Calculation of the Emission Factor of the Electricity System of the Southern African Power Pool

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Report prepared by
GFA ENVEST GmbH

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Abreviations

BM	Build Margin
BMU	German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety
BPC	Botswana Power Cooperation
CDM	Clean Development Mechanism
CDM EB	CDM Executive Board
CEC	Copperbelt Energy Corporation Limited
CERs	Certified Emission Reductions
CES	Connected Electricity System
CM	Combined Margin
DRC	Democratic Republic of the Congo
EdM	Electricidade de Mozambique
GEF	Grid Emission Factor
GWh	Giga Watt hour
HCB	Hidroelectrica de Cahora Bassa SARL
HVDC	High Voltage Direct Current Line (533kV)
IPCC	Intergovernmental Panel on Climate Change
kW	Kilo Watt
kV	Kilo Volt
LEC	Lesotho Electric Company
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
PES	Project Electricity System
RSA	Republic of South Africa
SAPP	Southern African Power Pool
SAPP CC	SAPP Coordination Centre
SEC	Swaziland Electricity Company
SNEL	Societé Nacional d'Electricité
SSA	Sub-Saharan Africa
SSC	Small Scale
tCO_2	Tons Carbon Dioxide
UNEP	United Nations Environmental Program
UNFCCC	United Nations Framework Convention on Climate Change
ZESA	Zimbabwe Electricity Supply Authority
ZESCO	Zambia Electricity Supply Corporation

Introduction

With financial support from the German Federal Ministry of the Environment UNEP and the UNEP Risoe Center initiated a study to examine how to best take into account exports and imports of electricity across the national boundaries in the South African Power Pool (SAPP) and to systematically analyze issues associated with the sub-regional grid electricity system in order to develop national grid emission factors (GEFs) in SAPP member countries for application in Clean Development Mechanism projects.

The calculation of the grid emission factor is based on the most recent version of UNFCCC's "Tool to calculate the emission factor for an electricity system" (Version 2.2.1, hereafter referred to as the "tool"), CDM Executive Board (CDM EB) 63, Annex 19. The tool can be found under following link:

http://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v2.2.1.pdf

The study was implemented by GFA ENVEST GmbH. The study team comprised Martin Burian (Project Coordinator), Dr. Peter Zhou (EECG, Botswana), Francis Masawi (EiL, Zimbabwe) and Prof. Dr. Francis Yamba (CEEEZ, Zambia). Contact details may be found in below box:

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STEP 1. Identify the Relevant Electricity Systems

The SAPP covers nine operating member counties. These are the Botswana, Democratic Republic of Congo (DRC), Lesotho, Mozambique, Namibia, South Africa, Swaziland, Zambia and Zimbabwe. These member countries feature powerful transmission lines allowing for substantial electricity trades between the countries, their national power companies as well as between Independent Power Producers. Given this setup, the Project Electricity System (PES) is defined as the region covered by the nine member countries.

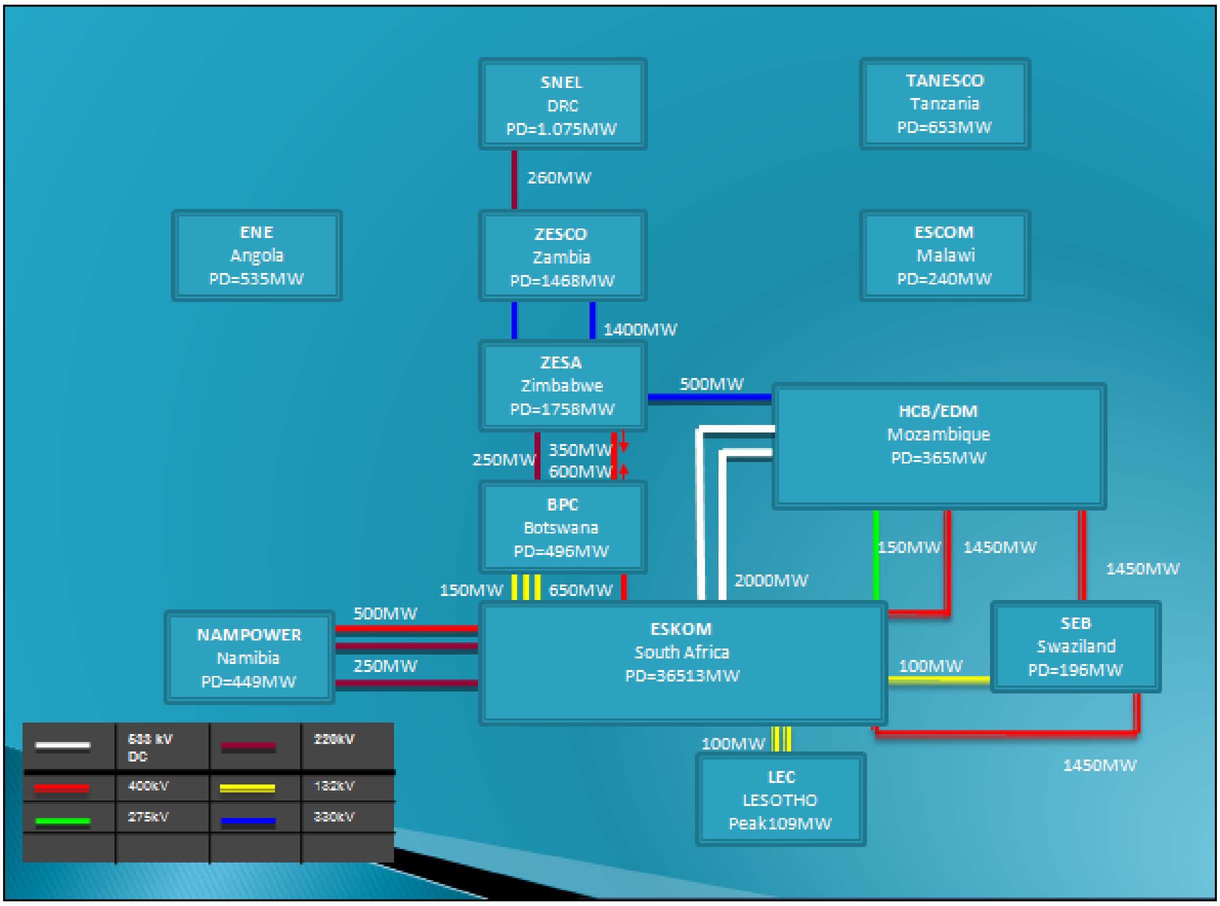
The Build Margin (BM), the Operating Margin (OM) as well as the resulting Combined Margin (CM) are determined for the joint PES. This is consistent with CDM EB 28, §14 and with the current version of the tool. In order to refer to an electricity system which covers more than one country, the tool requests to demonstrate that there are no transmission constraints. The tool offers two options to evaluate the existence of transmission constraints:

- One is the investigation of price differences for electricity between countries/regions.
- The second refers to bottle necks of the operational capacity of the transmission system. Following the tool, transmission constraints persist if a transmission line is operated above 90% of its capacity for 90% of the year or more.

As there is no price information from a power pool available, the proposed project evaluates the actual bottle necks of the transmission lines. Figure 3 shows the existing transmission lines between SAPP member countries, their operational transfer limits[1], as well as the countries' Peak Demand (PD) in MW.

[1] The operational transfer limits are established each year by the SAPP CC using a methodology developed in 2006 to assist operators to maintain high reliability in cross-border electricity trading and operational support (SAPP, 2006).

Figure 1: Transmission Lines and Capacities between SAPP Members



Source: Information provided by the SAPP Coordination Centre

In a first step, transmission constraints were evaluated by comparing the operational capacity of tie lines with their current load factor. The Tool proposes that transmission constraints do not exist if transmission line operates 90% or less of its capacity for 90% or more of the year. To make this determination, data for the operational capacity of tie lines, as well as the current electricity trades between SAPP member countries were provided by the SAPP CC.

Table 1 below outlines the findings. The table shows the actual trades for the year 2010 between SAPP power utilities. If appropriate, trades were evaluated for both directions, i.e. trade from Utility A to Utility B and trade from Utility B to Utility A. This was compared with the operational capacity of the transmission lines. Dividing the actual trades by the operational capacities allows for the assessment of the transmission lines' load factor. If the load factor for both directions was below 90%, it was concluded that there is no existing transmission constraint (i.e. Check: Ok).

Table 1: Evaluation of SAPP Transmissions Constraints by Transfer							
Utility A	Utility B	Transfer from B to A (in MWh)	Transfer from A to B (in MWh)	Transmission Capacity (in MWh)	Transmission Load Factor B to A (in %)	Transmission Load Factor A to B (in %)	Check
ZESCO	ZESA	424,613		6,132,000	7%	0%	**Ok**
SNEL	ZESCO	107,870		2,277,600	5%	0%	**Ok**
ZESA	BPC	1,568,531		2,628,000	60%	0%	**Ok**
BPC	Eskom	1,452,837	2,353,865	4,599,000	32%	51%	**Ok**
HCB	ZESA	1,810,723	0	4,380,000	41%	0%	**Ok**
Eskom	NamPower	1,683,997	2,722	5,475,000	31%	0%	**Ok**
Eskom	SEC	575,842	172,174	11,388,000	5%	2%	**Ok**
Eskom	LEC	164,327	0	876,000	19%	0%	**Ok**
Eskom	EdM-South	1,882,564	0	10,512,000	18%	0%	**Ok**
HCB	Eskom	10,643,400	0	17,520,000	61%	0%	**Ok**
EDM-South	SEC	172,174	0	10,512,000	2%	0%	**Ok**
Source: All data for the year 2010, data provided by SAPP CC							

As can be seen from Table 1, the load factor for all transmission lines is below 90% in both directions. Following the tool's definition of transmission barriers, it is concluded that, there are no transmission constraints between the interconnected SAPP members. Hence all SAPP member countries listed in Table 1 above may form one single Project Electricity System.

As can be seen from Table 1, the Project Electricity System is not connected to the neighboring countries. Consequently, electricity imports from the Connected Electricity System were not considered for the calculation of the GEF

STEP 2. Choose whether to Include Off-Grid Power Plants

Following CDM EB63, Annex 19 page 4f, the tool offers two options to calculate the OM and BM emission factor:

- Option I: Only grid power plants are included in the calculation.
- Option II: Both grid power plants and off-grid power plants are included in the calculation.

The project participant may choose whether to include off-grid emissions. After careful evaluation, it was decided not to consider off-grid emissions. Option I was chosen.

STEP 3. Select a Method to Determine the Operating Margin

The calculation of the operating margin emission factor ($EF_{grid,OM,y}$) is based on the simple OM is applied. This section analyses whether the share of Low-Cost/Must-Runs (MR) is below 50%. In a first step, the share of Non-Must-Runs (NMR) in the PES is determined. For this case, NMRs are defined as steam power plants, gas turbines, combined cycle power, and diesel plants. Annex I provides a list of all power plants located in the nine countries. The far left column shows the fuel type. Using above definition allows for classifying all power plants in MR and NMR.This definition is based on the guidance of the tool (please refer to CDM EB63, Annex 19, p5, footnote 2).

A conservative approach for the definition of NMR would be followed, if it is ensured that NMR comprise only those fossil fueled power plants which serve the peak load of the electricity system. In exchange, fossil fueled power plants would have to be classified as MR, if the power plants (or units of the power plants) would serve the base load. Fossil fueled power plants/units generate base load only if:

- The power plant (or units of the power plants) is designed as a district heating/cooling power plant (i.e. Combined Heat and Power (CHP)). As the CHP not only generates electricity but also supplies heat, the power plant (or units of the power plant) may also serve the base load of an electricity system, and/or
- The power plant (or units of the power plant) applies supercritical coal technology. Supercritical coal technology features high initial investments and comparably low operational expenditures. Hence this project type is usually operated to serve the base load of an electricity system.

Table 5 below provides a list of fossil fuel power plants. None of the power units covered by these power plants is based on supercritical coal nor features a CHP design[2].

- Based on above analysis, the standard definition was adopted as the PES. The team ensured the correctness of this definition by consultation with the SAPP Coordination Centre.
- Finally the classification was submitted to all power companies involved for revision. No objection was received.

The table below shows that the five year average total generation amounts to 286.99 TWh/yr whereas the average share of MR amounts to 57.38 TWh/yr. The share of MR amounts to 19.995%.

Table 2: Determination of the Low-Cost/Must-Run Share

Year	2006	2007	2008	2009	2010
Total electricity generation	316,618,455	275,631,982	275,574,856	280,234,980	286,866,671
Average annual electricity generation in five years	286,985,389				
Generation from low-cost/must-run power units	48,608,358	51,740,930	61,123,528	62,124,380	63,322,625
Average generation from total grid generation	57,383,964				
Low-Cost/Must-Run Resource share	19.995%				
Applicability of Simple OM or Average OM	Simple OM				

[2] The first supercritical coal power plant in Africa is envisaged to be constructed in RSA. Still this project is the planning phase and not yet operational. For further information, please refer to the press coverage from 25th November 2011: http://allafrica.com/stories/201111250216.html

Please note, the data for 2006 and 2007 could only be collected for 7 out of nine countries. It was not possible to collect data for these two years for Mozambique and Zimbabwe. In order to come up with a conservative assessment of the share of low-cost/Must runs, the following approach was applied:

- The total net electricity generation of these two countries for 2008 was determined. This is considered to be conservative, as the electricity generation tends to increase from year to year.
- Second, the countries' total electricity generation was accounted as low-cost/must-runs which is considered as conservative as Zimbabwe also features a substantial generation share of NMR.

It is concluded that as the share of MR is below 50%, the simple OM can be applied.

Conservativeness. The conservativeness of the evaluation was ensured by:

- Discussing the classification of NMR/MR at the power unit level,
- For Mozambique and Zimbabwe, no electricity generation data could be collected for the years 2006 and 2007. Hence the electricity generation data of 2008 was applied for the two previous years and the annual total generation was classified as NMR.

STEP 4. Calculate the Operating Margin Emission Factor

In a next step the simple OM was calculated. The following input data was used:

- All fuel consumption data and all electricity consumption data was collected directly from the power companies or gathered through the SAPP Coordination Centre from the power companies.
  Annex I provides a list of all power plants, their fuel consumption as well as their electricity generation for 2008, 2009 and 2010.
  All data on ESKOM power plant were published by ESKOM[3]. This comprises power generation, fuel consumption, Net Caloric Values (NCV) and emission factors (EFs).
- Annex III., Table 10 provides a list of NCV for different fuel types.
- Annex IV., Table 11 provides a list of emission factors for the various fuels used.
- For some power plants, the actual fuel data could not be collected. For those plants, the A2 calculation approach was applied. These plants are listed in Table3 below. For the determination of plants' overall emission levels, CDM EB's default efficiency factors were applied (Please refer to Annex II., Table 9).

Below table lists those power plants, where not fuel consumption data could be collected. The related emission levels were determined following the A2 Calculation approach outline below.

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Table 3: List of Power Plants Following the A2 Calculation Approach		
No.	Power Company – Name	Calculation Approach
1	ESKOM – Acacia	A2
2	ESKOM – Ankerlig	A2
24	BPC – Matshelagabedi	A2
26	NAMPOWER van Eck	A2
27	NAMPOWER – Paratus	A2
43	SEB - Edwaleni D6	A2
44	SEB - Edwaleni D7	A2
24	BPC – Matshelagabedi	A2

Based on the above outlined input data, the OM emission factor was determined. Following CDM EB63, Annex 19, p7, formula (1), this allows in a subsequent step to calculate the OM emission level:

$$EF_{grid,OMsimple,y} = \frac{\sum_m EG_{m,y} \ x \ EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

$EF_{grid,OMsimple,y}$	Simple operating margin CO2 emission factor in year *y* (tCO2/MWh)
$FC_{i,y}$	Amount of fossil fuel type *i* consumed in the project electricity system in year *y* (mass or volume unit)
$NCV_{i,y}$	Net calorific value (energy content) of fossil fuel type *i* in year *y* (GJ/mass or volume unit)
$EF_{CO2,i,y}$	CO2 emission factor of fossil fuel type *i* in year *y* (tCO2/GJ)
$EG_{,y}$	Net electricity generated and delivered to the grid by all power sources serving the system, not including low-cost/must-run power plants/units, in year *y* (MWh)
y	Most recent historical year for which power generation data is available

For those power plants, where the fuel consumption data for the years 2008-2010 was available, we applied the A1 calculation approach (CDM EB63, Annex 19, formula 2). These are all power plants listed in Annex I, Table 8, besides those listed Table 3 above).

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \ x \ NCV_{i,y} \ x \ EF_{CO2,i,y}}{EG_{m,y}}$$

Where:

$EF_{EL,m,y}$	CO_2 emission factor of power unit *m* in year *y* (tCO_2/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* (GJ/mass or volume unit)
$EF_{CO2,i,y}$	CO2 emission factor of fossil fuel type *i* in year *y* (tCO2/GJ)
$EG_{,m,y}$	Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)
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

For those power plants, where the fuel consumption data was not available (listed in Tabl3 above), the A2 calculation approach was applied (CDM EB63, Annex 19, formula 2):

$$EF_{EL,m,y} = \frac{EF_{CO2,m,i,y} x\ 3.6}{\eta_{m,y}}$$

Where:

$EF_{EL,m,y}$	CO_2 emission factor of power unit *m* in year *y* (tCO_2/MWh)
$EF_{CO2,m,i,y}$	Average CO_2 emission factor of fuel type *i* used in power unit *m* in year *y* (tCO_2/GJ)
$\eta_{m,y}$	Average net energy conversion efficiency of power unit *m* in year *y* (ratio)
m	All power units serving the grid in year *y* except low-cost/must-run power units
y	Most recent historical year for which power generation data is available

Table 4: SAPP Simple Operating Margin Data

No.	Name of Power Plant	2008		2009		2010	
		Net Electricity Generation	CO2 Emission Factor	Net Electricity Generation	CO2 Emission Factor	Net Electricity Generation	CO2 Emission Factor
		MWh	t-CO_2/MWh	MWh	t-CO_2/MWh	MWh	t-CO_2/MWh
1	ESKOM - Acacia	0	0.0000	0	0.0000	992	0.6702
2	ESKOM - Ankerlig	38,951	0.6702	10,842	0.6702	129,395	0.6702
3	ESKOM - Arnot	11,987,281	0.9726	13,227,864	0.9726	12,194,878	0.9726
4	ESKOM - Camden	6,509,079	0.8448	7,472,070	1.1582	7,490,836	1.0760
6	ESKOM - Duvha	21,769,489	0.9026	22,581,228	0.9007	20,267,508	0.9683
8	ESKOM - Gourikwa	47,806	0.3258	15,145	0.3366	65,527	0.3366
9	ESKOM - Grootvlei	1,249,556	0.8808	2,656,230	0.9444	3,546,952	1.1586
10	ESKOM - Hendrina	12,296,687	1.0315	12,143,292	0.9970	11,938,206	1.1187
11	ESKOM - Kendal	23,841,401	0.9897	23,307,031	0.9763	25,648,258	0.9607
13	ESKOM - Komati	0	0.0000	1,016,023	1.1356	2,060,141	1.1774
14	ESKOM - Kriel	18,156,686	0.8936	15,906,816	0.9841	18,204,910	0.9754
15	ESKOM - Lethabo	23,580,232	0.8534	25,522,698	0.8678	25,500,366	0.9288
16	ESKOM - Majuba	22,678,924	0.9519	22,340,081	0.9670	24,632,585	0.9830
17	ESKOM - Matimba	26,256,068	0.8885	27,964,141	0.7984	28,163,040	0.8265
18	ESKOM - Matla	21,863,400	0.8851	21,954,536	0.9051	21,504,422	0.9891
20	ESKOM - Port Rex	0	0.0000	0	0.0000	5,507	0.6702
21	ESKOM - Tutuka	21,504,122	0.9078	19,847,894	0.9458	19,067,501	0.9766
23	BPC - Morupule A	566,948	0.8084	432,339	0.8504	412,839	0.8234
24	BPC - Matshelagabedi	0	0.8566	0	0.6702	1,680	0.6702
26	NAMPOWER van Eck	146,476	0.9029	82,842	0.9029	20,616	0.9029
27	NAMPOWER - Paratus	4,603	0.8190	2,760	0.8190	4,493	0.8190
43	SEB - Edwaleni D6	10	0.6970	23	0.6970	9	0.6970
44	SEB - Edwaleni D7	10	0.6970	23	0.6970	30	0.6970
50	ZESA - Harare	36,000	1.2648	14,000	1.8344	0	0.0000
51	ZESA - Munyati	3,600	0.8361	0	0.0000	79,500	1.1769
52	ZESA - Bulawayo	22,000	1.2241	0	0.0000	0	0.0000
53	ZESA - Hwange	1,892,000	0.5673	1,741,000	0.6185	2,885,000	0.5809
Annual Electricity Generation in Total		214,451,328		218,238,877		223,825,191	

Based on above calculation, the OM was determined. The findings are presented in Table 5 below.

Table 5: Calculation of the Simple OM	
2008 Electricity Generation (in MWh)	214,451,328
$EF_{grid,OMsimple,2008}$ (in tCO2)	0.9145
2009 Electricity Generation (in MWh)	218,238,877
$EF_{grid,\ OMsimple,\ 2009}$ (in tCO2)	0.9270
2010 Electricity Generation (in MWh)	223,825,191
$EF_{grid,\ OMsimple,\ 2010}$	0.9612
Operating Margin Emission Factor(t-CO_2/MWh)	**0.9346**

Conservativeness. The conservativeness of the calculation was ensured by:

- Using the most accurate data (i.e. measured data) when ever feasible,
- Using published data for ESKOM power plants, where available (I.e. power generation, fuel consumption, NCVs and EFs)
- For some power plants, IPCC default values for NCVs and EFs were applied. The lower value of the 95% confidence interval was applied instead of the mean value.
- Comparing the IPCC default values (i.e. NCV and EF) for specific power plants with those values, measured by Zhou et al. 2009[4] and applying the lower IPCC values.

STEP 5. Identify the Group of Power Units to be Included in the BM

Following CDM EB63, Annex 19, Step 5, §a-§f, the sample group of power units m used to calculate the build margin consists of either:

- The set of five power units that have been built most recently; or
- The set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.

Following the guidance of the tool, this analysis was conducted for the most recent year (i.e. 2010). The last five power plants generate 815,362 MWh (2.9% of total generation). The set which comprises the last 20% of the system generation covers 9 power plants. These 9 plants generate 80,205, 141 MWh in 2010 (27.96% of total generation). Therefore the latter option shall be applied, as it

[4] Please refer to Peter P. ZHOU, Francis D. YAMBA, Philip LLOYD, Lovemore NYAHUMA, Cornelius MZEZEWA, Frederick KIPONDYA, John KEIR, Joe ASAMOAH and Henry SIMONSEN, 2009, Determination of Regional Emission Factors for the Power Sector in Southern Africa, Journal of Energy in Southern Africa, Vol 20. No 4.

encompasses the set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.

Following this approach results in a BM which comprises nine facilities commissioned between 2010 and 1987. Matimba in RSA is the power plant on the margin[5]. Without Matimba, the BM group would generate only 18.14% of the total 2010 generation. Including Matimba increases the generation share to 27.95%. Following the stipulations of the Tool, Matimba has to be included. Calculating the BM emission factor results in a value of 0.9007 tCO2/MWh. Details may be found in Table 6.

According to information gathered from the SAPP CC and the power plants, there is no power plant which is a) already commissioned b) developed under the CDM and c) supplies electricity to the grid. Hence, the analysis of the BM is constrained to those power plants which comprise the last 20% of system generation.

Step 6. Calculate the Build Margin Emission Factor

According to the tool, the build margin emissions factor is the generation-weighted average emission factor (tCO2/MWh) of all power units m identified in step 5 above. To calculate the BM, the following formula was applied (CDM EB63, Annex 19, formula 12):

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} x\, EF_{EL,m,y}}{\sum_m EG_{m,y}}$$

Where:

$EF_{grid,BM,y}$	Build margin CO_2 emission factor in year y (tCO_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 (tCO_2/MWh)
m	Power units included in the build margin
y	Most recent historical year for which power generation data is available

5 On the margin indicates that Matimba is the power plant for which the 20% threshold is reached and bypassed.

Following this approach leads to the determination of the BM emission level for 2010. The results are presented in Table 6.

Table 6: Calculation of the SAPP Build Margin for 2010

Build Margin Group Option		(b)The set of power capacity additions in the electricity system that comprise 20% of the system generation (in MWh) and that have been built most recently.				
No.	Name of power plant	Year commissioned	Fuel Type Energy Source	Net Electricity Generation (MWh/yr)	Emission Factor tCO_2/MWh	Emissions (tCO_2)
24	BPC - Matshelagabedi	2010	Gas/Diesel Oil	1,680	0.6702	1,126
8	ESKOM - Gourikwa	2007	Natural Gas	65,527	0.3366	22,056
2	ESKOM - Ankerlig	2007	Gas/Diesel Oil	129,395	0.6702	86,715
41	SEB - Maguga	2006	Hydro	123,697	0.0000	0
25	LEC - Muela	1999	Hydro	495,063	0.0000	0
16	ESKOM - Majuba	1996	Sub-Bituminous Coal	24,632,585	0.9830	24,213,805
19	ESKOM - Palmiet	1988	Hydro	945,896	0.0000	0
11	ESKOM - Kendal	1988	Sub-Bituminous Coal	25,648,258	0.9607	24,639,723
17	ESKOM - Matimba	1987	Sub-Bituminous Coal	28,163,040	0.8265	23,277,813
Total				**80,205,141**		**72,241,238**
Build Margin Emission Factor ($t\text{-}CO_2/MWh$)						**0.9007**

Conservativeness. The conservativeness of the calculation was ensured by:

- Using the most accurate data (i.e. measured data) when ever feasible,
- Using published data for ESKOM power plants, where available (I.e. power generation, fuel consumption, NCVs and EFs)
- For some power plants, IPCC default values for NCVs and EFs were applied. The lower value of the 95% confidence interval was applied instead of the mean value.

STEP 7. Calculate the Combined Margin Emissions Factor

Based on standard weighting of the BM and the OM, the SAPP region offers a GEF of 0.9216 tCO2/MWh. Details are found in Table 7. Guidance on the selection of alternative weights can be found in the tool (CDM EB63, Annex 19, page 18f).

Table 7: Summary of the Regional SAPP GEF			
OM Emission Factor (in t-CO_2/MWh)	**0.9346**		
BM Emission Factor (in t-CO_2/MWh)	**0.9007**		
	Weight of the OM	Weight of the BM	CM Emission Factor (in t-CO2/MWh)
Wind and solar power generation project activities for the first crediting period and for subsequent crediting periods	0.75	0.25	**0.9261**
All other projects for the first crediting period	0.5	0.5	**0.9176**
All other projects for the second and third crediting period	0.25	0.75	**0.9092**

Annex I. Fuel Consumption and Electricity Generation Data

Table 8: SAPP Electricity Generation and Fuel Consuption										
No.	Name of Power Plant	Date Installed	Installed Capacity (MW)	Net Electricity Generation (MWh)			Fuel Consumption (t/year)			Fuel Type/ Energy Source
		Year		2008	2009	2010	2008	2009	2010	
1	Eskom - Acacia	1976	171	0	0	992			444,957	Gas/Diesel Oil
2	Eskom - Ankerlig	2007	1,338	38,951	10,842	129,395				Gas/Diesel Oil
3	Eskom - Arnot	1971	2,352	11,987,281	13,227,864	12,194,878	6,395,805	6,794,134	6,525,670	Sub-Bituminous Coal
4	Eskom - Camden	1966	1,520	6,509,079	7,472,070	7,490,836	3,286,211	4,732,163	4,269,763	Sub-Bituminous Coal
5	Eskom - Drakensberg	1981	1,000	1,913,923	1,761,460	2,006,662				Hydro
6	Eskom - Duvha	1980	3,600	21,769,489	22,581,228	20,267,508	11,393,553	11,744,606	10,639,393	Sub-Bituminous Coal
7	Eskom - Gariep	1971	360	527,454	575,927	1,035,727				Hydro
8	Eskom - Gourikwa	2007	746	47,806	15,145	65,527				Natural Gas
9	Eskom - Grootvlei	1969	1,200	1,249,556	2,656,230	3,546,952	674,538	1,637,371	2,132,979	Sub-Bituminous Coal
10	Eskom - Hendrina	1970	1,965	12,296,687	12,143,292	11,938,206	7,122,918	6,905,917	7,139,198	Sub-Bituminous Coal
11	Eskom - Kendal	1988	4,116	23,841,401	23,307,031	25,648,258	15,356,595	13,866,514	15,174,501	Sub-Bituminous Coal
12	Eskom - Koeberg	1984	1,930	13,003,730	12,806,426	12,098,673				Nuclear
13	Eskom - Komati	1966	940		1,016,023	2,060,141		664,497	1,271,010	Sub-Bituminous Coal
14	Eskom - Kriel	1976	3,000	18,156,686	15,906,816	18,204,910	9,420,764	8,504,715	9,527,185	Sub-Bituminous Coal
15	Eskom - Lethabo	1985	3,708	23,580,232	25,522,698	25,500,366	16,715,323	18,170,227	17,774,699	Sub-Bituminous Coal
16	Eskom - Majuba	1996	4,110	22,678,924	22,340,081	24,632,585	12,554,406	12,261,833	13,020,512	Sub-Bituminous Coal
17	Eskom - Matimba	1987	3,990	26,256,068	27,964,141	28,163,040	13,991,453	14,637,481	14,596,842	Sub-Bituminous Coal

18	Eskom - Matla	1979	3,600	21,863,400	21,954,536	21,504,422	12,689,387	12,438,391	12,151,421	Sub-Bituminous Coal
19	Eskom - Palmiet	1988	400	858,479	980,436	945,896				Hydro
20	Eskom - Port Rex	1976	171			5,507			281,941	Gas/Diesel Oil
21	Eskom - Tutuka	1985	3,654	21,504,122	19,847,894	19,067,501	11,231,583	10,602,839	10,191,709	Sub-Bituminous Coal
22	Eskom - Vanderkloof	1975	240	554,225	697,978	924,428				Hydro
23	BPC - Morupule A	1985	132	566,948	440,139	412,839	429,478	344,516	318,514	Sub-Bituminous Coal
24	BPC - Matshelagabedi	2010	70	0	0	1,680				Gas/Diesel Oil
25	LEC - Muela	1999	72	499,624	503,469	495,063				Hydro
26	NamPower - van Eck	1979	120	146,476	82,842	20,616				Sub-Bituminous Coal
27	NamPower - Paratus	1976	24	4,603	2,760	4,493				Gas/Diesel Oil
28	NamPower - Ruacana	1980	249	1,265,600	1,397,930	1,312,069				Hydro
29	ZESCO - Kariba North	1976	990	3,271,966	4,151,856	2,766,570				Hydro
30	ZESCO - Kafue Gorge	1968	530	5,310,815	4,848,388	6,787,930				Hydro
31	ZESCO - Victoria Falls	1950	108	731,191	742,394	722,425	-	-	-	Hydro
32	ZESCO - Mulungushi	1955	47	286,078	303,224	329,224	-	-	-	Hydro
33	ZESCO - Mini-hydro	1963	12	59,708	88,992	93,690				Hydro
34	SEB - Ezulwini	1985	20	51,342	75,757	77,231				Hydro
35	SEB - Edwaleni I	1964	2,5	12,004	6,083	15,725				Hydro
36	SEB - Edwaleni II	1964	2,5	9,709	13,557	14,327				Hydro
37	SEB - Edwaleni III	1964	2,5	10,338	13,638	15,209				Hydro
38	SEB - Edwaleni IV	1965	2,5	11,912	14,262	15,714				Hydro
39	SEB - Edwaleni V	1969	5	31,327	33,199	35,052				Hydro
40	SEB - Mbane Hydro	1954	0,.5	1,673	1,338	682				Hydro

41	SEB - Maguga	2006	20	85,100	108,127	123,697				Hydro
42	SEB - Maguduza	1969	5,6	32,713	22,822	36,342				Hydro
43	SEB - Edwaleni D6	1968	4,5	10	23	9	3	10	3	Gas/Diesel Oil
44	SEB - Edwaleni D7	1970	4,5	10	23	30	3	10	8	Gas/Diesel Oil
45	EdM - Corumana	1975	12	12,131	50,287	37,497				Hydro
46	EdM - Chicamba	1975	50	10,643,400	10,643,400	10,643,400				Hydro
47	EdM - Mavuzi	1975	50	0	597,862	766,180				Hydro
48	EdM - HCB	1977	2,075	325,811	321,292	316,938				Hydro
49	ZESA - Kariba South	1954	750	5,713,000	5,464,000	5,806,000				Hydro
50	ZESA - Harare	1960	135	36,000	14,000	0	25,565	14,419	0	Other Bituminous Coal
51	ZESA - Munyati	1960	120	3,600	0	79,500	1,690	0	52,531	Other Bituminous Coal
52	ZESA - Bulawayo	1960	120	22,000	0	0	15,120	0	0	Other Bituminous Coal
53	ZESA - Hwange	1983	780	1,892,000	1,741,000	2,885,000	1,005,730	1,009,033	1,570,454	Sub-Bituminous Coal
54	SNEL - Inga I	1974	351	2,207,520	2,207,520	2,207,520				Hydro
55	SNEL - Inga II	1982	1,424	8,731,968	8,731,968	8,731,968				Hydro
56	SNEL - Koni	1950	42	257,544	257,544	257,544				Hydro
57	SNEL - Nseke	1956	248	1,520,736	1,520,736	1,520,736				Hydro
58	SNEL - Nzilo	1952	108	662,256	662,256	662,256				Hydro
59	SNEL - Mwadingusha	1930	63	416,976	416,976	416,976				Hydro
60	SNEL - Zongo	1965	75	459,900	459,900	459,900				Hydro
61	SNEL - Ruzizi 1	1972	29,8	49,056	49,056	49,056				Hydro
62	SNEL - Inga-Kolwezi	1982	260	1,594,320	1,594,320	1,594,320				Hydro

Annex II. Default Efficiency Factors for Power Plants

Table 9: Default Efficiency Factors for Grid-Connected Power Plants			
Generation Technology		Old units (before and in 2000)	New units (after 2000)
Coal	Subcritical	37%	39%
	Supercritical	-	45%
	Ultra-upercritical	-	50%
	IGCC	-	50%
	FBS	35,50%	-
	CFBS	36,50%	40%
	PFBS	-	41,50%
Oil	Steam turbine	37,50%	39%
	Open cycle	30%	39,50%
	Combined cycle	46%	46%
Naural gas	Steam turbine	37,50%	37,50%
	Open cycle	30%	39,50%
	Combined cycle	46%	60%
CDM EB50, Annex 14, page 25			

Annex III. Default NCVs, Upper and Lower Limits

Table 10: Default NCVs, Lower and Upper Limits				
Fuel type Description		Net calorific value (TJ/Gg)	Lower	Upper
	Crude Oil	42.3	40.1	44.8
	Orimulsion	27.5	27.5	28.3
	Natural Gas Liquids	44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
	Jet Kerosene	44.1	42	45
	Other Kerosene	43.8	42.4	45.2
	Shale Oil	38.1	32.1	45.2

	Gas/Diesel Oil	43	41.4	43.3
	Residual Fuel Oil	40.4	39.8	41.7
	Liquefied Petroleum Gases	47.3	44.8	52.2
	Ethane	46.4	44.9	48.8
	Naphtha	44.5	41.8	46.5
	Bitumen	40.2	33.5	41.2
	Lubricants	40.2	33.5	42.3
	Petroleum Coke	32.5	29.7	41.9
	Refinery Feedstocks	43	36.3	46.4
Other Oil	Refinery Gas	49.5	47.5	50.6
	Paraffin Waxes	40.2	33.7	48.2
	White Spirit and SBP	40.2	33.7	48.2
	Other Petroleum Products	40.2	33.7	48.2
	Anthracite	26.7	21.6	32.2
	Coking Coal	28.2	24	31
	Other Bituminous Coal	25.8	19.9	30.5
	Sub-Bituminous Coal	18.9	11.5	26
	Lignite	11.9	5.5	21.6
	Oil Shale and Tar Sands	8.9	7.1	11.1
	Brown Coal Briquettes	20.7	15.1	32
	Patent Fuel	20.7	15.1	32
Coke	Coke Oven Coke and Lignite Coke	28.2	25.1	30.2
	Gas Coke	28.2	25.1	30.2
	Coal Tar	28	14.1	55
Derived Gases	Gas Works Gas	38.7	19.6	77
	Coke Oven Gas	38.7	19.6	77
	Blast Furnace Gas	2.47	1.2	5
	Oxygen Steel Furnace Gas	7.06	3.8	15
	Natural Gas	48	46.5	50.4
	Municipal Wastes (non-biomass fraction)	10	7	18
	Industrial Wastes	NA	NA	NA
	Waste Oil	40.2	20.3	80
Solid	Peat	9.76	7.8	12.5
	Wood/Wood Waste	15.6	7.9	31

Biofuels	Sulphite lyes (black liquor)	11.8	5.9	23
	Other Primary Solid Biomass	11.6	5.9	23
	Charcoal	29.5	14.9	58
Liquid Biofuels	Biogasoline	27	13.6	54
	Biodiesels	27	13.6	54
	Other Liquid Biofuels	27.4	13.8	54
GasBiomass	Landfill Gas	50.4	25.4	100
	Sludge Gas	50.4	25.4	100
	Other Biogas	50.4	25.4	100
Other non-fossil fuels	Municipal Wastes (biomass fraction)	11.6	6.8	18

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, page 1.18

Notes: 1 The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5.
2 Japanese data; uncertainty range: expert judgement
3 EFDB; uncertainty range: expert judgement
4 Coke Oven Gas; uncertainty range: expert judgement
5-7Japan and UK small number data; uncertainty range: expert judgement
8 For waste oils the values of Lubricants" are taken
9 EFDB; uncertainty range: expert judgement
10 Japanese data ; uncertainty range: expert judgement
11 Solid Biomass; uncertainty range: expert judgement
12 EFDB; uncertainty range: expert judgement
13-14Ethanol theoretical number; uncertainty range: expert judgement;
15 Liquid Biomass; uncertainty range: expert judgement
16 -18Methane theoretical number uncertainty range: expert judgement; "

Annex IV. Default CO2 Emission Factors for Combustion

Table 11: Default CO2 Emission Factors for Combustion						
Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO2 emission factor (kg/TJ) 2		
				Default value 3	95% confidence interval	
		A	B	C=A*B*44/ 12*1000	Lower	Upper
	Crude Oil	20	1	73,300	71,100	75,500
	Orimulsion	21	1	77,000	69,300	85,400
	Natural Gas Liquids	17.5	1	64,200	58,300	70,400
Gasoline	Motor Gasoline	18.9	1	69,300	67,500	73,000
	Aviation Gasoline	19.1	1	70,000	67,500	73,000
	Jet Gasoline	19.1	1	70,000	67,500	73,000
	Jet Kerosene	19.5	1	71,500	69,700	74,400
	Other Kerosene	19.6	1	71,900	70,800	73,700
	Shale Oil	20	1	73,300	67,800	79,200
	Gas/Diesel Oil	20.2	1	74,100	72,600	74,800
	Residual Fuel Oil	21.1	1	77,400	75,500	78,800
	Liquefied Petroleum Gases	17.2	1	63,100	61,600	65,600
	Ethane	16.8	1	61,600	56,500	68,600
	Naphtha	20	1	73,300	69,300	76,300
	Bitumen	22	1	80,700	73,000	89,900
	Lubricants	20	1	73,300	71,900	75,200
	Petroleum Coke	26.6	1	97,500	82,900	115,000
	Refinery Feedstocks	20	1	73,300	68,900	76,600
Other Oil	Refinery Gas	15.7	1	57,600	48,200	69,000
	Paraffin Waxes	20	1	73,300	72,200	74,400
	White Spirit & SBP	20	1	73,300	72,200	74,400
	Other Petroleum Products	20	1	73,300	72,200	74,400
	Anthracite	26.8	1	98,300	94,600	101,000
	Coking Coal	25.8	1	94,600	87,300	101,000
	Other Bituminous Coal	25.8	1	94,600	89,500	99,700
	Sub-Bituminous Coal	26.2	1	96,100	92,800	100,000
	Lignite	27.6	1	101,000	90,900	115,000

	Oil Shale and Tar Sands	29.1	1	107,000	90,200	125,000
	Brown Coal Briquettes	26.6	1	97,500	87,300	109,000
	Patent Fuel	26.6	1	97,500	87,300	109,000
Coke	Coke oven coke and lignite Coke	29.2	1	107,000	95,700	119,000
	Gas Coke	29.2	1	107,000	95,700	119,000
	Coal Tar	22	1	80,700	68,200	95,300
Derived Gases	Gas Works Gas	12.1	1	44,400	37,300	54,100
	Coke Oven Gas	12.1	1	44,400	37,300	54,100
	Blast Furnace Gas	70.8	1	260,000	219,000	308,000
	Oxygen Steel Furnace Gas	49.6	1	182,000	145,000	202,000
	Natural Gas	15.3	1	56,100	54,300	58,300
	Municipal Wastes (non-biomass fraction)	25	1	91,700	73,300	121,000
	Industrial Wastes	39	1	143,000	110,000	183,000
	Waste Oil	20	1	73,300	72,200	74,400
Solid Biofuels	Peat	28.9	1	106,000	100,000	108,000
	Wood/Wood Waste	30.5	1	112,000	95,000	132,000
	Sulphite lyes (black liquor)	26	1	95,300	80,700	110,000
	Other Primary Solid Biomass	27.3	1	100,000	84,700	117,000
	Charcoal	30.5	1	112,000	95,000	132,000
Liquid Biofuels	Biogasoline	19.3	1	70,800	59,800	84,300
	Biodiesels	19.3	1	70,800	59,800	84,300
	Other Liquid Biofuels	21.7	1	79,600	67,100	95,300
Gas biomass	Landfill Gas	14.9	1	54,600	46,200	66,000
	Sludge Gas	14.9	1	54,600	46,200	66,000
	Other Biogas	14.9	1	54,600	46,200	66,000
Other non-fossil fuels	Municipal Wastes (biomass fraction)	27.3	1	100,000	84,700	117,000

Source: 2006 IPCC Guidelines for National Greenhouse Gas Inventories, page 1.23
Notes: 1 The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5, 2 TJ = 1000GJ
3 The emission factor values for BFG includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas.
4 The emission factor values for OSF includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas
5 Includes the biomass-derived CO_2 emitted from the black liquor combustion unit and the biomass-derived CO_2 emitted from the kraft mill lime kiln.