CLEAN DEVELOPMENT MECHANISM

CDM-MP70-A16

Information note

Analysis and proposal on revision of “Tool to calculate emission factor of electricity system” to include guidance on small isolated grid systems and transmission constraints

Version 01.0

United Nations
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Climate Change

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1. Procedural background

1. The Board at its eighty-ninth meeting requested the Methodologies Panel (MP) to propose the revision to the "Tool to calculate the emission factor for an electricity system" (the grid tool) to:

   (a) Better accommodate small isolated grids in Small Island developing States (SIDS) and least developed countries (LDCs); and

   (b) Enhance the clarity of the requirements related to the demonstration of transmission constraints.

2. Purpose

2. The document aims to recommends:

   (a) simplified approaches to determine the baseline emission factor in the case of grid systems of SIDS and LDCs; and

   (b) further clarify procedure to determine transmission constraints in identifying relevant project electricity systems

3. Key issues and proposed solutions

3.1. Issues

3. Experience gained through the assessment of standardized baselines suggests that typical characteristics of the electricity system in SIDS or isolated grid system in LDCs and/or data paucity in these countries limit application of the grid tool, particularly in estimating the operating margin (OM)/ build margin (BM) emission factor. Some of the examples where data are not often available are:

   (a) A cohort of five recently built power plants/units is needed to determine build margin emission factor.

   (b) Commissioning dates of the power plants.

   (c) Historical data to determine OM.

4. Currently, there seems to be a lack of clarity for the standardized baseline (SB) developers on the application of grid tool in the context of determining transmission constraint as required by the tool.

3.2. Analysis and recommendations

3.2.1. Approach to determine grid emission factor for isolated grid/system

5. Where data to determine BM emission factor are not available (i.e. cohort of five recently built plants and commissioning dates), flexible provisions that are already available in the grid tool can be applied. In other words, in the specific case of grids in SIDS/LDCs, simplified Combined Margin (CM) can be calculated by setting the weight of BM to 0 and

the weight of OM to 1, where OM is determined as the average operating margin (para 88 from the Tool)

6. In the case of electricity system in LDCs/SIDS comprising of less than five power plant/unit (frequently occurring cases in SIDS, see for example Annex 2, Table 2), current provisions in the tool can be used to determine the OM. In the specific case of an electricity system involving a single power plant/unit, the emission factor should be derived based on the emission factors of the most recently built plants in the country that are less than 10 years old and of similar technology.

7. Furthermore, as an alternative to the above, a simplified procedure (including default values) as discussed below is proposed for small isolated grids located in SIDS/LDCs, specially where data/information as required in the tool to determine the OM/BM are not available.

8. The provisions contained in the Annex 1 are based on methodology AM0103, which offers default emission factor values for isolated grid system under some specific requirements. The Meth Panel noted that, for the specific case of the default value (0.8 tCO2/MWh) in AM0103, it would not be conservative as compared to the values reported in literature and other sources. The emission factor values for DG sets (< 10 MW) reported in recent literatures seem to be in the range of **0.558 to 0.593** tCO2/MWh based on the attained efficiency of around 44% to 47%. Also, default efficiency values for small-scale off-grid DG plants/units indicated in the grid tool show up to 45% for plants/units higher than 1000 kW. Table 1, 2 and 3 of Annex 2 of this document provides the comparision of emission factors of DG plants by sizes/load factors and the values derived from the approved standardized baselines.

9. The MP also noted that emission factor of 0.8 tCO2/MWh for plants/units greater than certain sizes (e.g., size greater than 200 kW) in small scale methodologies (e.g., AMS-I.F) was derived from the 2001 RET Screen model based on the efficiency of DG sets with an efficiency around 30% in the context of mini-grid exclusively based on DG plants/units.

10. Taking into account the above, the MP is considering to recommend the following options regarding determining grid emission factor for isololated grid systems in SIDs/LDCs[1]

    (a) **Case 1:** This applies for isololated grid systems in SIDS/LDCs when using exclusively Diesel/ Fuel oil mix, and there is no combined cycle power plants installed. In this case the MP is considering to opt for one of the following options taking into account any public input that will be received:

        (i) **Option 1:** Use default emission factors contained in Table 1 below based on size of power plants/units. These values are derived using size-range and efficiency values from the grid tool and fossil fuel EF from IPCC (see also table 1 of Annex 2).

[1] **Isolated grid systems in** LDC/SIDS here means an electrical networks supplying electricity to household users, and if applicable, industries and commercial areas that is not connected to any other electrical network (e.g., national/regional or interconnected power system)

Table 1. Default emission factors for isololated grid exclusively based on Diesel/ Fuel oil with no combined cycle power plants installed

	Generator Size (kW)						
	10< x <= 20	20<x <= 50	50< x <= 100	100< x <= 200	200< x <= 400	400< x <= 1000	>1000
EF (tCO_2/MWh)	0.93	0.79	0.75	0.71	0.67	0.62	0.58

(ii) **Option 2:** Use a default emission factor of 0.79 tCO_2/MWh for plants/units less than 50 kW and use 0.58 tCO_2/MWh for plants/unit greater than 50 Kw

(iii) **Option 3:** Use a single default emission factor, which is the minimum value from the table 1 above, i.e., 0.58 (tCO_2/MWh)

(b) **Case 2:** This applies for isololated grid systems in SIDS/LDCs with energy mix predominantly[2] based on mixed fossil fuel sources i.e., liquid, solid and gaseous fossil fuels with no combined cycle power plants installed. In this case, use a single default emission factor of 0.45 tCO2/MWh or determine weighted average emission factor as per the procedure provided in Annex 1 of tis document, i.e., based on electricity generation or installed capacity.

(c) **Case 3:** This is the same case as the case 2 above but with combined cycle power plants installed. In this case, use a single default emission factor of 0.38 tCO2/MWh or determine weighted average emission factor as per the procedure provided in Annex 1 of this document, i.e., based on electricity generation or installed capacity.

3.2.2. Requirements on transmission constraints

11. As per the grid tool "Connected electricity system" is defined as an electricity system that is connected by transmission lines to the project electricity system. Power plants within the connected electricity system can be dispatched **without significant transmission constraints** but transmission to the project electricity system has **significant transmission constraint**, **<u>and/or</u>** the transmission capacity of the transmission line(s) that is connecting electricity systems is less than 10 per cent of the installed capacity either of the project electricity system or of the connected electricity system, whichever is smaller."

12. The grid tool further prescribes "There are no transmission constraints" if any one of the following criteria is met:

(a) In case of electricity systems with spot markets for electricity: there are differences in electricity prices (without transmission and distribution costs) of less than five per cent between the two electricity systems during 60 per cent or more of the hours of the year; or

(b) The transmission line is operated at 90 per cent or less of its rated capacity at least during 90 per cent of the hours of the year

[2] At least 65 per cent of the power generated based in the most recent three years shall be based on fossil fuel.

13. The MP agreed to recommend to further clarify in the revised grid tool that the transmission line has significant constraints if one of the following conditions is met ((a) and (b) apply for electricity systems where there is no spot market)):

    (a) The transmission capacity of the transmission line(s) that is connecting electricity system and the connected electricity system is less than 10 per cent of the installed capacity either of the project electricity system or of the connected electricity system, whichever is smaller using the most recent year data;

    (b) The transmission line is operated at 90 per cent or more of its rated capacity at least during 10 per cent of the hours of the year demonstrated ?using the algorithm below:

        (i) For every hour of the year, check whether the transmission line is operated at 90 per cent or less of its rated capacity.

        (ii) Each hour of the year when the transmission line was operated at less than 90 per cent of its rated capacity should be counted as zero;

        (iii) Each hour of the year when the transmission line was operated at 90 per cent or <u>more</u> of its rated capacity should be counted as one.

        (iv) There is no transmission constraint if the total sum resulting from the previous step (i.e., (c) above) is less than ten per cent of the hours of the year (e.g. 876 for even year and 878 for leap year).

    The algorithm can be illustrated by the following equation

$$\sum_{1}^{8760}\left[\frac{Hourly\ power\ transmission\ (MWh)}{\left[Maximum\ line's\ load\ capacity\ (MW)\right]} > 90\%\right] < 876$$

    (c) In case of electricity systems with spot markets for electricity: there are differences in electricity prices (without transmission and distribution costs) of more than five per cent between the two electricity systems during 40 per cent or more of time of the year;

14. The MP also agreed to explore considering alternative options to determine transmission constraints. The MP welcomes any specific input from the public in this regards.

Appendix 1. Determination of emission factor for isolated grid located in LDCs/SIDs

1. Calculation of weighted average emission factor based on electricity production data

1. **Option 1:** Weighted average emission factor (**tCO2/MWh**) based on electricity production using the equation below. If electricity production data is not available, option 2 below can be used.

$$EF_{isolated\_grid,y} = \frac{EG_{LS\_FF,y} + 0.45 * EG_{LCC\_FF,y} + 0.5 \cdot EG_{G\_FF,y} + 0.38 * EG_{GCC\_FF,y} + 0 * EGren,y}{EG_{LS\_FF,y} + EG_{LCC\_FF,y} + EG_{G\_FF,y} + EG_{GCC\_FF,y} + EG_{ren,y}}$$

Equation (1)

and

$$EG_{LS\_FF,y} = \sum_{p=1}^{P} f_p * EG_{LS\_FF,p,y} \; ; \; EG_{LCC\_FF,y} = \sum_{q=1}^{Q} EG_{LCC\_FF,q,y} \; ; \; EG_{G\_FF,y} = \sum_{r=1}^{R} EG_{G\_FF,r,y} \; ;$$

$$EG_{GCC\_FF,y} = \sum_{s=1}^{S} EG_{GCC\_FF,s,y} \; ; \; EG_{gen,ren,y} = \sum_{s=1}^{S} EG_{ren,s,y}$$

Where:

fp	=	Default factor that would depend upon one of the options chosen described under Case 1, para 10 (a) Option 1, 2 and 3
$EF_{isolated\_grid}$	=	Emission factor of the isolated grid (t CO_2/MWh)
$EG_{LS\_FF,y}$	=	Total electricity supplied to the isolated grid by the power plants using liquid or solid fossil (but excluding combined cycle power plants) in year *y* (MWh/yr)
$EG_{LCC\_FF,y}$	=	Total electricity supplied to the isolated grid by the combined cycle power plants using liquid or solid fossil in year *y* (MWh/yr)
$EG_{G\_FF,y}$	=	Total electricity supplied to the isolated grid by the gaseous fossil fuel open cycle power plants in year *y* (MWh/yr)
$EG_{GCC\_FF,y}$	=	Total electricity supplied to the isolated grid by the gaseous fossil fuel combined cycle power plants in year *y* (MWh/yr)
$EG_{LS\_FF,p,y}$	=	Quantity of net electricity generation supplied by the power plant *p* that uses liquid or solid fossil (but excluding combined cycle power plants) to the isolated grid in year *y* (MWh/yr)
$EG_{LCC\_FF,q,y}$	=	Quantity of net electricity generation supplied by the liquid fossil fuel combined cycle power plant *q* to the isolated grid in year *y* (MWh/yr)
$EG_{G\_FF,r,y}$	=	Quantity of net electricity generation supplied by the gaseous fossil fuel open cycle power plant *r* to the isolated grid in year *y* (MWh/yr)
$EG_{GCC\_FF,s,y}$	=	Quantity of net electricity generation supplied by the gaseous fossil fuel combined cycle power plant *s* to the isolated grid in year *y* (MWh/yr)

$EGren,y$	=	Quantity of net electricity generation supplied by renewable energy sources to the isolated grid in year *y* (MWh/yr
p	=	Power plants that use only liquid or solid fuels, excluding combined cycle power plants, and that dispatched electricity to the isolated grid in year *y*
q	=	Combined cycle power plants that use liquid fossil fuels and that dispatched electricity to the isolated grid in year y
r	=	Open cycle power plants that use gaseous fossil fuels and that dispatched electricity to the isolated grid in year y
s	=	Combined cycle power plants that use gaseous fossil fuels and that dispatched electricity to the isolated grid in year y
P	=	Total number of plants that use liquid or solid fossil fuels, excluding combined cycle power plants, that dispatched electricity to the isolated grid in year y
Q	=	Total number of combined cycle power plants that use liquid fossil fuels that dispatched electricity to the isolated grid in year y
R	=	Total number of open cycle power plants that use gaseous fossil fuels that dispatched electricity to the isolated grid in year y
S	=	Total number of combined cycle power plants that use gaseous fossil fuels that dispatched electricity to the isolated grid in year y

2. **Option 2**: Weighted average emission factor **(tCO_2/MWh)** based on installed capacity using the equation below

$$EF_{isolated\_grid,y} = \frac{P_{LS\_FF,y} + 0.45 * P_{LCC\_FF,y} + 0.5 * P_{G\_FF,y} + 0.38 * P_{GCC\_FF,y} + 0 * \mathrm{P}_{\mathrm{r}\,en,\,y}}{P_{LS\_FF,y} + P_{LCC\_FF,y} + P_{G\_FF,y} + P_{GCC\_FF,y} + \mathrm{P}_{\mathrm{r}\,en,\,y}}$$

Equation (2)

and

$$P_{LS\_FF,y} = \sum_{p=1}^{P} f_p * P_{LS\_FF,p,y}\ ;\ P_{LCC\_FF,y} = \sum_{q=1}^{Q} P_{LCC\_FF,q,y}\ ;\ P_{G\_FF,y} = \sum_{r=1}^{R} P_{G\_FF,r,y}\ ;\ P_{GCC\_FF,y} = \sum_{s=1}^{S} P_{GCC\_FF,s,y}\ ;$$

$$P_{ren\_y} = \sum_{s=1}^{S} P_{ren\_,y}$$

Where:

$EF_{isolated\_grid}$	=	Emission factor of the isolated grid (t CO_2/MWh)
$P_{LS\_FF,y}$	=	Total power capacity of the power plants connected to the grid using liquid or solid fossil (but excluding combined cycle power plants) in year *y* (MW)
$P_{LCC\_FF,y}$	=	Total power capacity of the power plants connected to the isolated grid by the combined cycle power plants using liquid or solid fossil in year *y* (MW)
$P_{G\_FF,y}$	=	Total power capacity of the open cycle power plants connected to the isolated using gaseous fossil fuel in year *y* (MW)
$P_{GCC\_FF,y}$	=	Total power capacity of the combined cycle power plants connected to the isolated using gaseous fossil fuel in year *y* (MW)
$P_{LS\_FF,p,y}$	=	Power capacity of the power plant 'p' that uses liquid or solid fossil (but excluding combined cycle power plants) connected to the isolated grid in year *y* (MW)
$P_{LCC\_FF,q,y}$	=	Power capacity of the liquid fossil fuel combined cycle power plant *q* connected to the isolated grid in year *y* (MW)
$P_{G\_FF,r,y}$	=	Power capacity of the gaseous fossil fuel open cycle power plant *r* connected to

		the isolated grid in year *y* (MW)
$P_{GCC\_FF,s,y}$	=	Power capacity of the gaseous fossil fuel combined cycle power plant *s* connected to the isolated grid in year *y* (MW)
$\Pr en, y$	=	Power capacity of renewable energy sources connected to the isolated grid in year *y* (MWh/yr
p	=	Power plants that use only liquid or solid fuels, excluding combined cycle power plants, connected to the isolated grid in year *y*
q	=	Combined cycle power plants that use liquid fossil fuels connected to the isolated grid in year *y*
r	=	Open cycle power plants that use gaseous fossil fuels connected to the isolated grid in year *y*
s	=	Combined cycle power plants that use gaseous fossil fuels connected to the isolated grid in year *y*
P	=	Total number of plants that use liquid or solid fossil fuels, excluding combined cycle power plants, connected to the isolated grid in year *y*
Q	=	Total number of combined cycle power plants that use liquid fossil fuels connected to the isolated grid in year *y*
R	=	Total number of open cycle power plants that use gaseous fossil fuels connected to the isolated grid in year *y*
S	=	Total number of combined cycle power plants that use gaseous fossil fuels connected to the isolated grid in year *y*

Note:(1) LNG shall be considered as a gaseous fuel source, and (2) dual fuel plants which consume natural gas and a liquid fuel shall be categorized as a gaseous fossil fuel plant.

Appendix 2. Emission factors of Diesel Generator plants/units

Table 1. Emission factors of DG sets by capacity sizes[3]

EF (tCO2/MWh	Load factor	Generator Size (kW)						
		10< x <= 20	20<x <= 50	50< x <= 100	100< x <= 200	200< x <= 400	400< x <= 1000	>1000
EF Derived from a new source[(a)]	**25%**	1.152	1.591	1.111	0.920	0.869	0.837	0.823
	50%	0.864	1.125	0.850	0.753	0.723	0.703	0.694
	75%	0.832	1.024	0.774	0.714	0.688	0.671	0.663
	100%	0.768	0.946	0.748	0.696	0.689	0.684	0.681
Default EF from AMS-I.F	**25%**	2.40	1.90	1.30	0.90	0.80	0.80	0.80
	50%	1.40	1.30	1.00	0.80	0.80	0.80	0.80
	100%	1.20	1.10	1.00	0.80	0.80	0.80	0.80
Default EF from AM0103	-	0.80						
Literature[(b)] (for plants up to 10 MW size)	0.558-0.593							
EF derived using efficiency values from the grid tool[4] and fossil fuel EF from IPCC	-	0.933	0.792	0.747	0.706	0.670	0.622	0.581

Note:

(a) Derived based on fuel consumption values from http://www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx.

(b) https://www.jcm.go.jp/pw-jp/methodologies/18.

[3] Size range in the table is based on Table 2, Appendix 1 of the grid tool

[4] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v5.0.pdf

Table 2: Average emission factor of DG plants of size > 1000 kW based on SBs from SIDS

Standardized Baselines (Approved/Pipeline)	Number of Power Plants/Units (>1000 kW)	Total Installed Capacity (MW)	Average Emission factor calculate using actual input /output data using OM method (tCO2/MWh)
Cape Verde	8	77.3	0.548
	2	4.7	0.599
	2	3.8	0.736
	1	2.2	0.745
	1	1.4	0.726
	1	1.1	0.667
St Vincent & Grenadines	1	4	0.823
	1	3.1	0.822
	1	1.3	0.857
Grenada	1	52.4	0.599
	1	3.2	0.640
Antigua & Barbuda	3	107.9	0.643
Weighted Average EF			**0.614**

Table 3. Average emission factor of DG plants by sizes and load factors

DG Set Emission Factor				
Generator Size (kW)	LF:0.25	LF:0.50	LF:0.75	LF:1.0
	EF (tCO2/ MWh)			
20	1.152	0.864	0.832	0.768
30	1.664	1.152	1.024	0.928
40	1.536	1.104	1.024	0.960
60	1.152	0.928	0.811	0.768
75	1.229	0.871	0.785	0.781
100	0.999	0.787	0.743	0.711
125	0.952	0.768	0.727	0.699
135	0.939	0.768	0.721	0.697
150	0.922	0.755	0.717	0.698
175	0.900	0.746	0.710	0.697

DG Set Emission Factor				
200	0.903	0.739	0.704	0.691
230	0.885	0.735	0.696	0.693
250	0.876	0.730	0.696	0.691
300	0.871	0.723	0.687	0.688
350	0.867	0.719	0.684	0.689
400	0.855	0.715	0.682	0.687
500	0.845	0.711	0.676	0.686
600	0.845	0.704	0.672	0.685
750	0.835	0.702	0.671	0.684
1000	0.830	0.699	0.667	0.683
1250	0.827	0.696	0.666	0.682
1500	0.824	0.695	0.664	0.682
1750	0.823	0.694	0.664	0.681
2000	0.822	0.693	0.663	0.681
2250	0.821	0.692	0.662	0.681

Source: Emission factors are estimated based on fuel consumption data from the source http://www.dieselserviceandsupply.com/Diesel_Fuel_Consumption.aspx

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