A planned value	
ΔT	Temperature rise of water (or hear carrier) by the solar water heating system (K)	A planned value	
C	Specific heat of water (or hear carrier) (GJ/t·K)	A literature value	
ρ	Density of water (or heat carrier) (t/m^3)	A literature value	
W$_{Main,CO2}$	Average mass fraction of carbon dioxide in the produced steam (t-CO_2/t)	N/A	A planned value based on the measured value of the similar plant

$W_{Main,CH4}$	Average mass fraction of methane in the produced steam (t-CH$_4$/t)		A planned value based on the measured value of the similar plant
GWP_{CH4}	Global warming potential of methane		25
$M_{S,y}$	Quantity of steam produced in year y (t)		A planned value
$FC_{i,y}$	Consumption of fossil fuel i at the power plant in year y (t/y)		A planned value
NCV_i	Net calorific value of the fossil fuel i (TJ/Gg = TJ/kt)		A default value (Table 1 and 2, Appendix) If there is no default value applied or if there is another appropriate value, that value may be used.
$EF_{fuel,i}$	CO$_2$ emission factor of the fossil fuel i (kg-CO$_2$/TJ)		

5. Others

(1) Project Boundary

The physical boundary for estimating GHG emissions includes the facilities in the project site.

(2) Leakage

There are indirect emissions that potentially lead to leakage due to activities such as manufacturing and transport of materials and construction processes. However, these emissions are temporary and negligible compare to the project scale. Therefore, they can be ignored.

(3) Comparison with existing methodologies

There are CDM methodologies such as AMS I.D. (Grid connected renewable electricity generation), AMS-I.F. (Renewable electricity generation for captive use and mini-grid) and ACM0002 (Consolidated baseline methodology for grid-connected electricity generation from renewable sources) can be references for development of the methodology.

Compared with these CDM methodologies, the logic of emission reduction calculation in the methodology is basically same. However, this methodology simplifies the calculation way by providing default values for the grid CO$_2$ emission factor.

The CDM methodology is applicable to the projects of generation capacity may not exceeding 15 MW (AMS I.D.) and hydropower projects with a reservoir greater than 4 W/m^2 (AMS I.D. and ACM0002). However, these applicability conditions are not included in this methodology.

(4) CH$_4$ and N$_2$O

Since methane (CH$_4$) and nitrous oxide (N$_2$O) do not have a significant impact on emission reductions by the project, they were not considered for simplification.

(5) Revision history

Version	Year/Month	Revisions
2.0	March 2014	• Combined four methodologies (17. Hydro power (Ver1.0), 18. Wind power (Ver1.0), 19.

		Photovoltaic power/ Solar heat (Ver1.0) and 20. Geothermal power (Ver1.0)) as the methodological logic was identical • Amended baseline emission calculation to use the amount of generated electricity and a default value for the CO_2 emission factor of the grid electricity (so that baseline emissions are calculated as emissions from annual electricity consumption which is replaced by the project)
3.0	September 2019	• Prioritized the use of default values • Added instructions not to consider CH_4 and N_2O emissions
4.0	March 2023	• Change the title to "15. Renewable Energy / Solar, Wind and Others". • Deleted the column "Ex-post" in "4. Data and Parameters Estimated and Need Monitoring": current version of Climate-FIT aims to quantify GHG emission reductions in the "planning phase").
5.0	March 2024	• No revision.