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RWANDA ENVIRONMENT MANAGEMENT AUTHORITY

P.O.BOX 7436 KIGALI-RWANDA

Rwanda Grid Emission Factor Standardized Baseline

Kigali

20 May 2014

The Rwanda grid emission factor (GEF) standardardized (SB) was developed in collaboration with Perspectives Climate Change and completed as part of a comprehensive capacity development project, which aims to facilitate access to the global carbon markets for Rwanda by strengthening the institutional capacity of the Designated National Authority (DNA) for developing CDM standardized baselines. Funding for project was provided by the International Climate Initiative (ICI) of the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB). The authors were Courtney Blodgett and Stephan Hoch, with assistance provided by Stefan Wehner.

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Executive Summary

The following proposed standardized baseline (SB) is based on the Grid Emission Factor (GEF), and applies to the power sector of Rwanda. The GEF SB is applicable for grid connected renewable energy and energy efficient Clean Development Mechanism (CDM) projects and programmes. The Rwanda national grid currently includes 13 hydropower plants, 1 solar power plant, 1 methane powered plant and 4 diesel powered plants. Electricity data from 2011 – 2013 was used; it was provided by the Rwanda Energy, Water and Sanitation Authorityin March 2014.

The 2013 build margin is 0.537 tonnes of carbon dioxide per megawatt-hr (tCO_2/MWh). The 2011 - 2013 operating margin is 0.504 tCO_2/MWh. The 2013 combined margin for non-wind and non-solar activities is 0.520 tCO_2/MWh and 0.512 tCO_2/MWh for wind and solar activities.

Abbreviations

BM ..... build margin
CO_2 ..... carbon dioxide
CM ..... combined margin
EG ..... electricity generation
EF ..... emission factor
EWSA ..... Energy, Water and Sanitation Authority
GJ ..... gigajoule
LDC ..... least developed country
LCMR ..... low-cost-must-run
MWh ..... megawatt-hr
NCV ..... net calorific value
OM ..... operating margin
PoA ..... programme of activity
REMA ..... Rwandan Environment Management Authority
SB ..... standardized baseline

Introduction

Standardization of the CDM is an important part of the on-going reform process, which aims to broaden access to the CDM for underrepresented countries, particularly those in sub-Saharan Africa. Standardized baselines (SBs) are a particularly relevant component of this process as they simplify the applicability of CDM methodologies and facilitate CDM project and programme of activity (PoA) development. This is because SBs typically provide readily available default values for key required elements of CDM documentation which project participants do not have to research and calculate individually for each activity. Therefore, SBs are highly relevant methodological tools, which can simplify the implementation of the CDM and potentially also other climate finance mechanisms by project developers in Rwanda.Grid emission factor (GEF) SBs have a high potential to facilitate project/programme development; demonstrating this, two of the four approved SBs are GEFs.In this case, the SB is based on the "Tool to calculate the emission factor for an electricity system, version 4.0", and provides a default value for the value of the combined margin (CM).

This SB is for the GEF for Rwanda. The GEF SB will facilitate the development of CDM projects in Rwanda in sectors such as hydropower, geothermal and solar. This document details the steps taken to calculate Rwanda's GEF SB.

Step 1. Identify the Relevant Electricity System

The relevant electricity system is the Rwanda national grid. This grid is run by the Rwandan Energy, Water and Sanitation Authority (EWSA). The Rwanda national electricity grid is comprised of:

- 13 hydropower plants
- 1 solar power plant
- 1 methane powered plant[1]
- 4 diesel powered plants[2].

[1] The methane is extracted from Lake Kivu. Lake Kivu is one three lakes in the world to have this phenomenon of methane trapped within the waters of the lakehttp://www.lake-kivu.org/methane_extraction. As this methane is renewable, the power plant is considered to be a low-cost-must-run plant.

[2] The 5 MW diesel plant Aggreko Mukungwa was commissioned in 2006; it was de-commissionned in 2009. It was then re-commissioned 2012 with an additional 5 MW, for a total of 10 MW. In the GEF calculations, to account for the additional 5MW capacity included in the build margin, each 5 MW of capacity was listed separately (i.e. Aggreko Mukungwa I commissioned in 2006, Aggreko Mukungwa II commissioned in 2012).

Electricity is exported at three tie points:

- Rusizi I
- Rusizi II
- Kabale.

Electricity is imported at three tie points:

- Cyanika-Gisoro
- Gisenyi-Goma
- Mururu II.

The boundary of the grid can be seen in Figure 1.

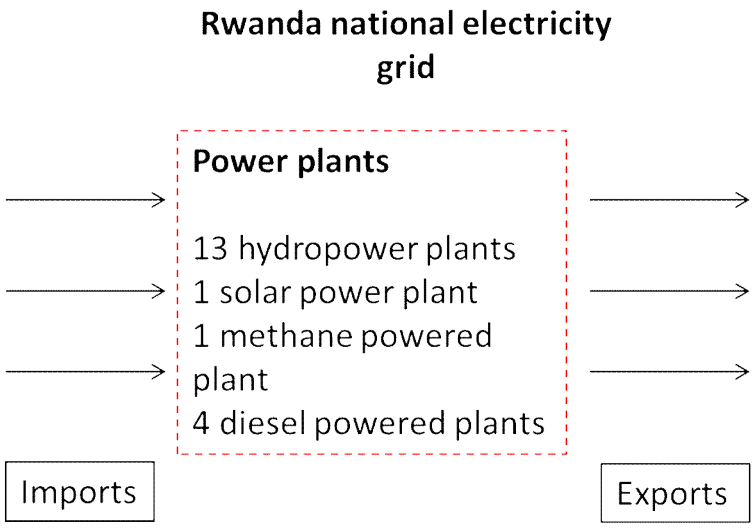

Figure 1 Rwanda national electricity grid

Data for this standardized baseline was acquired from EWSA in March 2014. EWSA provided: the power plant names and commissioning dates, fuels used by plant, fuel consumption volumes by plant, and five years of electricity generation amounts by plant. Default values were used for: density of diesel and heavy fuel oil[3], net calorific value of fuels[4], and emissions factors of fuels[5].

[3] DECC/DEFRA (2013): Greenhouse gas conversion factors. Available at: https://www.gov.uk/measuring-and-reporting-environmental-impacts-guidance-for-businesses#greenhouse-gas-conversion-factors

[4] IPCC (2006): Default net NCV (Tj per Gg). Table 1.2., Vol 2 Ch 1, Introduction

[5] IPCC (2006): Emission factors for combustion (kg of greenhouse gas per TJ on a Net Calorific Basis). Table 1.4., Vol 2 Ch1, Introduction

The carbon dioxide (CO_2)emission factor(s) for net electricity imports from the connected electricity system will be 0 tCO_2 per megawatt-hr (MWh). None of the power plants in the electricity grid are registered CDM projects or PoAs.

The data for the above mentioned power plants will be used to calculate the build margin (BM), operating margin (OM), and finally the CM.

Step 2: Off grid power plants

Option II of Step 2 is selected: Both grid power plants and off-grid power plants are included in the calculation.Off grid plants will be included in determining both the OM and the BM.

Option IIb will be applied; the default value of 0.8 tCO_2/MWh will be used as the CO_2 emission factor for offgrid plants. In accordance with the methodological tool requirements to use this default value: Rwanda is a least developed country (LDC), the project activities consist of grid connected renewable energy power generation and there is a load shedding program in place[6].

For off grid plants, options a) Value of 10% of total electricity generation by grid power plants in the electricity system for the purpose of the OM determination and b) Value of 10% of generation included in BM sample group are applied.

Step 3: Select a method to determine the OM

Option a) the simple OM method is applied as the total low-cost/must-run (LCMR) average for 2009 to 2013 is 44%. See Annex 1 for details.

Time duration option a) ex-ante is selected. Therefore, the GEF will be valid for the duration of the SB. A 3-year (2011-2013) generation-weighted average based on the most recent available data is used.

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

[6]Government of Rwanda.(2009). Rwanda State of the Environment and Outlook Report.

Majyambere, G. (2012, September 25). EWSA's call to save energy.The New Times. Rwanda. Retrieved from http://www.newtimes.co.rw/news/index.php?i=15126&a=58745

Unknown. (2012, January 19). Ngoma: EWSA promises to solve the load shedding problem soon. Rwanda Energy. Rwanda. Retrieved from http://www.rwandaenergy.com/2012/01/ngoma-ewsa-promises-to-solve-the-load-shedding-problem-soon/

According to the Tool to calculate the emission factor for an electricity system, version 4.0, the simple OM emission factor is calculated as the generation-weighted average CO_2 emissions per unit net electricity generation (EG) (in tCO_2/MWh) of all generating power plants serving the system, not including low-cost/must-run power plants/units. To calculate the Simple OM, option A –Based on the net electricity generation and a CO_2 emission factor (EF) of each power unit – is utilized. The calculation utilizes the following equation, Equation 1 in this document:

$$EF_{grid,OMsimple,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} \quad \text{(Equation 1)}$$

Where:

$EF_{grid,Omsimple,y}$ = Simple operating margin CO_2 emission factor in year y (t CO_2/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_2 emission factor of power unit m in year y (t CO_2/MWh)

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

y = The relevant year as per the data vintage chosen in Step 3.

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

The emission factor of each power unit *u* is calculated using option A1as for a power unit m data on fuel consumption and electricity generation is available. Therefore, the emission factor ($EF_{EL,m,y}$) is determined as per Equation 2 of this document:

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2,i,y}}{EG_{m,y}} \quad \text{(Equation 2)}$$

Where:

$EF_{EL,m,y}$ = CO_2 emission factor of power unit m in year y (t CO_2/MWh)

$FC_{i,m,y}$ = Amount of fuel type i consumed by power unit m in year y (Mass or volume unit)

$NCV_{i,y}$ = Net calorific value (NCV) (energy content) of fuel type i in year y (gigajoule (GJ)/mass or volume unit)

$EF_{CO2,i,y}$ = CO_2 emission factor of fuel type i in year y (t CO_2/GJ)

$EG_{m,y}$ = 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 u nits

i = All fuel types combusted in power unit m in year y

y = The relevant year as per the data vintage chosen in Step 3.

Determination of $EG_{m,y}$

For grid power plants, EG_{my} is determined using EWSA generation data, see Annex 1. For off-grid power plants, as Rwanda is a LDC (see Step 2), a default value of 10% of total electricity generation by grid power plants in the electricity system for the purpose of the OM determination is applied.

Operating margin result

Using the above equations, the $EF_{grid,OMsimple,2011\_2013}$= 0.504t$CO_2$/MWh. See Annex 2 for details.

Step 5: Calculate the build margin emission factor

In terms of vintage of data, option 1 is selected: for the first crediting period, calculate the build margin emission factor ex ante based on the most recent information available on units already built for sample group m. For the second crediting period, the build margin emission factor should be updated based on the most recent information available on units already built at the time of submission of the request for renewal of the crediting period to the DOE. For the third crediting period, the build margin emission factor calculated for the second crediting period should be used. This option does not require monitoring the emission factor during the crediting period.

In accordance with the grid tool, the sample group of power units m used to calculate the build margin should be determined as per the following procedure, consistent with the data vintage selected above:

(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_{5units}) and determine their annual electricity generation ($AEG_{SET\text{-}5\text{-}units}$, in 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 per cent of AEG_{total} (if 20 per cent falls on part of the generation of a unit, the generation of that unit is fully included in the calculation) ($SET_{\geq 20per\ cent}$) and determine their annual electricity generation ($AEGSET_{\geq 20per\ cent}$, in MWh);

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

The five most recently built power plants[7]generated43,400 MWh in 2013; these five plants include: Cyimbili, Nkora, Mazimeru, Musarara and Aggreko Mukungwa (II). This is 10.3% of the total generation. In order to reach 20% of the generation, the 11 newest plants must be considered; please see Annex 3. These plants generated 176,125MWh, or 41.9%, in 2013. Therefore, the BM sample set is comprised of newest units that produce 20% of the total generation of the project electricity system.

The BM emissions factor is then calculated using the generation-weighted average emission factor (tCO_2/MWh) of all power units m during 2013 for which electricity generation data is available, calculated as using Equation 3:

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} \quad \text{(Equation 3)}$$

Where:

$EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year y (t CO_2/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_2 emission factor of power unit m in year y (t CO_2/MWh)

m = Power units included in the build margin

y = Most recent historical year for which electricity generation data is available.

The CO_2 emission factor of each power unit m ($EF_{EL,m,y}$) is determined as per the guidance in Step 4 for the simple OM, using Options A1, using 2013for y the most recent historical year for which electricity generation data is available, and using for m the power units included in the build margin.

For off-grid power plants, $EG_{m,y}$ is determinedapplying a default value of 10% of generation included in BM sample group.

Build margin result

Using the above equations, $EF_{grid,BM,2013}$= 0.537 tCO_2/MWh. Please see Annex 3 for further information.

Step 6: Calculate the combined margin emissions factor

The calculation of the CM emission factor ($EF_{grid,CM,y}$) is based on method: (a) Weighted average CM.

[7] The five most recently built plants include 5 MW additional capacity of the Aggreko Mukungwa installed in 2012.

Weighted average CM

The combined margin emissions factor is calculated as per Equation 4:

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM}$$

Where:

$EF_{grid,BM,y}$ = Build margin CO_2 emission factor in year y (t CO_2/MWh)

$EF_{grid,OM,y}$ = Operating margin CO_2 emission factor in year y (t CO_2/MWh)

W_{OM} = Weighting of operating margin emissions factor (per cent)

W_{BM} = Weighting of build margin emissions factor (per cent).

The following default values are used for W_{OM} and W_{BM}:

(a) Wind and solar power generation project activities: W_{OM} = 0.75 and W_{BM} = 0.25 (owing to their intermittent and non-dispatchable nature) for the first crediting period and for subsequent crediting periods;

(b) All other projects: W_{OM} = 0.5 and W_{BM} = 0.5 for the first crediting period, and W_{OM} = 0.25 and W_{BM} = 0.75 for the second and third crediting period.

Combined margin result

For activities other than wind and solar:

$EF_{grid,CM,2011\_2013}$= 0.520 tCO_2/MWh.

For wind and solar activities:

$EF_{grid,CM,2011\_2013}$= 0.512 tCO_2/MWh.

Annex 1 2009 – 2013 Generation data[8]

[8]Data provided by Head of Electricity Generation Unit, EWSA, 2014

No	Plant Name	Fuel type	Other	Year commissioned	Capacity (MW)	2009 generation (kWh)	2010 generation (kWh)	2011 generation (kWh)	2012 generation (kWh)	2013 generation (kWh)	
1	NTARUKA	Hydro	Domestic	1959	11.25	29,413,000	39,849,200	30,840,640	45,904,520	23,323,000	
2	MUKUNGWA	Hydro	Domestic	1981	12.4	62,599,700	67,073,520	68,466,770	77,928,030	71,468,150	
3	GISENYI	Hydro	Domestic	1957	1.2	1,219,631	-	991,517	3,691,476	4,850,368	
4	GIHIRA	Hydro	Domestic	1984	1.84	5,666,000	4,652,500	2,860,223	10,546,201	9,330,220	
5	RUKARARA	Hydro	Domestic	2010	9.5			34,957,140	34,556,300	32,870,360	
6	MURUNDA	Hydro	Domestic	2010	0.1		435,482	629,117	554,295	624,867	
7	RUGEZI	Hydro	Domestic	2011	2.2			4,395,775	2,007,777	834,729	
8	KEYA	Hydro	Domestic	2011	2.2			4,043,800	503,200	682,680	
9	CYIMBILI	Hydro	Domestic	2011	0.3			342,885	1,002,302	260,700	
10	NKORA	Hydro	Domestic	2011	0.64			1,245,206	2,770,000	1,442,400	
11	MAZIMERU	Hydro	Domestic	2012	0.5			-	1,987,097	2,764,748	
17	JALI SOLAR	Solar	Domestic	2007	0.25	362,917	323,865	298,791	305,864	298,388	
18	Musarara	Hydro	Domestic	2013	0.438	-	-	-	-	2,747,573	
19	Mukungwa 2	Hydro	Domestic	2013	2.5	-	-	-	-	2,565,956	
Total renewables					45.318	99,261,248	112,334,567	149,071,864	181,757,062	154,064,139	
16	Kibuye Power 1	Methane	Domestic	2008	3.6	3,311,590	8,972,564	6,110,211	8,826,162	9,937,590	
Total methane					3.6	3,311,590	8,972,564	6,110,211	8,826,162	9,937,590	
12	JABANA I	LFO	Domestic	2004	7.8	16,325,766	12,334,890	11,506,710	6,373,200	5,041,390	
13	JABANA II	LFO&HFO	Domestic	2009	20.5	73,866,951	74,216,292	97,794,960	106,122,907	97,451,524	
14	AGGREKO GIKONDO	LFO	Domestic	2005	10	42,820,811	68,421,682	80,458,071	82,222,772	85,629,855	
15	AGGREKO MUKUNGWA I	LFO	Domestic	2006	5	12,732,117	-	-	3,841,402	33,879,725	
16	AGGREKO MUKUNGWA II	LFO	Domestic	2012	5	-	-	-	3,841,402	33,879,725	
Total fossil fuel					48.3	145,745,645	154,972,864	189,759,741	202,401,683	255,882,219	
Total national production					**97.218**	**248,318,483**	**276,279,995**	**344,941,816**	**392,984,907**	**419,883,948**	
Off grid default generation						**24,831,848.30**	**27,627,999.50**	**34,494,182**	**39,298,491**	**41,988,395**	
1	RUZIZI I	Hydro	Import			14,337,080	12,779,580	19,984,800	20,154,060	22,325,300	
2	RUZIZI II	Hydro	Import			47,448,000	65,008,000	52,362,000	68,298,000	69,776,000	
3	KABALE (UEB)	Uganda	Import			475,500	1,967,000	2,776,928	2,393,473	1,184,074	
4	Gisenyi-Goma	DRC	Import			125,726	-	-	-	-	
Total import						**62,386,306**	**79,754,580**	**75,123,728**	**90,845,533**	**93,285,374**	
1	CYANIKA - GISORO		Export			2,622,837	2,781,750	2,910,800	2,912,936	3,007,495	
2	GISENYI - GOMA		Export			197,794	-	-	-	-	
3	MURURU II		Export			94,220	24,000	34,000	26,000	44,000	
Total export						**2,914,851**	**2,805,750**	**2,944,800**	**2,938,936**	**3,051,495**	
FINAL NATIONAL OFFER						307,789,938	353,228,825	417,120,744	480,891,504	510,117,827	
						2009	**2010**	**2011**	**2012**	**2013**	**Average$_{2009_2013}$**
	Total LCMR					41%	44%	45%	48%	39%	44%
	Total fossil fuel					59%	56%	55%	52%	61%	56%

Annex 2: 2011 – 2013 Operating margin data[9]

Plant Name	Fuel type	Other	Year	Capacity	Generation			Fuel consumption						Net Calorific Value		Emission factor								OM
					2011 generation (MWh)	2012 generation (MWh)	2013 generation (MWh)	2011		2012		2013						2011	2011	2012	2012	2013	2013	2011-2013
								LFO/diesel (tonne)	HFO (tonne)	LFO/diesel (tonne)	HFO (tonne)	LFO/diesel (tonne)	HFO (tonne)	LFO/diesel (TJ/t)	HFO (TJ/t)	LFO/diesel (tCO2e/TJ)	HFO (tCO2e/TJ)	$EF_{EL,m,y}$ [tCO2e/MWh]	tCO2e	$EF_{EL,m,y}$ [tCO2e/MWh]	tCO2e	$EF_{EL,m,y}$ [tCO2e/MWh]	tCO2e	
JABANA I	LFO	Domestic	2004	7.8	11,507	6,373	5,041	2,592	-	1,453	-	1,226		0.0414		72.60		0.68	7,791	0.69	4,368	0.73	3,684	
JABANA II	LFO&HFO	Domestic	2009	20.5	97,795	106,123	97,452	2,915	18,409	1,068	23,844	2,566	19,871	0.0414	0.0398	72.60	75.50	0.66	64,077	0.71	74,859	0.69	67,423	
AGGREKO GIKONDO	LFO	Domestic	2005	10	80,458	82,223	85,630	18,173		17,498	-	19,306		0.0414		72.60		0.68	54,623	0.64	52,593	0.68	58,027	
AGGREKO MUKUNGWA I	LFO	Domestic	2006	5	-	3,841	33,880			958	-	7,475		0.0414		72.60		-	-	0.75	2,878	0.66	22,467	
AGGREKO MUKUNGWA II	LFO	Domestic	2012	5		3,841	33,880			958		7,475		0.0414		72.60				0.75	2,878	0.66	22,467	
Total fossil fuel				**48.3**	189,760	202,402	255,882												-					
Off grid default					**34,494**	**39,298**	**41,988**											0.80	27,595	0.8	31,439	0.8	33,591	
Total import					**75,124**	**90,846**	**93,285**											0	-	0		0		
Total generation from fossil fuel plants, imports & off grid default generation (MWh/yr)					**299,378**	**332,546**	**391,156**																	
Total emissions (tCO2e/yr)																			154,087		169,015		207,660	
Operating margin																			0.463		0.508		0.531	0.504

[9] Data provided by Head of Electricity Generation Unit, EWSA, 2014

Annex 3: 2013 BM data[10]

Plant Name	Fuel type	Year	Capacity	Generation	Fuel consumption		Net Calorific Value		Emission factor		Plant	Plant EF	BM
				2013 generation (MWh)	2013	2013					2013	2013	2013
					LFO/diesel (tonne)	HFO (tonne)	LFO/diesel (TJ/t)	HFO (TJ/t)	LFO/diesel (tCO2e/TJ)	HFO (tCO2e/TJ)	$EF_{EL,m,y}$ [tCO2e/MWh]	tCO2e	
JABANA II	LFO&HFO	2009	20.5	97,452	2,566	19,871	0.0414	0.0398	72.60	75.50	0.69	67,423	
Aggreko Mukungwa II	LFO&HFO	2012	5	33,880	7,475	-	0.0414	0.0398	72.60	75.50	0.66	22,467	
RUKARARA	Hydro	2010	9.5	32,870							0	0	
MURUNDA	Hydro	2010	0.1	625							0	0	
RUGEZI	Hydro	2011	2.2	835							0	0	
KEYA	Hydro	2011	2.2	683							0	0	
CYIMBILI	Hydro	2011	0.3	261							0	0	
NKORA	Hydro	2011	0.64	1,442							0	0	
MAZIMERU	Hydro	2012	0.5	2,765							0	0	
Musarara	Hydro	2013	0.438	2,748									
Mukungwa 2	Hydro	2013	2.5	2,566									
Total generation (MWh/yr)				**419,884**									
20% of total national production				**83,977**									
Generation of 5 newest plants				**43,400**									
% of total generation				**10.3%**									
Generation of newest plants comprising >20%				**176,125**									
% generation				**41.9%**									
Off grid generation				**17,613**							0.8	14,090	
Total generation of plants included in the sample group				**193,738**									
Total emissions (tCO_2e/yr)												103,980	
Emission factor (tCO_2e/MWh)													0.537

[10] Data provided by Head of Electricity Generation Unit, EWSA, 2014