

# **CO<sub>2</sub> Emission Factor Calculation for the Uzbekistan National Grid (2011)**

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## Abbreviations

BM	Build Margin
CDM	Clean Development Mechanism
CDM EB	CDM Executive Board
CERs	Certified Emission Reductions
CHP	Combined Heat and Power Plant
CM	Combined Margin
GEF	Grid Emission Factor
GHG	Green houses gases
GWh	Giga Watt hour
IPCC	Intergovernmental Panel on Climate Change
kW	Kilo Watt
kV	Kilo Volt
MR	Non-Must-Runs Low-Cost/Must-Runs
MW	Mega Watt
MWh	Mega Watt hour
NCV	Net Caloric Value
NMR	Non-Must-Runs
OM	Operating Margin
PD	Peak Demand
RES	Renewable Energy Sources
SSC	Small Scale
tCO <sub>2</sub>	Tons Carbon Dioxide
TPP	Thermal Power Plant
UNFCCC	United Nations Framework Convention on Climate Change

## Introduction

This report estimates the grid emission factor for the Uzbekistan National Grid, thus establishing a standardized baseline for renewable energy generation projects, as well as other projects substituting grid electricity.

The grid emission factor for Uzbekistan is determined using “Tool to calculate the emission factor for an electricity system” (Version 03.0.0), approved by the CDM Executive Board [1] and valid since November 23, 2012. The tool can be found under following link:

[http://cdm.unfccc.int/methodologies/PAMethodologies/tools/am-tool-07-v3.0.0.pdf/history\\_view](http://cdm.unfccc.int/methodologies/PAMethodologies/tools/am-tool-07-v3.0.0.pdf/history_view)

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For the calculation of CO<sub>2</sub> emissions at thermal power stations, data on NCV and fuel consumption was provided by State Joint Stock Company “UzbekEnergo” (SJSC “UzbekEnergo”). SJSC “UzbekEnergo”, formerly the Ministry of Energy of Uzbekistan, is the national company in charge of generation, transmission and distribution of electricity in Uzbekistan. It possesses complete and up-to-date information and data on the operation of the Uzbekistan power grid, including power generation and fuel consumption by individual plants<sup>1</sup>. For cases when data for fuel consumption is not available, especially in the case of CHP plants when the fuel consumption data does not provide clear differentiation between fuel used for heat generation and for electricity generation, fuel consumption was estimated using default plant efficiencies as per Annex I of the Tool [1]. As no local CO<sub>2</sub> emission factors for different types of fuels are available, the IPCC 2006 lower values at 95% confidence interval were applied [2]. The steps of the Tool are applied as follows.

### Step 1: Identify the relevant electricity system

The relevant project electricity system is the Uzbekistan national grid.

### Step 2: Choose whether to include off-grid power plants in the project electricity system (optional)

Option I, only grid connected power plants are included in the calculation, is selected.

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<sup>1</sup> Although, not all of the information presented is publicly available, the DNA of Uzbekistan can provide the full data set to any DOE for the purpose of CDM validation and verification. The complete data set is also provided to the UNFCCC Secretariat as part of this submission.

### Step 3: Select a method to determine the operating margin (OM)

In the case of Uzbekistan, low-cost/must run plants include HPP and CHP plants. CHP plants are a special case of a low-cost/must-run generation units. Heat plants in Uzbekistan operate in a heat-supply mode, i.e. the plants should meet the heat demand (industrial steam and district heating) of their consumers and electricity generation will depend on the amount of heat supplied. In other words, electricity supply is a secondary product of the CHP plants' operation and does not depend on the electricity demand by grid connected consumers.

As low-cost/must run plants constitute 14.35 % of total electricity generation, which is less than 50% in the Uzbekistan grid generation in the average of the five most recent years (2007 – 2011), the Simple OM method is selected. As data for net electricity generation and CO<sub>2</sub> emission factor of each power unit is available, Option A for OM calculation is selected.

**Table 1: Salient Features of the Uzbekistan national electricity grid - Gross Generation (MWh)<sup>2</sup>**

	2007	2008	2009	2010	2011
<b>Total for Uzbekistan (GWh)</b>	<b>48 816,7</b>	<b>50 078,4</b>	<b>50 063,1</b>	<b>51 935,0</b>	<b>52 772,2</b>
Hydro (GWh)	6 457,1	4 385,9	6 483,3	8 192,1	5 721,3
CHP(GWh)	1 219,9	1 101,4	1 028,6	878,2	914,1
<b>Others (CHPs at plants etc.)</b>	<b>215,5</b>	<b>218,7</b>	<b>225,7</b>	<b>227,5</b>	<b>212,9</b>
Low Cost/Must Run as % ratio from total generation	15,7%	11,0%	15,0%	17,5%	12,6%
5 Year Average	<b>14,35%</b>				

For the purpose of this report, OM will be calculated both ex-post, using the three year data average for the most recent three years for which data is available (2009 – 2011) and ex-ante using the most recent available one year data (2011). In case the ex-ante approach is used, the project participants should update the baseline every time this standard baseline is updated.

### Step 4: Calculate the operating margin emission factor according to the selected method

“Option A - Calculation based on average efficiency and electricity generation of each plant” is applied as follows:

$$EF_{grid,OMsimple,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} \quad [1]$$

Where:

$EF_{grid,OMsimple,y}$  Simple operating margin CO<sub>2</sub> emission factor in year  $y$  (tCO<sub>2</sub>/MWh)

$EG_{m,y}$  Net quantity of electricity generated and delivered to the grid by power plant/unit  $m$  in year  $y$  (MWh)

$EF_{EL,m,y}$  CO<sub>2</sub> emission factor of power unit  $m$  in year  $y$  (tCO<sub>2</sub>e/MWh)

$m$  All power units serving the grid in year  $y$  except for low-cost/must-run power plants

$y$  The relevant year as per the data vintage chosen

*Determination of  $EF_{EL,m,y}$*

<sup>2</sup> Information taken from report data of SJSC "Uzbekenergo"; Annual Report; 2007, 2008, 2009, 2010, 2011.

The emission factor of each power unit  $m$  is determined according to Option A1.

**Option A1.** If for a power unit  $m$  data on fuel consumption and electricity generation is available, the emission factor ( $EF_{EL,m,y}$ ) is determined as follows:

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}} \quad [2]$$

Where:

- $EF_{EL,m,y}$  CO<sub>2</sub> emission factor of power unit  $m$  in year  $y$  (tCO<sub>2</sub>e/MWh)
- $FC_{i,m,y}$  Amount of fossil fuel type  $i$  consumed by power unit  $m$  in year  $y$  (Mass or volume unit)
- $NCV_{i,y}$  Net calorific value (energy content) of fossil fuel type  $i$  in year  $y$  (TJ/mass or volume unit)
- $EF_{CO2,i,y}$  CO<sub>2</sub> emission factor of fossil fuel type  $i$  in year  $y$  (tCO<sub>2</sub>/TJ)
- $EG_{m,y}$  Net quantity of electricity generated and delivered to the grid by power unit  $m$  in year  $y$  (MWh)
- $m$  All power units serving the grid in year  $y$  except low-cost/must-run power plants/ Units
- $i$  All fossil fuel types combusted in power unit  $m$  in year  $y$
- $y$  The relevant year as per the data vintage chosen in Step 3

In case the OM is fixed *ex-ante*, the generation weighted three year average OM is calculated. Based on this above, the OM emission factor is estimated to be **0.569 tCO<sub>2</sub>/yr**. In case the OM is updated *ex-post*, the OM emission factor using the data for 2011 is calculated to be **0.536 tCO<sub>2</sub>/yr**

### Step 5: Calculate the build margin (BM) emission factor

Project participants have the option of updating the build margin emission factor annually for the first crediting period (Option 2) or fix it *ex-ante* (Option 1). Depending on the option selected, project participants may have to update the emission factor once this standardized baseline is updated.

The sample group of power generation units  $m$  used to calculate the build margin is determined as per the procedure below using data for 2011, the most recently available data for electricity generation.

(a) Identify the set of five power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently ( $SET_{5-units}$ ) and determine their annual electricity generation ( $AEG_{SET-5-units}$ , in MWh);

The five most recently built plants in Uzbekistan are presented in Table 2 below.

**Table 2: Five most recently built power plants in Uzbekistan**

	Power station/power generating units	Year commissioned
1	Gissarak HPP	2011
2	Andijan-2 HPP	2010

	Power station/power generating units	Year commissioned
3	Akhangaran HPP	2010
4	Tupalang HPP	2006
5	Urgut HPP	2005

For the five most recently built power plants ( $SET_{5-units}$ ) total annual electricity generation ( $AEG_{SET_{5-units}}$ ) is 331,200 MWh.

(b) Determine the annual electricity generation of the project electricity system, excluding power units registered as CDM project activities ( $AEG_{total}$ , in MWh). Identify the set of power units, excluding power units registered as CDM project activities, that started to supply electricity to the grid most recently and that comprise 20% of  $AEG_{total}$  (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) ( $SET_{\geq 20\%}$ ) and determine their annual electricity generation ( $AEG_{SET_{\geq 20\%}}$ , in MWh);

The total power generation in Uzbekistan in 2011 was 47,073,600 MWh.

The most recently built power units that supplied 20% or more of total electricity generation are provided in Table 3 below. As no power units are registered as CDM projects in Uzbekistan, the relevant provisions for CDM registered projects are not applied.

**Table 3: Most recently built power units that supplied 20% or more of total electricity generation in Uzbekistan**

	Power station/power generating units	Year commissioned
1	Gissarak HPP	2011
2	Andijan-2 HPP	2010
3	Akhangaran HPP	2010
4	Tupalang HPP	2006
5	Urgut HPP	2005
6	Talimarjan TPP	2004
7	Novo-Angren TPP	1985
8	Mubarek CHP	1985

For set of power units ( $SET_{\geq 20\%}$ ), annual electricity generation ( $AEG_{SET_{\geq 20\%}}$ ) in 2011 is 12,353,100 MWh.

(c) From  $SET_{5-units}$  and  $SET_{\geq 20\%}$  select the set of power units that comprises the larger annual electricity generation ( $SET_{sample}$ );

As  $SET_{\geq 20\%}$  has higher value, it is selected as a relevant set ( $SET_{sample}$ )

Identify the date when the power units in  $SET_{sample}$  started to supply electricity to the grid. If none of the power units in  $SET_{sample}$  started to supply electricity to the grid more than 10 years ago, then use  $SET_{sample}$  to calculate the build margin. In this case ignore steps (d), (e) and (f).

The  $SET_{sample}$  include power units started to supply electricity to the grid more than 10 years ago.

(d) Exclude from  $SET_{sample}$  the power units which started to supply electricity to the grid more than 10 years ago. Include in that set the power units registered as CDM project activities, starting with power units that started to supply electricity to the grid most recently, until the electricity generation of the new set comprises 20% of the annual electricity generation of the project electricity system (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) to the extent is possible. Determine for the resulting set ( $SET_{sample-CDM}$ ) the annual electricity generation ( $AEG_{SET_{sample-CDM}}$ , in MWh); If the annual electricity generation of that set is comprises at least 20% of

the annual electricity generation of the project electricity system (i.e.  $AEG_{SET-sample-CDM} \geq 0.2 \times AEG_{total}$ ), then use the sample group  $SET_{sample-CDM}$  to calculate the build margin. Ignore steps (e) and (f).

As there are no CDM projects registered in Uzbekistan that supply electricity to the grid, excluding the plants that are built more than 10 years ago, i.e. before 2002 results in electricity generation of less than 20% of total electricity generation.

(e) Include in the sample group  $SET_{sample-CDM}$  the power units that started to supply electricity to the grid more than 10 years ago until the electricity generation of the new set comprises 20% of the annual electricity generation of the project electricity system (if 20% falls on part of the generation of a unit, the generation of that unit is fully included in the calculation);

This is equivalent to the set already identified in (c).

(f) The sample group of power units  $m$  used to calculate the build margin is the resulting set ( $SET_{sample-CDM->10yrs}$ ).

The total generation of the selected eight power plants in 2011 was 12,353,100 MWh, or 26.24 % of the total generation in Uzbekistan. The resulting plant set is shown in Table 4.

**Table 4: List of the Uzbekistan Power Plants Included in the Build Margin Calculations**

	Power station/power generating units	Year commissioned
1	Gissarak HPP	2011
2	Andijan-2 HPP	2010
3	Akhangaran HPP	2010
4	Tupalang HPP	2006
5	Urgut HPP	2005
6	Talimarjan TPP	2004
7	Novo-Angren TPP	1985
8	Mubarek CHP	1985

The build margin emissions factor ( $EF_{grid,BM,y}$ ) is the generation-weighted average emission factor (tCO<sub>2</sub>/MWh) of all power units  $m$  during 2011, the most recent year  $y$  for which electricity generation data is available, and is calculated as per Option A as follows:

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} \quad [3]$$

Where:

$EF_{grid,BM,y}$  Build margin CO<sub>2</sub> emission factor in year  $y$  (tCO<sub>2</sub>/MWh)

$EG_{m,y}$  Net quantity of electricity generated and delivered to the grid by power unit  $m$  in year  $y$  (MWh)

$EF_{EL,m,y}$  CO<sub>2</sub> emission factor of power unit  $m$  in year  $y$  (tCO<sub>2</sub>/MWh)

$m$  Power units included in the build margin



$y$  Most recent historical year for which power generation data is available, 2011

The emission factor ( $EF_{EL,m,y}$ ) of each power unit  $m$  calculated as per Option A1, except for CHPs and plant solder than 10 years, as follows:

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}} \quad [4]$$

Where:

- $EF_{EL,m,y}$  CO<sub>2</sub> emission factor of power unit  $m$  in year  $y$  (tCO<sub>2</sub>/MWh)
- $FC_{i,m,y}$  Amount of fossil fuel type  $i$  consumed by power unit  $m$  in year  $y$  (mass or volume unit)
- $NCV_{i,y}$  Net calorific value (energy content) of fossil fuel type  $i$  in year  $y$  (TJ/mass or volume unit)
- $EF_{CO2,i,y}$  CO<sub>2</sub> emission factor of fossil fuel type  $i$  in year  $y$  (tCO<sub>2</sub>/TJ)
- $EG_{m,y}$  Net quantity of electricity generated and delivered to the grid by power plants/ unit  $m$  in year  $y$  (MWh)
- $m$  Power units included in the build margin
- $i$  All fossil fuel types combusted in power unit  $m$  in year  $y$
- $y$  Most recent historical year for which power generation data is available, 2011

For CHPs, fuel consumption data cannot be separated into data for electricity and heat generation. Therefore, for the sake of conservativeness, Option A2 is used. The Tool further requires in paragraph 75 that for plants older than 10 years (i.e. Marubek CHP and Novo-Angren TPP) that Option A2 is applied. As per paragraph 45, or plants where more than one fuel is used, the fuel with the lowest emission factor is applied as well as the default efficiency for generation equipment using that fuel is used. Thus, in the case of the Novo-Angren TPP, natural gas power generation using steam turbine (efficiency 37.5%) is assumed. For the Marubek CHP, natural gas cogeneration (open cycle with efficiency 30%) is assumed. The emission factor for these plants is calculated as per the following equation:

$$EF_{EL,m,y} = \frac{EF_{CO2,m,i,y} \times 3.6}{\eta_{m,y}} \quad [5]$$

Where:

- $EF_{EL,m,y}$  CO<sub>2</sub> emission factor of power unit  $m$  in year  $y$  (tCO<sub>2</sub>/MWh)
- $EF_{CO2,m,i,y}$  Average CO<sub>2</sub> emission factor of fuel type  $i$  used in power unit  $m$  in year  $y$  (tCO<sub>2</sub>/GJ)
- $\eta_{m,y}$  Average net energy conversion efficiency of power unit  $m$  in year  $y$ , default values used (%)
- $m$  Power units (CHP) included in the build margin
- $y$  Most recent historical year for which power generation data is available, 2011

Based on the above data, the build margin emission factor is estimated to be 0.499 tCO<sub>2</sub>/MWh.

## Step 6: Calculate the combined margin

The combined margin is calculated using “Option (a): Weighted average CM”. The combined margin emission factor is calculated as follows:

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM} \quad [6]$$

Where:

$EF_{grid,BM,y}$	Build margin CO2 emission factor in year y (tCO <sub>2</sub> /MWh)
$EF_{grid,OM,y}$	Operating margin CO2 emission factor in year y (tCO <sub>2</sub> /MWh)
$w_{OM}$	Weighting of operating margin emissions factor (per cent)
$w_{BM}$	Weighting of build margin emissions factor (per cent)

The weights  $w_{OM}$  and  $w_{BM}$  (where  $w_{OM} + w_{BM} = 1$ ) by default are equal for the first crediting period ( $w_{OM} = w_{BM} = 0.5$ ).

In case the OM emission factor is fixed *ex-ante* and remains fixed during a particular crediting period:

$$EF_y = 0.5 * 0.569 + 0.5 * 0.499 = 0.534 \text{ tCO}_2/\text{MWh}.$$

Thus, CM<sub>EF,ex-ante</sub> for the Uzbekistan grid in 2011 is estimated to be **0.534 tCO<sub>2</sub>/MWh**.

For wind and solar projects, different weights are applied, i.e.  $w_{OM} = 0.75$  and  $w_{BM} = 0.25$ . Then,

$$EF_y = 0.75 * 0.569 + 0.25 * 0.499 = 0.551 \text{ tCO}_2/\text{MWh}.$$

Thus, CM<sub>EF,ex-ante,WS</sub> for the Uzbekistan grid for solar and wind projects in 2011 is estimated to be **0.551 tCO<sub>2</sub>/MWh**.

In case the OM emission factor is updated *ex-post* every time the standardized baseline is updated:

$$EF_y = 0.5 * 0.536 + 0.5 * 0.499 = 0.518 \text{ tCO}_2/\text{MWh}.$$

Thus, CM<sub>EF,ex-post</sub> for the Uzbekistan grid in 2011 is estimated to be **0.518 tCO<sub>2</sub>/MWh**.

For wind and solar projects, different weights are applied, i.e.  $w_{OM} = 0.75$  and  $w_{BM} = 0.25$ . Then,

$$EF_y = 0.75 * 0.536 + 0.25 * 0.499 = 0.527 \text{ tCO}_2/\text{MWh}.$$

Thus, CM<sub>EF,ex-post,WS</sub> for the Uzbekistan grid for solar and wind projects in 2011 is estimated to be **0.527 tCO<sub>2</sub>/MWh**.

**List of References:**

[1] Methodological tool – *Tool to calculate the emission factor for an electricity system*, Annex 19, Version 03.0, Report of UNFCCC CDM Executive Board 70, 23 November 2012.

[2] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2: Energy, Table 1.4: Default CO<sub>2</sub> emission factor for combustion