CLIMATEFOCUS

Ugandan Grid Emission Factor (GEF) 2013

Version 1.0

Funded by:

BTC BELGIAN DEVELOPMENT AGENCY

Cover photo: Switchyard of Bujagali Hydropower Plant, Jinja, Uganda. Bamshad Houshyani 2012

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Content

Acronyms

BM	Build Margin
CDM	Clean Development Mechanism
CM	Combined Margin
DNA	Designated National Authority
EF	Emission Factor
EG	Electricity Generated
ERA	Electricity Regulatory Authority
GEF	Grid Emission Factor
GEFCW	Grid Emission Factor Calculation Workgroup
IPCC	Intergovernmental Panel on Climate Change
kV	Kilo Volts
MW	Mega Watt
OM	Operating Margin
UETCL	Uganda Electricity Transmission Company Limited
UNFCCC	United Nations Framework Convention on Climate Change

1 Introduction

A grid emission factor (GEF) is the total amount of greenhouse gas emissions emitted for each unit of electricity generation by power plants in a country. It is commonly expressed in tons of carbon dioxide per megawatt hour electricity (tCO_2eq/MWh) and is a fundamental parameter used to calculate emissions reductions from grid-connected power plants and energy efficiency or energy saving projects of certain project types under the Clean Development Mechanism (CDM) or other carbon schemes.

Renewable energy and energy efficiency CDM projects benefit greatly from the availability of a national GEF that is centrally calculated and maintained: this avoids the need for individual project developers to obtain relevant data and perform complex calculations, and speeds up CDM project development, registration and issuance.

The Belgian Development Agency (BTC) is assisting the Government of Uganda (GoU) with its CDM Capacity Development Project through a grant to facilitate identification, development and implementation of CDM projects and/or CDM Programme of Activities (PoAs) that will enhance the sustainability of economic development in the country. In order to enable Uganda to benefit from the CDM, strengthen technical capacity on CDM project formulation and create awareness of investment opportunities under the CDM, BTC has contracted Climate Focus to calculate the latest GEF for Uganda and carry out capacity building and training for the relevant Ugandan entities to enable them to calculate and update the GEF when necessary. In future, the GEF Calculation Workgroup (GEFCW) will update the Ugandan GEF on an annual basis. The GEFCW is composed of the Climate Change Unit, acting as the Designated National Authority (DNA) Secretariat of Uganda under the Ministry of Water and Environment, working in collaboration with Ugandan authorities. By doing so, project participants will save time and avoid transaction costs related to calculating the GEF on a per-project basis.

This report and accompanying Uganda GEF Tool provide an updated Ugandan GEF, based on 2010-2012 power generation data, and has used the UNFCCC's Methodological Tool 07 *"Tool to calculate the emission factor for an electricity system"* (version 3.0.0)[1]. This updated GEF can be used for projects developed in 2013 and should be updated in 2014 by the GEFCW. A manual is being developed which will provide guidance on how to update the Ugandan GEF.

[1] Available online on the UNFCCC Tools page: http://cdm.unfccc.int/Reference/tools/index.html

2 Methodology

According to the *"Tool to calculate the emission factor for an electricity system"* (version 3.0.0), calculating the GEF is carried out through a six step process as follows:

Step 1: Identifying the relevant electricity systems;
Step 2: Choose whether to include off-grid power plants in the project electricity system;
Step 3: Select a method to determine the operating margin (OM);
Step 4: Calculate the operating margin emission factor according to the selected method;
Step 5: Calculate the build margin (BM) emission factor;
Step 6: Calculating the combined margin (CM) emission factor.

2.1 Step 1: Identifying the relevant electricity systems

The Ugandan DNA has not defined a project electricity system, therefore the relevant electricity system is defined according to the information provided by the Uganda Electricity Transmission Company Limited (UETCL), illustrated in Figure 1.

Project/Grid electricity system

Project or grid electricity system by definition is the spatial extent of the power plants that are physically connected through transmission and distribution lines to the project activity (e.g. the renewable power plant location or the consumers where electricity is being saved) and that can be dispatched without significant transmission constraints. The Uganda Electricity Transmission Company (UETCL) confirmed that Uganda has only one grid electricity system and that there are no transmission constraints within the grid.

Connected electricity systems

By definition according to the tool the connected electricity system is an electricity system that is connected by transmission lines to the grid electricity system. Power plants within the connected electricity system can be dispatched without significant transmission constraints but transmission to the grid electricity system has significant transmission constraint, and/or 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 grid electricity system or of the connected electricity system, whichever is smaller. UETCL confirmed that there is no connected electricity system in Uganda (see Figure 1). This was also confirmed through the interviews with the Ministry of Energy and Electricity Regulatory Authority (ERA).

International interconnection and import/export

UETCL confirmed that other than the 132 kV transmission line that is used for very limited occasional import/export from/to Kenya (1.0-1.5% of Uganda's total annual generation, see Table 1), there is no other so called international interconnection between Uganda and other neighbouring countries where the Ugandan grid can cover national grids of interconnected countries. What exists in Uganda's borders with Rwanda, Tanzania and Congo is 132 kV and 33 kV connection lines through which limited exports/imports occurs to areas in Uganda and the neighbouring countries that are not grid connected. These power transmission lines are not covering national grid network of the neighbouring countries, neither are controlled through power dispatch of one another. Hence, the connected electricity system in Uganda remains as the Ugandan national grid presented in Figure 1.

Uganda's 132 kV line is extended to Kenya in the east through Tororo, which is used for limited power export and import to and from Kenya, considered as the only international interconnected transmission line in Uganda. Uganda's 132 kV line in the south extends towards Bukoba in Tanzania for the purpose of power export but the extension in Tanzania is not connected to Tanzania's national grid. Uganda also exports limited amount of electricity to Rwanda using a 33 kV line at Katuna and imports power from Rwanda using a 33 kV line at Kyanika. UETCL is exporting power to Société nationale d'électricité (SNEL) of Congo (DRC) as well.

See Table 1 for the summary of import/export to/from Uganda for 2010, 2011 and 2012.

Table 1: Summary of electricity Import and Export to/from Uganda 2010-2012

Import / Export	2010	2011	2012
Import from Kenya (GWh)	29.211	36.313	31.515
Import from Rwanda (GWh)	0.267	2.751	3.202
Export to Kenya (GWh)	29.236	32.162	37.944
Export to Rwanda (GWh)	0.103	3.31	1.834
Export to Tanzania (GWh)	45.269	50.939	57.751
Export to Congo (GWh)	0	1.603	2.448
Total Import (GWh)	29.478	39.064	34.717
Total export (GWh)	74.608	86.411	97.529
Total grid generation (GWh)	2,456	2,556	2,829
Percentage of import | export from total annual generation	**1.2% | 3%**	**1.5% | 3.3%**	**1.2% | 3.4%**

Currently, electricity trade between Kenya and Uganda, and Tanzania and Uganda, is very limited (Table 1). The net electricity import to Uganda is accounted for in the GEF calculations for the 2010-2012 period. This is done only for OM calculations as per paragraph 21 of the tool. The emission factor of the imported electricity is considered as zero based on option a under paragraph 21 of the tool. Electricity exports are not to be subtracted from the electricity generation data and require no further analysis for the purposes of GEF determination.

Ugandan grid system

The Ugandan power transmission network consists primarily of 132 kV lines to the various load centres where it is distributed further on the 11 kV and 33kV distribution network. The transmission backbone runs from Jinja, where the Nalubaale, Kiira and Bujagali hydropower plants are situated, to Kampala. Future plans call for a regional 220 kV network around Lake Victoria. The new Bujagali lines are expected to run at 220 kV by installing transformers at the main substations. The 132 kV network extends to Bukoba in neighbouring Tanzania in the south and to Kenya via Tororo in the east. There are lower capacity transmission lines of 33 kV with Rwanda and Congo (DRC) as well.

According to the International Energy Agency (IEA), the electrification rate in Uganda is 9%, with urban and rural electrification rates of 43% and 3% respectively[2].

Centrally dispatched power plants

The main sources of power generation in Uganda are three hydropower plants: Nalubaale (180MW), Kiira (200MW)) and Bujagali (250MW). There are also five mini-hydro plants with a collective installed capacity of 51.9 MW, and two biomass plants Kinyara (53.1 MW) and Kakira Sugar Works (14MW). In addition there are three thermal plants: Mutundwe (Aggreko, 50 MW) and Namanve (Jacobsen, 50 MW) and Tororo (86 MW). A fourth thermal power plant was included in the Operating Margin (OM) EF calculations: the Kiira (Aggreko) plant which was operational up until July 2011.

[2] IEA, World Energy Outlook 2012

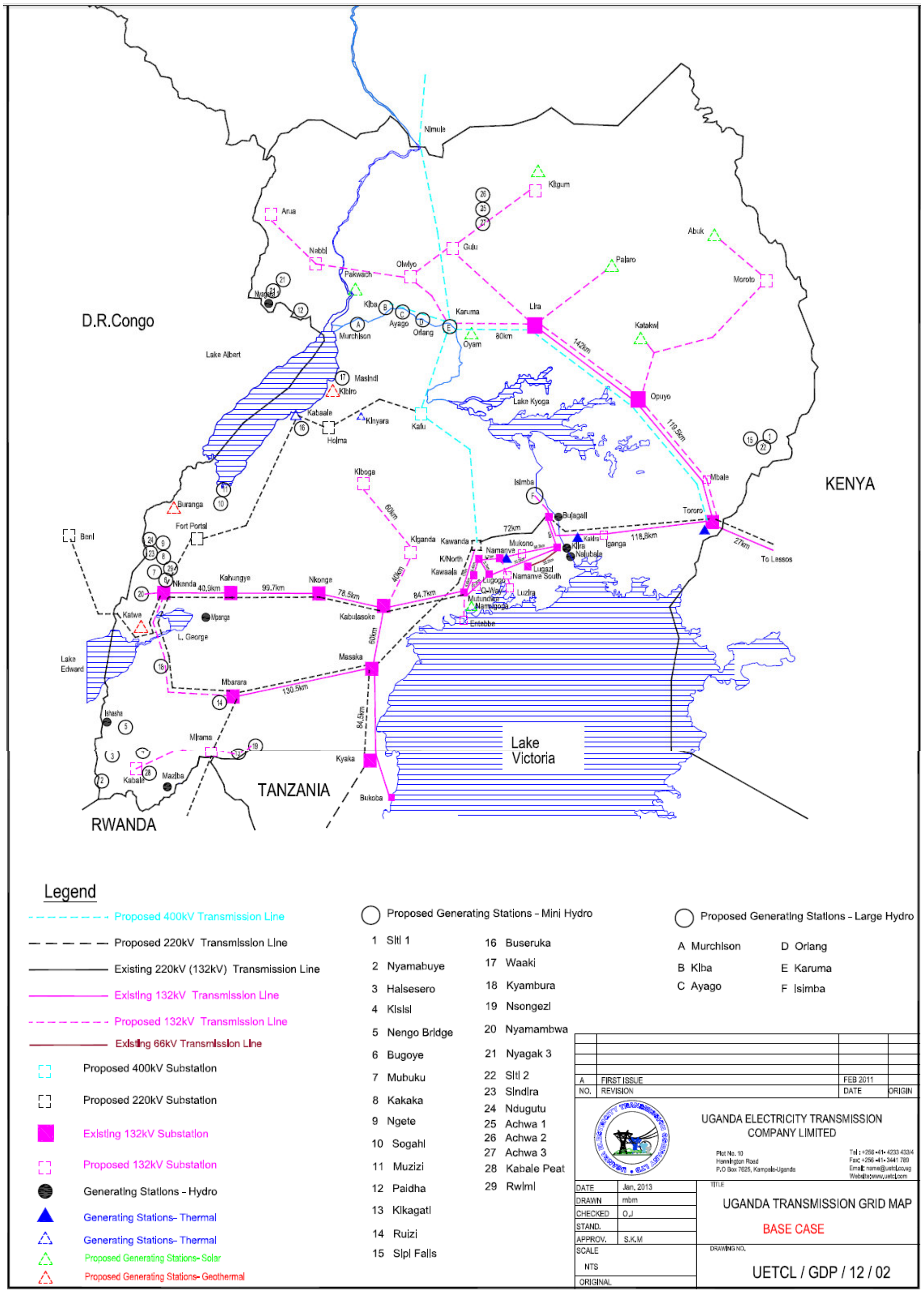

Figure 1: Relevant Uganda electricity systems

At the end of 2012 the grid-connected installed capacity in Uganda was 985 MW, consisting of hydroelectric, bagasse and thermal plants fuelled by diesel or heavy fuel oil. During the same year the total power generation was 2829 MWh. Figures 2 and 3 illustrate the contribution of each power source to the grid-connected energy mix in terms of installed capacity and power generation respectively.[3] It should be noted that from 2011 to 2012 the installed capacity increased by 250 MW (25%) when the Bujagali hydroelectric plant started operations.

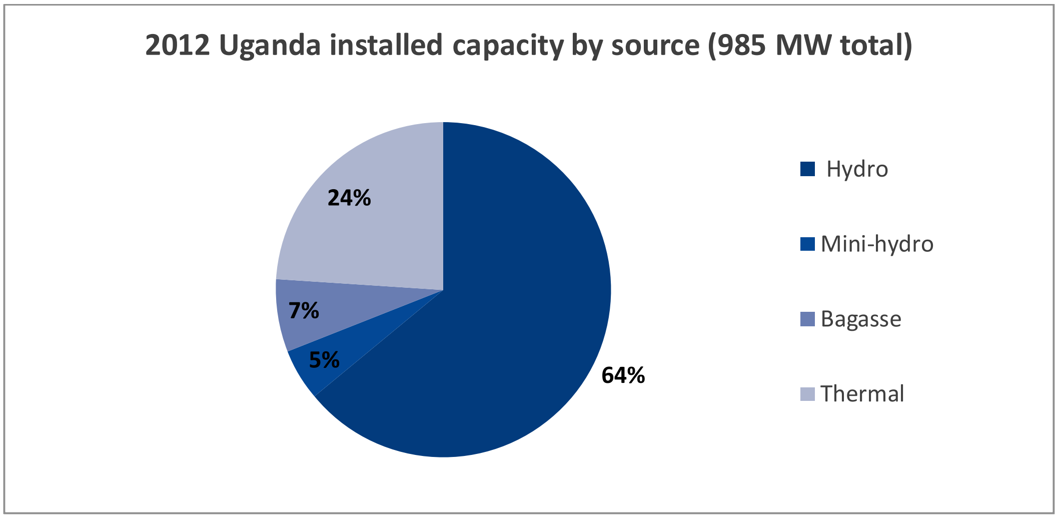

Figure 2: Installed capacity by source

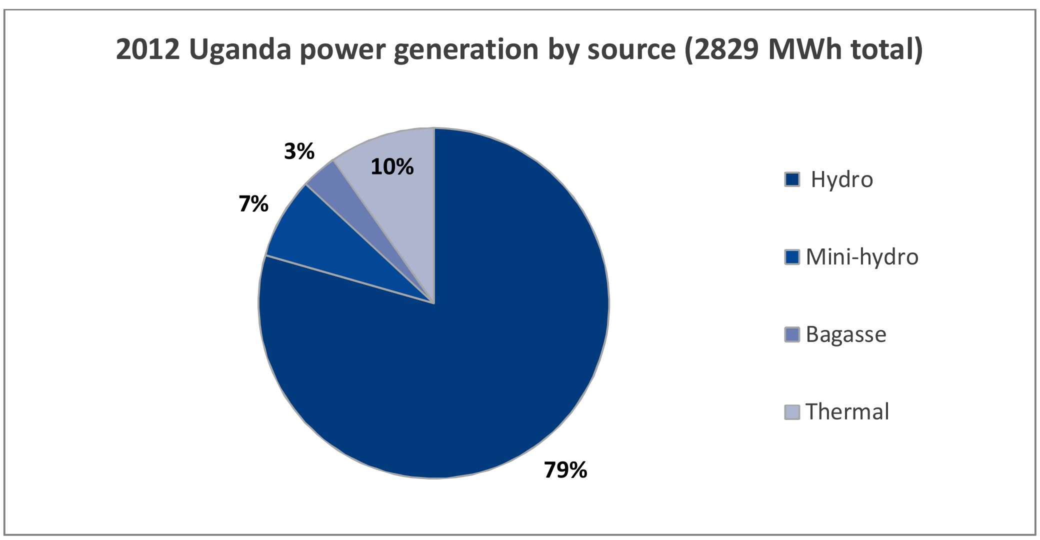

Figure 3: Power generation by source

[3] Statistics and data mentioned in this report are from the latest grid information retrieved from Uganda Electricity Transmission Company Limited (UETCL) and Electricity Regulatory Authority (ERA) between March-May 2013.

CDM Projects

Registered CDM projects need to be identified as they cannot be included in the calculation of the Build Margin Emissions Factor (BM EF). Table 2 lists the registered CDM projects that feed electricity into the national grid, and that therefore excluded from the BM EF calculation.

Table 2: Registered CDM projects in Uganda that feed electricity into the grid[4]

CDM Project	Project Type	Phase	UNFCCC Reference
Bugoye 13.0 MW run-of-river Hydropower project	Run of river	Registered	3017
Bujagali Hydropower Project	Run of river	Registered	4217
Buseruka Mini Hydro Power Plant	Run of river	Registered	5770
Ishasha 6.6 MW Small Hydropower Project	Run of river	Registered	6381

Annex 1 contains the Uganda's current power plant database and identifies each plant's operator, location, power source, number of units and unit rating, installed capacity and capacity additions, and annual net generation to UETCL for 2010-2013. In Uganda's case, low-cost/must-run resources are all hydropower and bagasse plants.

Based on the definition of a grid/project electricity system under paragraph 10 from the applied tool, and the elaborated information on Uganda's transmission grid, the grid extension presented in Figure 1 is considered as the grid/project electricity system for Uganda's GEF calculation.

2.2 Step 2: Choose whether to include off-grid power plants in the project electricity system

Project participants may choose between the two options to calculate the operating margin and build margin 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 methodology presents two options for the inclusion of off-grid power:

- Option IIa Option IIa requires collecting data on off-grid power generation as per appendix 2 and can only be used if the conditions outlined therein are met. Option IIa is not applicable due to lack of data availability; UETCL confirmed that they have no detail data availability on off-grid power plants;
- Option IIb, as an alternative approach, the default CO_2 emission factor and the default value of the electricity generated by the off-grid power plants can be applied for the first crediting period. This option can be used if the following conditions can be met:
    - The project activity is located in (i) a Least Developed Country (LDC); or (ii) a Small Island Developing States (SIDS) or in (iii) a country with less than 10 registered CDM projects at the starting date of validation; and

[4] UNEP Risoe CDM Pipeline Project Database, last updated May 2013, http://www.cdmpipeline.org/

- The project activities consist of grid-connected renewable power generation; and
- It can be demonstrated that there is a load shedding program in place to compensate the deficit of the generation capacities.

Uganda is a LDC and since the UETCL confirms that the grid has had a load-shedding program in place between 2010-2012, option IIb is included in the calculations for grid-connected renewable power generation.

Please note that the GEF tool prepared for the calculation of Ugandan grid emission factor leaves the options open to include or exclude the off-grid power plants in the emission factor calculation. The reason is that option IIb used for the inclusion of off-grid plants is applicable for grid connected renewable power generation only (e.g. grid connected hydropower, wind, solar etc.). Thus the tool does not consider the inclusion of off-grid power plants in the combined margin emission factor calculation if the project activity is not categorised as grid connected renewable power generation.

According to the tool, Option IIb can only be utilized to calculate the GEF for grid connected renewable energy projects for their first crediting period. For all other projects which are not grid connected renewable energy projects the GEF will not take into account off-grid power and will therefore always use Option I to calculate OM EF and BM EF.

Since the necessary conditions to use Option IIb are met, off-grid power plants are taken into account using the default emission factor and default estimate for off-grid power generation in Table 3, as described in the tool (articles 31-32 of the tool).

Table 3: Default estimate for off-grid power generation

	Emission factor (EF, tCO2/MWh)	Estimate for off-grid generation (EG, MWh)
OM	0.8	10% of total generation by grid power plants for the purposes of the OM determination
BM	0.8	10% of total generation by grid power plants in the sample group used to calculate BM EF

2.3 Step 3: Selecting an operating margin (OM) method

According to the methodology, the calculation of the operating margin emission factor ($EF_{grid,OM,y}$) should be based on one of the following methods:

(a) Simple OM,
(b) Simple adjusted OM,
(c) Dispatch data analysis OM,
(d) Average OM.

The Simple OM method can only be used if low-cost/must-run resources constitute less than 50% of total grid generation (excluding off-grid power plants) in the five most recent years (2008-2012). Low-cost/must-run resources are the power plants with low marginal generation cost, in Uganda's case they are the hydropower and bagasse plants. As illustrated in Table 5, during this period low-cost/must-run resources accounted for an average 68.5% of electricity generation, therefore the Simple OM method cannot be currently applied to calculating the GEF (see Table 4).

Table 4: List of low-cost/must-run resources in the grid

Nr.	Power Plant	Power Source	Total Capacity (MW)	Year of Commissioning	Net generation 2010 (GWh)	Net generation 2011 (GWh)	Net generation 2012 (GWh)
1	Kilembe Mines (Mubuku I)	Mini Hydro	5	1954	22	23	23
2	Nalubaale (Owen Falls)	Hydro	180	1954 - 1968	1255	1339	1275
3	Kiira (Owen Falls Extension) Power Station	Hydro	200	2003	With Nalubaale (Owen Falls)	With Nalubaale (Owen Falls)	With Nalubaale (Owen Falls)
4	Bugoye (Mubuku II)	Mini Hydro	13	2009	66	80	78
5	Kasese Cobalt (Mubuku III)	Mini Hydro	10.5	2009	3	4	5
6	Kakira Sugar Works	Bagasse	12	1994	80	58	85
7	Kinyara Sugar Works	Bagasse	18	1976	5	2	9
8	Mpanga Power Station	Mini Hydro	18	2011	0	70	79
9	Ishasha (Kanungu) Power Station	Mini Hydro	6.4	2011	0	23	28
10	Bujagali	Hydro	250	2012	0	0	972
11	Buseruka Power Station	Mini Hydro	9	2012	-	-	-

Table 5: Share of low-cost/must-run resources in the annual electricity production

	2008	2009	2010	2011	2012
Total gross generation (GWh)	2,042	2,251	2,456	2,556	2,829
Low cost/must run (GWh)	1,452	1,354	1,432	1,598	2,554
Share of Low cost/must run (%)	71.1%	60.2%	58.3%	62.5%	90.3%
Average share of LCMR plants in generation (%)			68.5%		

Option (c) "dispatch data analysis OM" requires dispatched data which is not available and is not included in the Tool.

This leaves (b) Simple adjusted OM, and (d) Average OM as the two options for calculating the OM Emission Factor. For the calculation of GEF simple adjusted OM (Option b) has been selected.

Two data vintages can be used in calculating: Ex-ante and Ex-post, both of which are captured in the Tool:

- *Ex-ante*: This is based on the 3-year generation-weighted average by using the most recent data available at the time of updating the OM EF. If the OM EF is calculated for submitting a project for validation, there will be no need for monitoring and recalculating the emission factor during the crediting period.
- *Ex-post*: The EF will have to be updated for the year in which the power plant displaces grid electricity. This emission factor should be updated annually for the rest of the crediting period during the monitoring.

For the calculation of GEF, option (b) Simple adjusted OM based on ex-ante data is applied.

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

For option (b) Simple adjusted OM Option A (Article 41 in the tool) is used to calculate the OM emission factor based on the net electricity generation of each power plant and an emission factor for each power plant.

Simple adjusted OM

The simple adjusted OM emission factor is calculated as the CO_2 emissions per unit net electricity generation (tCO_2/MWh) where the power plants/units are separated in low-cost/must-run power sources (*k*) and other sources (*m*). The simple adjusted OM calculates the net electricity generation of each power unit and an emission factor for each power unit as follows:

$$EF_{grid,OM-adj,y} = (1-\lambda_y) \times \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} + \lambda_y \times \frac{\sum_k EG_{k,y} \times EF_{EL,k,y}}{\sum_k EG_{k,y}} \qquad \textbf{(Equation 1)}$$

Where:

$EF_{grid,OM-adj,y}$	=	Simple adjusted operating margin CO_2 emission factor in year *y* (tCO_2/MWh)
λ_y	=	Factor expressing the percentage of time when low-cost/must-run power units are on the margin in calendar year y.
$EG_{m,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)
$EG_{k,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit *k* in year *y* (MWh)
$EF_{EL,m,y}$	=	CO_2 emission factor of power unit *m* in year *y* (tCO_2/MWh)
$EF_{EL,k,y}$	=	CO_2 emission factor of power unit *k* in year *y* (tCO_2/MWh). By definition, for low-cost/must-run plants, $EF_{EL,k,y}$= 0 (tCO_2/MWh)

m	=	All grid power units serving the grid in year *y*, except low-cost/must-run power units
k	=	All low-cost/must-run grid power units serving the grid in year *y*
y	=	The relevant year as per the data vintage chosen in step 3

The parameter λ_y is defined as follows:

λ_y (%) = (Number of hours low-cost/must-run sources are on margin in year *y*) / (8760 hours per year*)

*For leap years such as 2012, use 8784 hours per year

The second term in the equation cancels out as low-cost/must-run in the Ugandan electricity system are renewable zero emission power resources by definition and are characterized by $EF_{EL,k,y}$= 0 (tCO_2/MWh), therefore equation 1 converts to :

$$EF_{grid,OM-adj,y} = (1-\lambda_y) \times \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}} \quad \text{(Equation 2)}$$

Only grid-connected power plants are included in the determination of λ_y. A three step process is used to determine λ_y as per Article 56 of the tool. This process is carried out for each of the three years 2010, 2011, and 2012:

i. Chronological load data (in MW) for each hour of the year was provided by UETCL. This data was sorted from the highest to the lowest MW level and plotted against 8760 hours in the year (8784 hours in 2012), in descending order.
ii. The total annual generation (in MWh) from low-cost/must-run power plants was calculated and plotted next to the Load Curves.
iii. The "Number of hours for which low-cost/must-run resources are on the margin" was determined by subtracting the number of hours where low-cost/must-run resources intersects the load curve from the total number of hours in the year.

Table 6: Simple-Adjusted OM Lambda values

	2010	2011	2012
Total Net Electricity Generated Low Cost Must Run (MWh)	1,432,048	1,598,418	2,553,982
Number of hours low-cost/must-run are on the margin	53	24	2263
Lambda λ (%)	0.00605	0.00273	0.25762
1 - Lambda (1 - λ) (%)	0.99395	0.99726	0.74237

Note that the increased number of hours low-cost/must-run resources are on the margin in 2012 and the corresponding higher value for λ_y correspond to generation from Bujagali.

The CO_2 emission factor $EF_{EL,m,y}$ is calculated using Option A1 (Article 44) for each of the four thermal plants, using the fuel consumption data provided by Uganda Electricity Transmission

Company Limited (UETCL) and the Electricity Regulatory Authority (ERA). The Raw Data is included in Annex 2.

$$EF_{EL,m,y} = \frac{\sum_i FC_{i,m,y} \times NCV_{i,y} \times EF_{CO2i,y}}{EG_{m,y}}$$

(Equation 3)

Where:

$EF_{EL,m,y}$	=	CO_2 emission factor for 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 (energy content) of fuel type *i* in year *y* (GJ/mass or volume unit). If fuel-specific NCV data is not available, conservative IPCC values can be used.
$EF_{CO2i,y}$	=	CO_2 emission factor of fuel type *i* in year *y* (t CO_2/GJ). If fuel-specific EF data is not available, conservative IPCC values can be used.
$EG_{m,y}$	=	Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y*
m	=	All power units serving the grid in year *y* except low-cost/must-run power units
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

When fuel specific data (CO_2 emission factor and net calorific value were not provided by the plant operator), conservative IPCC values can be used. These are displayed in Table 7 below.

Table 7. Conservative IPCC CO_2 emission factor and net calorific value

IPCC Values	CO_2 EF[5] (tCO_2/GJ)	Net Calorific Value[6] (GJ/kg)
Diesel	0.0726	0.0414
Heavy Fuel Oil	0.0755	0.0398

[5] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Table 1.4

[6] 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Volume 2, Table 1.2

Table 8. OM EF calculations for 2010, 2011 and 2012

2010

Thermal Power Plant	Fuel	EGm,y (MWh)	FCi,m,y (kg)	NCV (GJ/kg)	EFi,m,y (tCO_2/MWh)	EG*EF (t CO_2)
Tororo	Diesel	82,562	416,166	Use IPCC	0.7763	64,096
	Heavy Fuel Oil		20,914,244	Use IPCC		
Kiira	Diesel	150,976	34,771,243	Use IPCC	0.7030	106,133
Mutundwe	Diesel	417,776	93,907,311	Use IPCC	0.6861	286,635
Namanve	Heavy Fuel Oil	372,581	80,384,812	Use IPCC	0.6483	241,548

2011

Thermal Power Plant	Fuel	EGm,y (MWh)	FCi,m,y (kg)	NCV (GJ/kg)	EFi,m,y (tCO_2/MWh)	EG*EF (t CO_2)
Tororo	Diesel		69,782	Use IPCC		
	Heavy Fuel Oil	69,958	17,029,967	0.0402	0.7417	51,885
Kiira	Diesel	132,922	30,376,357	Use IPCC	0.6975	92,718
Mutundwe	Diesel	363,843	83,193,965	Use IPCC	0.6979	253,935
Namanve	Heavy Fuel Oil	391,209	84,507,696	Use IPCC	0.6491	253,937

2012

Thermal Power Plant	Fuel	EGm,y (MWh)	FCi,m,y (kg)	NCV (GJ/kg)	EFi,m,y (tCO_2/MWh)	EG*EF (t CO_2)
Tororo	Diesel		373,452	Use IPCC		
	Heavy Fuel Oil	70,133	16,717,248	0.0406	0.7459	52,315
Kiira	Diesel	0	0	Use IPCC	0.0000	0
Mutundwe	Diesel	56,572	6,639,308	Use IPCC	0.3582	20,265
Namanve	Heavy Fuel Oil	148,697	30,165,933	Use IPCC	0.6096	90,646

Table 9.Summary of OM Emission Factors for 2010, 2011 and 2012

	2010	2011	2012
Total Net Electricity Generated Low Cost/Must Run (MWh)	1,432,048	1,598,418	2,553,982
Total Net Electricity Generated Thermal (MWh) + imports	1,053,372	996,997	310,119
Total Net Electricity Generated LC-MR + Thermal (MWh) + imports	2,485,420	2,595,415	2,864,101
Simple Adjusted OM	0.65335	0.64734	0.38999
Simple Adjusted OM + Off-grid Power	0.66624	0.66102	0.40853

Table 10. 2013 Simple-adjusted OM Emission Factors

	Ex-ante (2010-2012)
Simple Adjusted OM	0.55645
Simple Adjusted OM + Off-grid Power	0.57163

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

The BM EF can be calculated using either ex-ante or ex-post data vintages, paying attention to the restrictions imposed depending on the crediting period of the project activity:

- *Ex-ante (Option 1)*: For the first and second crediting periods, calculate the BM EF based on the most recent data available. For the third crediting period, use the BM EF calculated for the second crediting period.
- *Ex-post (Option 2)*: The emission factor should be updated for the year in which the power plant displaces grid electricity. This emission factor should be updated annually for the rest of the crediting period during the monitoring. This method can only be used for the first crediting period. For the second crediting period use ex-ante calculation method and for the third use the BM calculated during the second crediting period.

Crediting Period	BM Options
First	Ex-ante (Option 1) or Ex-post (Option 2)
Second	Ex-ante (Option 1) only
Third	Use the BM calculated in the second crediting period

Determine the sample group of power plants used to calculate the BM EF

To calculate the BM EF, it is necessary to determine the sample group (SET_{Sample}) of power plants *m* based on the most recent data is available (see Figure 4), for which the following criteria are met:

- The sample group (SET_{Sample}) consists of at least the five most recent power plants (SET_{5units}) to feed electricity to the grid. If SET_{5units} accounts for less than 20% of the annual electricity generation, the sample group is expanded to include the next operational power plant until sample group *m* accounts for 20% of the annual electricity generation.
- Exclude the power plants that are CDM registered projects, as identified in Step 1.
- Exclude the power plants that started operations more than 10 years ago.

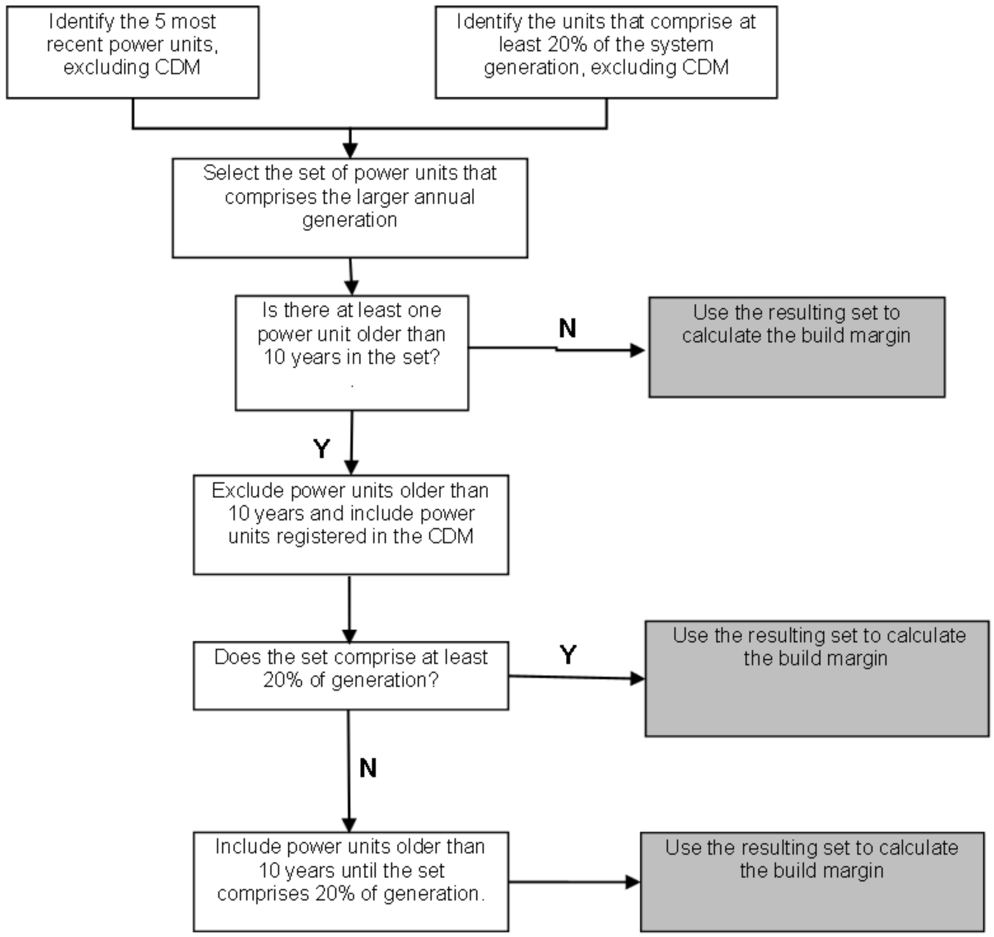

Figure 4. Procedure to determine the sample group of power units m used to calculate the build margin

Table 9 summarizes the sample group of power plants used in determining EF. This group meets the requirements summarized above (Article 71).

Table 11: Sample Group (SET_{Sample}) of power plants m used for BM EF determination

Power Plant (m)	In-service year	Project Type	2012 EGm,y (MWh)	EG*EF (t CO2)
Mpanga	2011	Mini Hydro	78,829	0
Kasese Cobalt (Mubuku III)	2009	Mini Hydro	4,616	0
Tororo	2009	Thermal	70,133	52,315
Namanve	2008	Thermal	148,697	90,646
Aggreko - Mutundwe	2008	Thermal	56,572	19,955

Table 12: Share of power plants power generation chosen for BM calculation

Total ∑EG without CDM (MWh)	1,750,909
20% of ∑EG (MWh)	350,182
∑SET (MWh)	358,846
∑SET % of Total EG	20.5%

Once the SET_{Sample} has been identified, the build margin emission factor is calculated as the generation-weighted average emission factor (tCO_2/MWh) of all power units *m* in the sample, during the most recent year:

$$EF_{grid,BM,y} = \frac{\sum_m EG_{m,y} \times EF_{EL,m,y}}{\sum_m EG_{m,y}}$$ (Equation 4)

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 (SETsample)
y	=	The relevant year as per the data vintage chosen in step 3

The CO_2 emission factor of each power plant *m* ($EF_{EL,m,y}$) has been determined using Equation 3 while calculating the OM.

Table 13. 2013 BM emission Factor: Ex-ante and Ex-post

	Ex-ante (2012)
BM	0.45400
BM + Off-grid Power	0.48545

2.6 Step 6: Calculate the combined margin (CM) emission factor

After calculating the OM and BM emission factors the combined margin (CM) emission factor or the baseline emission factor (EF_y) is calculated using the following equation:

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

(Equation 5)

Where:

$EF_{grid,CM,y}$	=	Baseline emission factor (tCO_2/MWh),
$EF_{grid,OM,y}$	=	Operating margin CO_2 emission factor in year *y* (t CO_2/MWh)
$EF_{grid,BM,y}$	=	Build margin CO_2 emission factor in year *y* (t CO_2/MWh)

w_{OM}	=	Weighting of operating margin emission factor (%)
w_{BM}	=	Weighting of operating margin emission factor (%)

Options for calculating weighted average CM emission factor are summarized depending on the crediting period and project activity:

- For wind and solar power generation projects, W_{OM} = 0.75, W_{BM} = 0.25 for all crediting periods
- For all other projects, W_{OM} = 0.5, W_{BM} = 0.5 for the first crediting period, and W_{OM} = 0.25, W_{BM} = 0.75 for second and third crediting period

A simplified combined margin can be calculated using Equation 7 where W_{OM} = 1, W_{BM} = 0. All options are summarized below:

Table 14: Options for calculating W_{OM} and W_{BM}

Option	W_{OM}	W_{BM}
CM EF for First, Second and Third crediting periods for wind and solar	0.75	0.25
CM EF for First crediting period for all other projects	0.5	0.5
CM EF for Second and Third crediting period for all other projects	0.25	0.75
Simplified CM (using Average OM method)	1	0

3 Results

OM and BM EF results are summarized in Table 15, grouped into two categories, depending on whether or not off-grid power is included.

Table 15: Summary of OM and BM EF Results

	Grid-connected[7] (tCO_2/MWh)	Grid-connected including off-grid[8] (tCO_2/MWh)
OM Simple-Adjusted - Ex Ante (2010-2012)	0.55645	0.57163
BM - Ex-ante or Ex-post (2012)	0.45400	0.48545

The recommended GEF for various technologies at different crediting periods are illustrated in Table 16. These recommendations are based on the most advantageous GEF to project developers. Other potential results for GEF are possible, based on user selection of crediting period, project activity and data vintage in the 'Home Tab' of the GEF Tool.

Table 16 Recommended GEF values for various technologies and crediting period (ex-ante)

Project Type	Criteria	GEF (tCO_2/MWh
Wind or solar project in the 1st crediting period	– Off-grid power included – OM Ex-ante, BM Ex-ante – w_{OM} = 0.75, w_{BM} = 0.25	0.55009
Wind or solar projects in the 2nd or 3rd crediting period	– Off-grid power cannot be included for 2nd and 3rd crediting period – OM Ex-ante, BM Ex-ante – w_{OM} = 0.75, w_{BM} = 0.25	0.53084
All other renewable projects in 1st crediting period	– Off-grid power included – OM Ex-ante, BM Ex-ante – w_{OM} = 0.5, w_{BM} = 0.5	0.52854
All other projects in 2nd or 3rd crediting period	– Off-grid power cannot be included for 2nd and 3rd crediting period – OM Ex-ante, BM Ex-ante – w_{OM} 0.25, w_{BM} = 0.75	0.47961
Energy efficiency projects in the 1st crediting period	– Off-grid power cannot be included for energy efficiency projects	0.50522

[7] Based on Step 2 Option I

[8] Based on Step 2 Option IIb, Valid only for renewable projects in the 1st crediting period

	– OM Ex-ante, BM Ex-ante – $w_{OM} = 0.5$, $w_{BM} = 0.5$	
Energy efficiency projects in 2nd or 3rd crediting period	– Off-grid power cannot be included for for energy efficiency projects, neither for 2nd and 3rd crediting period – OM Ex-ante, BM Ex-ante – w_{OM} 0.25, $w_{BM} = 0.75$	0.47961

4 Data Collection: Gaps and Recommendations

The first step in updating the GEF is accurately identifying and collecting the raw data, including information regarding the relevant electric system, annual generation of each power plant and fuel consumption data for each of the thermal plants.

Because Ugandan-relevant entities have only recently become involved in providing the data necessary to calculate the GEF, this process is not yet well-defined. Training of staff and utilization of standardized templates which will be included in the training manual will make the data collection process smoother and more efficient in the future. The gaps and recommendations identified with regards to data collection include:

1. **Gap:** Power generation data provided by UETCL combine the electricity generation for the Nalubaale (Owen Falls) and Kiira (Owen Extension) power plants. While these plants are located in proximity to each other, generation values should be reported separately.
   Recommendation: UETCL should report annual power generation by plant according to the templates provided.

2. **Gap:** Inconsistent reporting of fuel consumption data for thermal plants. UETCL was able to provide annual thermal plant data necessary for only one of the plants (Tororo). For the other three plants (Aggreko-Kiira, Aggreko-Mutuwndu, and Jacobsen-Namanve), UETCL provided monthly fuel data in a fragmented and inconsistent way. For these plants, fuel consumption data was provided by the ERA.
   Recommendation: UETCL should monitor and report fuel consumption data in a similar format for all plants as is done for Tororo. Staff training and utilization of templates will improve the data collection process.

3. **Gap:** Fuel characteristics for power plants Aggreko-Kiira, Aggreko-Mutuwndu, and Jacobsen-Namanve were not provided by UETCL or ERA. Conservative IPCC values were used instead.
   Recommendation: UETCL should collect fuel characteristics data for all plants as is done for Tororo. Staff training and utilization of templates will improve the data collection process.

5 Updating the GEF Manual and Training

Updating the Ugandan GEF using Climate Focus's in-house developed model is an effort that requires specific technical and computational knowledge on both data preparation and model operation levels. This knowledge will be partly transferred to the relevant entities through the capacity building, training sessions and the specific manual that will be distributed during the capacity building activity.

6 Annexes

6.1 Annex 1: Relevant Electric Power System

Nr	Power Plant	Name of Operator	Location	Power Source	Nr of Units	Unit Rating (MW)	Initial Installed	Additions from Retrofits (MW)	Total Capacity (MW)	Year of Commissioning	Year of Installed Additions	LC-MR (Y/N)	CDM (Y/N)	Net Gen to UETCL 2010 (GWh)	Net Gen to UETCL 2011 (GWh)	Net Gen to UETCL 2012 (GWh)
1	Kilembe Mines (Mubuku I)	Kilembe Mines Limited	Mubuku 1 Falls, River Mubuku, Kasese	Mini Hydro	1	5	5	-	5	1954	N/A	Y	N	22	23	23
2	Nalubaale (Owen Falls)	Eskom Uganda Limited	Owen Falls, Jinja	Hydro	10	15	150	30	180	1954 - 1968	Units initial rating of 15 MW. Uprates to 18 MW completed 1996	Y	N	1255	1339	1275
3	Kiira (Owen Falls Extension) Power Station	Eskom Uganda Limited	Owen falls, River Nile, Jinja	Hydro	5	40	200	-	200	2000-2007	-	Y	N			
4	Aggreko - Kiira	Aggreko	Kiira Hydro-power Plant	Thermal - Light Diesel	1	50	50	-	50	2006		N	N	151	133	0
5	Aggreko - Mutundwe	Aggreko	Mutundwe Substation	Thermal - Light Diesel	1	50	50	-	50	2008	-	N	N	418	364	57

6	Namanve	Jacobsen Uganda Power Plant Company	Namanve, Mukono District	Thermal - Heavy Fuel Oil	7	7.285	50	-	50	2008	-	N	N	373	391	149
7	Bugoye (Mubuku II)	Tronder Power Limited	Mubuku 11 Falls, River Mubuku, Kasese	Mini Hydro	2	6.5	13	-	13	2009	-	Y	Y	66	80	78
8	Tororo	Electro-maxx Uganda Limited	Tororo District	Thermal - Diesel and Heavy Fuel Oil	2	varies: Unit 1: 18 Unit 2: 32	18	32	50	2009	Unit 2: Dec 2012	N	N	83	70	70
9	Kasese Cobalt (Mubuku III)	Kasese Cobalt Company Limited	Mubuku 111 Falls, River Mubuku, Kasese	Mini Hydro	3	3.5	10.5	-	10.5	2009	-	Y	N	3	4	5
10	Kakira Sugar Works	Kakira Sugar Limited	Kakira Estate, Jinja	Bagasse	4	varies: Unit 1: 3 Unit 2: 3 Unit 3: 3 Unit 4: 3	6	6	12	1994	Unit 2 and 3: December 2007	Y	N	80	58	85
11	Kinyara Sugar Works	Kinyara Sugar Works Ltd	Masindi District	Bagasse	4	varies: Unit 1: 1 Unit 2: 1 Unit 3: 8 Unit 4: 8	2	16	18	1976	Unit 3 and 4: June 2009	Y	N	5	2	9
12	Mpanga Power Station	Africa Energy Management Systems	River Mpanga, Kamwenge District	Mini Hydro	3	6	18	-	18	2011	-	Y	N	0	70	79
13	Ishasha (Kanungu) Power Station	Eco Power Uganda Ltd	River Ishasha, Kanungu District	Mini Hydro	2	3.2	6.4	-	6.4	2011	-	Y	Y	0	23	28
14	Bujagali	Bujagali Energy Limited	Bujagali Falls, River Nile, Jinja	Hydro	5	50	250	-	250	2012	-	Y	Y	0	0	972

6.2 Annex 2: Thermal Plants Raw Data

Nr.	DATA	TORORO		KIIRA, AGGREKO	MUTUNDU, AGGREKO	NAMANVE, JACOBSEN
1	COMMISSIONING DATE	Unit 1: December 2009		October 2006	August 2008	September 2008
		Unit 2: October 2012				
2	INSTALLED CAPACITY	50 MW		50 MW	50 MW	50 MW
3	FUEL TYPES	Diesel and	Heavy Fuel Oil-HFO	Light Diesel	Light Diesel	Heavy Fuel Oil-HFO
4	FUEL CONSUMPTION (KG or L)					
		Units: KG	Units: KG	Units: L	Units: L	Units: KG
	2010	416,166	20,914,244	41,542,704	112,195,115	80,384,812
	2011	69,782	17,029,967	36,291,944	99,395,418	84,507,696
	2012	373,452	16,717,248	0	7,932,268	30,165,933
5	NCV (MJ/KG or MJ/L or GJ/tone)					
		Units: GJ/kg		Units: GJ/t	Units: GJ/t	Units: GJ/t
	2010	Use IPPC values	Use IPPC values	Use IPPC values	Use IPPC values	Use IPPC values
	2011	Use IPPC values	0.04019	Use IPPC values	Use IPPC values	Use IPPC values
	2012	Use IPPC values	0.04056	Use IPPC values	Use IPPC values	Use IPPC values
6	DENSITY (KG/m3 or KG/L)					
		Units: KG/m3	Units: KG/m3	Units: KG/L	Units: KG/L	Units: KG/L
	2010	850	Use IPCC values	0.85	0.85	0.92
	2011	850	934.45	0.85	0.85	0.92
	2012	850	957.18	0.85	0.85	0.92
7	CO_2 Emission Factors (tCO_2/GJ)					
		Use IPCC values	Use IPCC values	Use IPCC values	Use IPCC values	Use IPCC values