Additional information on calculating the conservative emission factor of Bangladesh

The value for $EF_{RE,i}$ is selected from the emission factor based on the national grid ($EF_{RE,grid}$), based on captive diesel power generator ($EF_{RE,cap,diesel}$) or based on captive gas power generator ($EF_{RE,cap,gas}$) in the following manner:

(a) In case the PV system in a proposed project activity is connected to the Bangladesh national grid including an internal grid which is not connected to a captive power generator, $EF_{RE,grid}$, **0.376 tCO_2/MWh** is applied.

(b) In case the PV system in a proposed project activity is connected to an internal grid which is connected to both the national grid and a captive power generator, $EF_{RE,grid}$, **0.376 tCO_2/MWh** is applied.

(c) In case the PV system in a proposed project activity is connected to a captive power generator but not connected to the national grid, $EF_{RE,cap,gas}$, **0.376 tCO_2/MWh** is applied unless the captive power generator uses only oil fuel. In case the captive power generator uses only oil fuel, $EF_{RE,cap,diesel}$, **0.533 tCO_2/MWh** is applied.

1. Current status of electricity mix in Bangladesh

Natural gas-fired power plants have the largest share of the power supply in Bangladesh. The share has been around 77% of the total. The share of petroleum is on the increase and constitutes around 20% of the power supply. The share of coal is only around 3%. The absolute amount supplied has increased during 1999 to 2015[1]. The combined margin (CM) emission factor of the grid for 2011 is calculated to be 0.674 tCO_2/MWh.

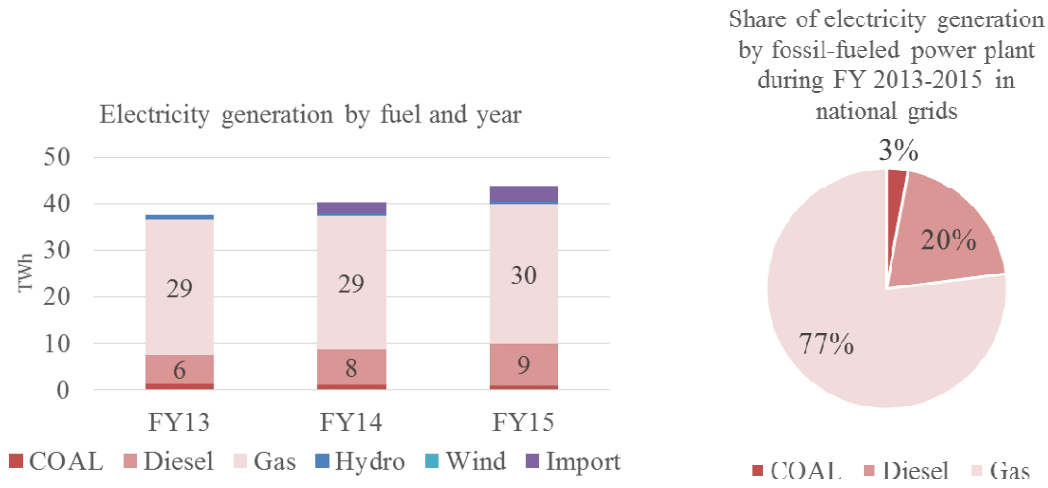

Figure 1. Electricity generation of national gird by fuel type

[1] Annual Report 2014-2015, Bangladesh Power Development Board.

2. Calculation of gas-fired power plants emission factor

In order to identify the conservative emission factor of the electricity system simplistically and to secure the net emission reduction, this methodology applies the lowest CO_2 emission factor of the gas-fired CHP power plant supplying electricity to the national grid.

Bangladesh Power Development Board (BPDB) published Annual Report of 2014-2015[1] and the gas-fired power plants identified in the report are listed in Table 1 for public sector and Table 2 for IPP. The most efficient power plant identified in the annual report is Haripur 412MW CCPP owned by the Electricity Generation Company of Bangladesh Limited (EGCB). The gas turbine of the plant is manufactured by the Mitsubishi Heavy Industry and has an efficiency of 52% (Lower Heating Value: LHV), and the figure 52% is close to the most efficient group of natural gas-fired power plants in commercial operation in Japan, which has a LHV efficiency of 56-59%.[2]

Table 1 Efficiency of natural gas-fired power plants in Bangladesh (Public Sector)

Name of power plant	Installed Capacity (MW)	Plant efficiency (LHV, %)
Chittagong Thermal Power Plan Unit #-1 (Raozan)	180	28.46
Chittagong Thermal Power Plan Unit #-2 (Raozan)	180	28
Sikalbaha 60 MW Steam Turbine	40	24.01
Sikalbaha 150 MW Gas Turbine	150	22.39
Ashuganj 2x64 MW Steam Turbine	97	28.13
Ashuganj 3x150 MW Steam Turbine	398	32.75
Ashuganj GT 2	40	21.76
Ashugonj 50 MW gas Engine	45	35.5
Ashuganj 225 MW CCPP	142	30.54
Chandpur 150MW CCPP	163	38.51
Ghorasal2x55 MW Steam Turbine (1 +2nd Unit)	85	28.21
Ghorasal 2x210 MW Steam Turbine(3+4th Unit)	350	30.18
Ghorasai2X210 MW S/T (5+6th Unit)	380	31.74
Siddhirganj 210 MW Steam Turbine	150	30.84
Siddhirganj 2x120 MW Gas Turbine	210	26.28
Haripur 3x33 MW Gas Turbine	60	21.04
Haripur 412 MW CCPP (EGCB)	412	51.57
Tongi 100 MW Gas Turbine	105	24.59
Shahjibazar 60 MW Gas Turbine	66	25.79
Sylhet 1x20 MWGasTurbine	20	24.62
Sylhet 1 x150 MW Gas Turbine	142	29.84
Fenchuganj C. C. (1st Unit)	80	33.35
Fenchuganj C.C. (2nd Unit)	90	28.73
Baghabari 71 MWGasTurbine	71	27.14
Baghabari 100 MW Gas Turbine	100	28.22
Sirajgonj 210 MW Gas Turbine (NWPGCL)	210	40.44

[2] https://www.env.go.jp/press/files/jp/24454.pdf

Table 2 Efficiency of natural gas-fired power plants in Bangladesh (IPP Sector)

Name of power plant	Installed Capacity (MW)	Plant efficiency (LHV, %)
NEPC (Haripur, BMPP)	110	41.03
RPCL 210 MW (Mymensingh)	202	45.15
AES, Haripur	360	49.06
AES, Meghnaghat	450	45.17
Ashuqanj 51 MW (Midland)	51	36.57
Ghorashal 108 MW (Regent Power)	108	37.3
Ashuganj modular 195 MW (United Power)	195	42.51
Bibiyana 2 (Summith) 341 MW	222	28.88
Boqra Rental (GBB) (15 Years)	22	29.02
Kumarqoan (Enerqy Prima)(3 Years)	50	34.27
Sahzibazar RPP (Energyprima) (3 Years)	50	28.43
Sahzibazar RPP (Shahjibazar Power) (15 Years)	86	27.26
Tangail SIPP (Doreen) (22 MW) (BPDB)	22	38.28
Feni SIPP (22 MW) (BPDB)	22	38.28
Kumargao 10 MW(Desh Energy) (15 Years)	10	35.56
Barabkundu	22	38.28
Bhola RPP (34.5 MW)	33	30.04
Jangalia ,Camilla (33 MW)	33	38.24
Fenchugonj 51 MW Rental (Barakatullah) (15 Yrs)	51	31.29
Malancha		41.09
Ashugonj 55 MW (Precision Energy) 3 Years Rental	55	32.5
Fenchugonj 50 MW (Energy Prima)	44	31.29
Ghorashal100 MW RPP Aggreko)	100	35.94
B.Baria 70 MW QRPP (3 Yrs Aggreco)	85	35.94
Ghorashal 78 MW QRPP (3 Yrs Max Power)	78	35.82
Ashugonj 80 MW QRPP (3 Yrs Aggreco)	95	35.94
Ashugonj 53 MW Q. Rental PP (3 Years) (United Power)	53	36.27
Bogra RPP 3 Yrs (Energy Prima)	20	41.79

Table 3 Constants for calculation of CO_2 emission factor

Item	Values	Source
CO_2 emission factor of natural gas	54,300 $kgCO_2/TJ$	TABLE 1.4 (PP 1.23-24), 2006 IPCC Guidelines for National Greenhouse Gas Inventories[3]
Plant efficiency (LHV) of most efficient natural gas-fired power plant	52%*	Table 1 and 2

* Since auxiliary power consumption is unknown, the plant efficiency of gross electricity generation is applied. This ensures the calculation of a conservative emission factor.

The CO_2 emission factor of power generation by natural gas-fired power plants can be calculated from the plant efficiency using the following equation.

CO_2 emission factor of power generation [$t\text{-}CO_2/MWh$]

= (CO_2 emission factor of natural gas [$kgCO_2/TJ$] $*3.6*10^{-6}$) / (Plant efficiency (LHV) [%]/100)

Applying the values indicated in Table 3, the emission factor of power generation by the most efficient

[3] 2006 IPCC Guidelines for National Greenhouse Gas Inventories

natural gas-fired power plant of 0.376 t-CO_2/MWh is derived. This value (0.376 t-CO_2/MWh) is lower than 0.674, the combined margin (CM) emission factor of the grid. From this result, it can be concluded that by applying the emission factor of power generation by the most efficient natural gas-fired power plant for grid electricity displaced by a solar PV system will ensure net emission reductions.

Table 4 Efficiency and CO_2 emission factor of natural gas-fired power plant

Plant efficiency of natural gas-fired power plant %	52
CO_2 emission factor ton-CO_2/MWh	0.376

3. Calculation of the emission factor of a diesel generator

To determine the emission factor of a diesel generator in a conservative and simple manner, the most efficient heat efficiency is applied.

The CO_2 emission factor of diesel power generation is calculated from the heat efficiency using the following equation:

CO_2 emission factor of power generation [t-CO_2/MWh]

= CO_2 emission factor of fuel source [kgCO_2/TJ] *3.6*10^{-6}/ (Heat efficiency (LHV) [%]/100)

Applying the default value of the CO_2 emission factor of diesel combustion which is 72,600 kgCO_2/TJ derived from "IPCC guideline 2006, Chapter 2, stationary combustion", together with the heat efficiency of 49%, the efficiency level which has not been achieved yet by the world's leading diesel generator, the CO_2 emission factor for diesel generator is calculated to be **0.533 tCO_2/MWh**.