# GRID EMISSION FACTOR

*Of*

São Tomé and Príncipe

**2010-2012**

UNEP RISØ Centre

With Coordination & technical support from RCC Lomé

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**November, 2013**

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# ABBREVIATIONS

| | |
|---|---|
| **ACP** | African, Caribbean and Pacific states |
| **BM** | Build Margin |
| **CDM** | Clean Development Mechanism |
| **CER** | Certified Emission Reduction |
| **CM** | Combined Margin |
| **$CO_2$** | Carbon Dioxide equivalent |
| **DNA** | Designated National Authority |
| **DOE** | Designated Operational Entity |
| **EMAE** | Empresa de Água e Electricidade de São Tomé e Princípe (State Electricity and Water Company) |
| **GEF** | $CO_2$ Grid Emission Factor |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **IPP** | Independent Power Producer |
| **MEAs** | Multilateral Environmental Agreements |
| **NCV** | Net Calorific Value |
| **OM** | Operating Margin |
| **PDD** | Project Design Document |
| **UNFCCC** | United Nations Framework Convention on Climate Change |

## INTRODUCTION

This report is the continuation of work based on the report titled “Grid Emission Factor Of Sao Tome And Principe 2009 – 2011” produced by UNEP Risø centre in October, 2012. The scope of the report covers the Grid Emission Factor (GEF) for the main electricity system of the Island of Sao Tome in the Democratic Republic of Sao Tome and Principe, and serves as support to the submission of the respective Standardized Baseline by the Designated National Authority (DNA) of the Democratic Republic of Sao Tome and Principe.

The methodology applied is described in the "Tool to calculate the emission factor for an electricity system – version 4.0", officially published by the United Nations Framework Convention on Climate Change (UNFCCC) – hereafter, referred to as the *Tool*.

Data on net electricity generation and fossil fuel consumption for the calendar years 2008 to 2012 is provided by the state's Water and Electricity Company, EMAE.

# DATA QUALITY PROVISIONS

According to the *Guidelines for quality assurance and quality control of data used in the establishment of standardized baselines* (UNFCCC, 2012), data quality is defined as 'the degree of which data are "fit for use" [and is ensured when] it can be demonstrated that the datasets are relevant, complete, consistent, reliable, current, accurate and objective. In addition, processing data to derive standardized baselines should be conservative, secure, transparent and traceable."

The approach for data collection, processing, compilation and reporting was as follows:

1. The data used for calculating the standardized baseline is, in its majority, primary data collected from a single data provider – the state-owned Water and Electricity Company of the Democratic Republic of Sao Tome and Principe.

2. The data was processed, compiled and reported using the guidance prescribed under the *Tool (UNFCCC, 2013)* and the official table formats[1].

3. The treatment of uncertainties was carried out by using conservative secondary data from reliable sources (IPCC, 2006; OECD/IEA, 2004).

The data aggregation system of EMAE :

In order to verify the reliability of the data system the authors have verified the data collection process of the EMAE through interviews and review **of records. A summary of the information collected is provided below:**

- **São Tomé Power Plant:** Fuel consumption is calculated by subtracting the remaining fuel stock from the stock originally purchased. This method is chosen due to the poor functioning of all meters installed in the various power units of São Tomé power plant. Electricity generation is metered at a unit level.
- **Santo Amaro Power Plant and Bobô-Fôrro I Power Plant:** Meters are installed to measure the fuel consumption and electricity generation. Regular checks are carried out to validate (and/or correct) the

[1] The table formats can be found in UNFCCC's *excel spreadsheets* of the *Tool to calculate the emission factor for an electricity system – version 4.0 [(Table to calculate the emission factor for an electricity system (version 02.0.0) ].*

consumption of diesel, by comparing the values obtained with the original volume bought from the supplier.

Fuel for all private power stations is supplied through EMAE. Fuel consumption for individual electricity units is taken from the report elaborated by the Directorate for Electricity of EMAE (Direcção De Electricidade/EMAE), relative to the calendar year 2012.

All information presented on EMAE's annual reports are subject to independent auditing by the government and certified hard copies of the annual reports are maintained with the finance department of EMAE.

Compliance with the data quality criteria is justified below:

| Criteria | Justification |
|---|---|
| **Relevance** | Data is relevant and in line with the requirements of the *Tool* (UNFCCC, 2013). |
| **Completeness** | Data is complete and according to the requirements of the *Tool* (UNFCCC, 2013). |
| **Consistency** | Data is consistent across the data vintage chosen. |
| **Credibility** | Primary data is provided by the state-owned Water and Electricity Company, EMAE. |
| **Currentness** | Data is monitored and recorded by EMAE on a regular basis. |
| **Accuracy** | Sources of errors and duplications were not encountered. |
| **Objectivity** | Data is compiled as per the requirements prescribed in the *Tool* (UNFCCC, 2013). |
| **Conservativeness** | Conservative and reliable default values were applied wherever data was not available. |
| **Security** | No security issues to be remarked. |
| **Transparency** | Data was used transparently in accordance with the *Tool* (UNFCCC, 2013). |

| | |
|---|---|
| **Traceability** | Data can be easily traceable (EMAE) and the standardized baseline can be easily reproduced and/or reviewed. |

In conclusion, the data used in this report complies with all data quality criteria and, therefore, it is deemed to be appropriate.

# BASELINE METHODOLOGY

**STEP 1. Identify the relevant electricity system**

A *grid/project electricity system* is defined by the "spatial extent of the power plants that are physically connected through transmission and distribution lines to the project activity" (UNFCCC, 2013). Table 1 in Annex 1 shows all the power units/plants connected to the electricity system under analysis in this report.

Isolated grids and private power units (auto-consumers), supply electricity in places not connected to the chosen electricity system or serve as backup power during grid shortages, in the case of the latter. There are no imports or exports with any other electricity system. Thus, no **connected electricity system** is considered in the calculation.

**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 1: Only grid power plants are included in the calculation; or
- Option 2: Both grid power plants and off-grid power plants are included in the calculation.

A study by the World Bank (World Bank, 2010) estimated an off-grid[2] capacity of around 8 MW of diesel-based power units in Sao Tome and Principe – the most part in the *tourism sector* in the country.

The lack of grid reliability and stability has led some enterprises to invest in their own generation units to balance the common grid shortages and black-outs, in order to keep a steady supply to their customers.

Despite their presence in the electricity generation sector, to simplify the calculation, off-grid power plants won't be considered and, therefore, Option 1 is chosen.

[2] The classification as *off-grid power plant* is based on the requirements set under Annex 2 of the *Tool*. Hence, off-grid in this context excludes all isolated systems not connected to the electricity system defined in Step 1.

**STEP 3. Select a method to determine the operating margin (OM)**

The *tool* offers four different methods to calculate the OM emission factor:

- **a)** Simple OM
- **b)** Simple adjusted OM
- **c)** Dispatch data analysis OM
- **d)** Average OM

The available data provided by EMAE is on a yearly basis, both on electricity generation and fossil fuel consumption of the power plants connected to the electricity system. This means that method b) can be excluded from further consideration, as it requires hourly data. In addition, in the context of establishing a standardized baseline, method c) can also be excluded, as it requires *ex-post* annual monitoring of data.

In order to use method a), it is compulsory to demonstrate that low-cost/must-run resources[3] constitute less than 50% of the total grid generation in one of the following two cases:

**1)** In the average of the five most recent years; or

**2)** Based on long-term averages for hydroelectricity production.

For the chosen electricity system, low-cost/must-run refers solely to hydro resources. Table 2 presents an average of the five most recent years of grid generation. The values are relative to the period 2008-2012, and are taken from EMAE's Annual Reports (EMAE, 2010 (2008 and 2009 data); EMAE, 2011; EMAE, 2012; EMAE, 2013).

As it can be noticed, hydroelectricity production is below 50% of the total grid generation in all the years considered (an average of around 11%), which means that method a) can be used to calculate the OM emission factor.

In order to justify the choice between method a) and method d), it is relevant to dwell on the concept of *Operating Margin*. In brief, the operating margin refers to the group of power units/plants whose operation is affected by the implementation of a new project that starts supplying electricity to the grid or reduces consumption of grid electricity.

Now, the only difference between the Simple OM and Average OM methods is the inclusion of low-cost/must-run power units/plants in the calculation (as in the case of the latter). In systems where the generation mix is dominated by low-cost/must-run resources (higher than 50%), it makes sense to assume that their operation would be affected by the implementation of a new project,

[3] Low-cost/must-run resources are defined as "power plants with low marginal generation costs or power plants that are dispatched independently of the daily or seasonal load of the grid. They typically include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. If coal is obviously used as must-run, it should also be included in this list, i.e. excluded from the set of plants." (UNFCCC, 2013)

even though they have low operational costs. On the other hand, in systems where the share of low-cost/must-run resources in the generation mix is not high (less than 50%), it is reasonable to assume that their operation won't be affected by the implementation of a new project and, in consequence, all these power units/plants can be excluded from the calculation of the *Operating Margin emission factor*.

In the particular case of the grid under analysis, low-cost/must-run resources constitute, in a 5-year average, around 11% of the generation mix and, therefore, we can assume that their operation will not be affected. Hence, the Simple OM method is chosen.

The Simple OM is calculated for the calendar years 2010, 2011 and 2012 – the most recent years to which data is available at the time of preparation of this report.

**STEP 4. Calculate the operating margin emission factor according to the selected method**

The *tool* presents two options to carry out the calculation. As the net electricity generation and a $CO_2$ emission factor of each power plant are available, **option A** in the *tool* will (and must) be used.

The OM emission factor, $\mathbf{EF_{grid,OMsimple,y}}$, is calculated using Equation 1:

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

where:

- $\mathbf{EF_{grid,OMsimple,y}}$: Simple operating margin $CO_2$ emission factor in year y (in $tCO_2/MWh$)
- $\mathbf{EG_{m,y}}$: Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (in MWh)
- $\mathbf{EF_{EL,m,y}}$: $CO_2$ emission factor of power unit *m* in year *y* (in $tCO_2/MWh$)
- **m**: All power units serving the grid in year *y* (except low-cost/must-run power units if the Simple OM method is used)
- **y**: The relevant year as per that data vintage chosen in **Step 3** (in this case the *ex ante* option was chosen).

The emission factor of each power unit *m* is calculated using **Option A1** (as per the *tool*), using Equation 2:

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

where:

- **$EF_{EL,m,y}$**: $CO_2$ emission factor of power unit *m* in year *y* (in $tCO_2$/MWh)
- **$FC_{i,m,y}$:** Amount of fossil fuel type *I* consumed by power unit *m* in year *y* (in mass or volume unit)
- **$NCV_{i,y}$:** Net calorific value (energy content) of fossil fuel type *I* in year *y* (in GJ/mass or volume unit)
- **$EF_{CO2,i,y}$:** $CO_2$ emission factor of fossil fuel type *i* in year *y* (in $tCO_2$/GJ)
- **$EG_{m,y}$**: Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (in MWh)
- **m**: All power units serving the grid in year *y* (except low-cost/must-run power units if the Simple OM method is used)
- **i:** All fossil fuel types combusted in power unit *m* in year *y*
- **y**: The relevant year as per that data vintage chosen in **Step 3** (in this case the *ex ante* option was chosen).

The IPCC default values for the **$NCV_{i,y}$**, at the lower limit of the uncertainty at a 95% confidence interval, are used. The latter can be found in Table 1.2 of Chapter 1 of Vol.2 (Energy) of the IPCC Guidelines on National GHG Inventories (IPCC, 1996). In this particular case, diesel is the only fossil fuel type to be considered and the condition of Equation 3 is applied.

$$NCV_{Diesel,y} = 41.4\ GJ\ per\ ton, \forall y \tag{3}$$

As data on fuel consumption is given in litres, in order to convert the values to tones, a density value for diesel is set by Equation 4. The information is extracted from (OECD/IEA, 2004).

$$\rho_{Diesel} = 0.84\ ton\ per\ m^3 \tag{4}$$

The IPCC default values for **$EF_{CO2,i,y}$**, at the lower limit of the uncertainty at a 95% confidence interval, are used. The latter can be found in Table 1.4 of Chapter 1 of Vol.2 (Energy) of the IPCC Guidelines on National GHG Inventories (IPCC, 1996). The value used for diesel is set by Equation 5.

$$EF_{Diesel,y} = 72.6\ tCO_2\ per\ TJ, \forall y \tag{5}$$

Table 3 presents the results of applying Equation 2 for all power plants serving the grid, while Table 4 presents the results of applying Equation 1 for method a).

The 3-year generation-weighted average Simple OM is **0.6666 $tCO_2$/MWh**, as it can be observed in Table 4.

**STEP 5. Calculate the build margin (BM) emission factor**

To calculate the BM emission factor, the *tool* presents two options (differentiated in terms of data vintage).

**Option 1** is chosen in this report. The BM emission factor is calculated *ex ante* "based on the most recent information available on units already built for sample group *m* at the time of CDM-PDD submission to the DOE for validation (…)" (UNFCCC, 2013), for the first crediting period. In the context of this report, the BM emission factor is calculated based on the most recent information available on units already built for sample group *m* at the time of submission of this standardized baseline.

Capacity additions from retrofits of power plants are not included in the calculation of the BM emission factor.

A sample group of power units to be used in the calculation is determined as per the guidance given by the *Tool*, and according to the data vintage selected.

Table 5 presents the results of this process. The latest information available is relative to 2012, where a total of 74,006 MWh was supplied to the grid.

As it can be observed, the 5 most recent power units constitute 6.59% of the total electricity generation in 2012. In order to reach a minimum of 20% share, the eigh most recent power units needed to be included (making up a share of 21.27%) and, as a result, all of these eight power units will be further considered throughout **Steps 5d-5f** of the *tool* ($AEG_{set\text{-}20\%} > AEG_{set\text{-}5\text{-}units}$).

Within this group of eight power units (comprising 21.27% of generation), none of them is registered as a CDM project and, at the same time, they have started to supply electricity to the grid in less than 10 years. As per **Step 5d** of the *tool,* these eight units will be part of the sample group.

The BM emissions factor is "the generation-weighted average emission factor of all power units *m* during the most recent year *y* for which electricity data is available (…)" (UNFCCC, 2013). It is calculated using Equation 6.

$$EF_{grid,BM,y} = \frac{\sum_m (EG_{m,y} \times EF_{EL,m,y})}{\sum_m EG_{m,y}} \qquad \textbf{(6)}$$

where:

- $\mathbf{EF_{grid,BM,y}}$: Simple operating margin $CO_2$ emission factor in year y (in $tCO_2$/MWh)

- **$EG_{m,y}$**: Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (in MWh)
- **$EF_{EL,m,y}$**: $CO_2$ emission factor of power unit *m* in year *y* (in $tCO_2$/MWh)
- **m**: Power units included in the build margin (Sample group)
- **y**: Most recent historical year for which electricity generation data is available (calendar year 2011, in this case)

Table 6 shows the results from Equation 6.

A Build Margin (BM) emission factor, $EF_{grid,BM,}$ of **0.6363 $tCO_2$/MWh** was calculated.

**STEP 6. Calculate the combined margin (CM) emission factor**

The calculation of the CM emission factor, $EF_{grid,CM,y}$, is based on the 'Weighted average CM' methodology, since one of the conditions[4] to apply the 'Simplified CM' option is not met – the data requirements to apply the build margin methodology are available.

Equation 7 is used to calculate the Weighted Average CM.

$$EF_{grid,CM,y} = EF_{grid,OM,y} \times w_{OM} + EF_{grid,BM,y} \times w_{BM} \qquad \textbf{(7)}$$

where the new variables refer to:

- **$w_{OM}$:** Weighting of operating margin emission factor (%)
- **$w_{BM}$:** Weighting of build margin emission factor (%)

Equation 8 sets the boundary condition to apply these weights, which can balance differently according to the type of CDM project.

$$w_{OM} + w_{BM} = 100\% \qquad \textbf{(8)}$$

The weights of wind and solar power project activities, due to their intermittent and non-dispatchable nature, can be set as in Equation 9, for all crediting periods.

$$w_{OM} = 75\% \qquad \textbf{(9a)}$$

[4] Sao Tome and Principe is a Least Developed Country.

$$w_{BM} = 25\% \quad \textbf{(9b)}$$

All other project activities should use weights as set by Equation 10, for the first crediting period only.

$$w_{OM} = 50\% \quad \textbf{(10a)}$$

$$w_{BM} = 50\% \quad \textbf{(10b)}$$

In the following crediting periods, CDM project proponents should use:

$$w_{OM} = 25\% \quad \textbf{(11a)}$$

$$w_{BM} = 75\% \quad \textbf{(11b)}$$

Table 7 shows the final results, using the three sets of weights above.

# CONCLUSION

The present work calculated the $CO_2$ emission factor for Sao Tome and Principe's main electricity system (in the Island of Sao Tome). Table 7 is repeated below, with the values found:

| Parameter | SI Unit | $W_{OM}$ | $W_{BM}$ | Description | Value |
|---|---|---|---|---|---|
| EFgrid,CM,y | tCO2/MWh | 0.5 | 0.5 | Combined margin CO2 emission factor for the project electricity system applicable to all project activities other than wind and solar for the first crediting period | 0.6514 |
| EFgrid,CM,y | tCO2/MWh | 0.75 | 0.25 | Combined margin CO2 emission factor for the project electricity system applicable to the wind and solar power generation | 0.6590 |
| EFgrid,CM,y | tCO2/MWh | 0.25 | 0.75 | Combined margin CO2 emission factor for the project electricity system applicable to all project activities other than wind and solar for the second or third crediting period | 0.6438 |
| EFgrid,BM,y | tCO2/MWh | n.a. | n.a. | Build margin CO2 emission factor for the project electricity system | 0.6363 |
| EFgrid,OM,y | tCO2/MWh | n.a. | n.a. | Operating margin CO2 emission factor for the project electricity system | 0.6666 |

These values can be used by CDM Project Proponents whose projects supply electricity to the grid or that result in savings of electricity that would have been provided by the grid.

# BIBLIOGRAPHY

Direcção De Electricidade/EMAE, *Dados Anual de Produção e Consumo nas Centrais Interligadas e Isoladas de S.Tomé Príncipe - EXPLORAÇÃO [JAN_DEZ] 2012*, 2013

Empresa de Água e Electricidade, Government of Sao Tome and Principe, *Relatório e Contas – Exercício de 2009*, 2010

Empresa de Água e Electricidade, Government of Sao Tome and Principe, *Relatório e Contas – Exercício de 2010*, 2011

Empresa de Água e Electricidade, Government of Sao Tome and Principe, *Relatório e Contas – Exercício de 2011*, 2012

Empresa de Água e Electricidade, Government of Sao Tome and Principe, *Relatório e Contas – Exercício de 2012*, 2013

IPCC, *2006 IPCC Guidelines on National GHG Inventories*, 2006. Available at: http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/2_Volume2/V2_1_Ch1_Introduction.pdf

OECD/IEA, *Energy Statistics Manual*, 2004. Available at: http://epp.eurostat.ec.europa.eu/cache/ITY_PUBLIC/NRG-2004/EN/NRG-2004-EN.PDF

UNEP Risø Centre, *Grid Emission Factor Of Sao Tome And Principe 2009 – 2011*, 2012

UNFCCC, *Guidelines for quality assurance and quality control of data used in the establishment of standardized baselines, Version 01.0*, *EB 66 – Annex 49*, 2012. Available at: http://cdm.unfccc.int/Reference/Guidclarif/

UNFCCC, *Tool to calculate the emission factor for an electricity system – Version 4.0*, 2013. Available at: http://cdm.unfccc.int/Reference/tools/index.html

World Bank, *Estudo sobre a Revitalização do Sector Eléctrico e Participação do Sector Privado em São Tomé e Príncipe – Relatório Preliminar,* 2010

# ANNEX 1 – TABLES

**Table 1** List of power plants connected to the main electricity system of the Island of Sao Tome.

| unit_number | plant_name | unit_name | installed_capacity | commissioning_date | fuel_type | Low-cost/ Must-run | Connected | | |
|---|---|---|---|---|---|---|---|---|---|
| m | | | | yy | i | | 2010 | 2011 | 2012 |
| | - | - | *kW* | - | - | *Y/N* | *Y/N* | *Y/N* | *Y/N* |
| 1 | S. Tomé | ABC 1 | 1,000 | 1990 | Diesel | N | Y | Y | Y |
| 2 | S. Tomé | ABC 2 | 1,000 | 1993 | Diesel | N | Y | Y | Y |
| 3 | S. Tomé | ABC 3 | 1,280 | 1996 | Diesel | N | Y | Y | Y |
| 4 | S. Tomé | Deutz 1 | 1,450 | 2001 | Diesel | N | Y | Y | Y |
| 5 | S. Tomé | Deutz 2 | 1,450 | 2001 | Diesel | N | Y | Y | Y |
| 6 | S. Tomé | Deutz 3 | 1,450 | 2001 | Diesel | N | Y | Y | Y |
| 7 | S. Tomé | Cater3516B (or Caterpilar) | 1,800 | 2009 | Diesel | N | Y | Y | Y |
| 8 | S. Tomé | Pielstick | 960 | 2009 | Diesel | N | Y | N | N |
| 9 | Santo Amaro | HIMSEN # 1 | 1,701 | 2010 | Diesel | N | Y | Y | Y |
| 10 | Santo Amaro | HIMSEN # 2 | 1,701 | 2010 | Diesel | N | Y | Y | Y |
| 11 | Santo Amaro | HIMSEN # 3 | 1,701 | 2010 | Diesel | N | Y | Y | Y |
| 12 | Santo Amaro | HIMSEN # 4 | 1,701 | 2010 | Diesel | N | Y | Y | Y |
| 13 | Santo Amaro | HIMSEN # 5 | 1,701 | 2010 | Diesel | N | Y | Y | Y |
| 14 | Bobô-Fôrro 2 (Private) | Group 1 - Group 5 | 7,458 | 2010 | Diesel | N | Y | Y | N |
| 15 | Contador | Turbine 1 | 960 | 1967 | **Hydro** | Y | Y | Y | Y |
| 16 | Contador | Turbine 2 | 960 | 1967 | **Hydro** | Y | Y | Y | Y |
| 17 | Guegue (Private) | Turbine 1 (Guegue) | 320 | 1994 | **Hydro** | Y | Y | Y | Y |
| 18 | Bobô-Fôrro 1 | Group 1 | 720 | 2011 | Diesel | N | N | N | Y |
| 19 | Bobô-Fôrro 1 | Group 2 | 720 | 2011 | Diesel | N | N | N | Y |
| 20 | Bobô-Fôrro 1 | Group 3 | 720 | 2011 | Diesel | N | N | N | Y |
| 21 | Bobô-Fôrro 1 | Group 4 | 720 | 2011 | Diesel | N | N | N | Y |
| 22 | Bobô-Fôrro 1 | Group 5 | 720 | 2011 | Diesel | N | N | N | Y |
| 23 | Bobô-Fôrro 1 | Group 6 | 720 | 2011 | Diesel | N | N | N | Y |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 24 | Bobô-Fôrro 1 | Group 7 | 720 | 2011 | Diesel | N | N | N | Y |

**Table 2** Average share of the total grid generation of low-cost/must-run for the five most recent years.

| Resource Type | Net electricity generation (kWh) | | | | | |
|---|---|---|---|---|---|---|
| | 2008[a] | 2009[b] | 2010[c] | 2011[d] | 2012[e] | 5-year average |
| Thermal | 43,063,007 | 39,681,561 | 50,354,914 | 58,734,255 | 67,620,211 | 51,890,790 |
| Low-cost/Must-run | 7,668,107 | 7,260,660 | 4,788,615 | 6,001,697 | 6,386,000 | 6,421,016 |
| **Total** | **50,731,114** | **46,942,221** | **5,143,529** | **64,735,952** | **74,006,211** | **58,311,805** |
| Percentage of low-cost/must run | 15.12% | 15.47% | 8.68% | 9.27% | 8.63% | **11.01%** |

[a] Based on total generation, including power stations in the island of Principe and other isolated units in São Tomé. As the production of isolated units in the island of São Tomé and thermal power stations in the island of Principe is marginal in comparison with the electricity sent to the main grid in São Tomé, the share of low-cost/must-run would only be slightly higher. The conclusion would be the same. Data for 2008 is sourced from (Empresa de Água e Electricidade, 2010)

[b] These values take into account only grid connected power stations. Source: Empresa de Água e Electricidade, 2011

[c] These values take into account only grid connected power stations. Source: Empresa de Água e Electricidade, 2011

[d] These values take into account only grid connected power stations. Source: Empresa de Água e Electricidade, 2012

[e] These values take into account only grid connected power stations. Source: Empresa de Água e Electricidade, 2013

**Table 3** Emission Factor ($tCO_2/MWh$) and $CO_2$ emissions of each power plant

| year | station_type | station_number | station_name | net_electricity | fossil_fuel_type | station_fuel_type | amount_fuel_type | Net_Calorific_Value | | | fuel_CO2_EF | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| y | | m | | $EG_{m,y}$ | i | | $FC_{i,m,y}$ | factor for NCV | $NCV_{i,y}$ | Option | Required $EF_{CO2}$ | factor for EF | $EF_{CO2,i,y}$ or $EF_{CO2,m,i,y}$ | $\eta_{m;y}$ | Partial $E_{m,y}$ | $EF_{EL,m,y}$ |
| | | | | [MWh] | | | [unit] | | [GJ/unit] | | | | [tCO2/GJ] | | [tCO2] | [tCO2/MWh] |
| 2010 | Grid | 1 | S. Tomé | 20,928 | Diesel | m3 | 6,125 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 15,463 | 0.7389 |
| 2010 | Grid | 2 | Santo Amaro | 10,294 | Diesel | m3 | 2,541 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 6,415 | 0.6232 |
| 2010 | Grid | 3 | Bobô-Fôrro 1 | 192 | Diesel | m3 | 253 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 639 | 3.3240 |
| 2010 | Grid | 4 | Bobô-Fôrro 2 (Private) | 18,941 | Diesel | m3 | 5,017 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 12,668 | 0.6688 |
| 2010 | Grid | 5 | Contador | 4,541 | - | - | - | 1 | 0.0000 | - | EFCO2,i,y | 1 | 0 | - | - | 0.0000 |
| 2010 | Grid | 6 | Guegue (Private) | 248 | - | - | - | 1 | 0.0000 | - | EFCO2,i,y | 1 | 0 | - | - | 0.0000 |
| 2011 | Grid | 1 | S. Tomé | 10,674 | Diesel | m3 | 3,113 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 7,859 | 0.7363 |
| 2011 | Grid | 2 | Santo Amaro | 36,863 | Diesel | m3 | 9,455 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 23,871 | 0.6476 |
| 2011 | Grid | 3 | Bobô-Fôrro 1 | - | Diesel | m3 | - | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | - | 0.0000 |
| 2011 | Grid | 4 | Bobô-Fôrro 2 (Private) | 11,197 | Diesel | m3 | 2,831 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 7,146 | 0.6382 |
| 2011 | Grid | 5 | Contador | 5,739 | - | - | - | 1 | 0.0000 | - | EFCO2,i,y | 1 | 0 | - | - | 0.0000 |
| 2011 | Grid | 6 | Guegue (Private) | 262 | - | - | - | 1 | 0.0000 | - | EFCO2,i,y | 1 | 0 | - | - | 0.0000 |
| 2012 | Grid | 1 | S. Tomé | 20,336 | Diesel | m3 | 5,408 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 13,653 | 0.6714 |
| 2012 | Grid | 2 | Santo Amaro | 40,471 | Diesel | m3 | 10,182 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 25,707 | 0.6352 |
| 2012 | Grid | 3 | Bobô-Fôrro 1 | 6,813 | Diesel | m8 | 1,731 | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | 4,371 | 0.6416 |
| 2012 | Grid | 4 | Bobô-Fôrro 2 (Private) | - | Diesel | m3 | - | 1 | 34.7760 | Option A1 | EFCO2,i,y | 1 | 0.0726 | - | - | 0.0000 |
| 2012 | Grid | 5 | Contador | 6,386 | - | - | - | 1 | 0.0000 | - | EFCO2,i,y | 1 | 0.0000 | - | - | 0.0000 |
| 2012 | Grid | 6 | Guegue (Private) | - | - | - | - | 1 | 0.0000 | - | EFCO2,i,y | 1 | 0.0000 | - | - | 0.0000 |

**Note:** According to the *Tool* (UNFCCC, 2013), "power plants can be considered if all power units at the site of the power plant belong to the group of low-cost/must-run units or if all power units at the site of the power plant do not belong to the group of low-cost/must-run units.". In this case, as all power units within each of the individual power plants are of the same type, data will be presented at an aggregated level for each power plant. Only aggregated power plant data is available in the annual reports of EMAE.

**Table 4** 3-year generation weighted average of the Simple OM emission factor for the period 2010-2012.

| | **2010** | **2011** | **2012** |
|---|---|---|---|
| Net electricity generation (excl. low cost/must-run) (MWh) | 50,355 | 58,734 | 67,620 |
| $\mathbf{EF_{grid,OMSimple,y}}$ ($tCO_2$/MWh) | 0.6987 | 0.6619 | 0.6467 |
| $\mathbf{EF_{grid,OMSimple}}$ | | **0.6666** | |

**Table 5. Sample group of power units to calculate the BM emission factor.**

| Unit_Name | Commissioning_date | Energy that comprises up to 20% of the system generation - $EG_{m,y}$ | | Amount of fossil fuel type consumed by grid power units comprises up to 20% of the system generation | Factor for NCV | Net Calorific Value (energy content) of fossil fuel type | Factor for EF | $EF_{CO2,i,y}$ = CO2 emission factor of fossil fuel type | $EF_{EL,m,y}$ |
|---|---|---|---|---|---|---|---|---|---|
| | dd/mm/yy | Total | | Diesel | | Diesel | | Diesel | |
| | | [MWh] | [%] | m3 | | [GJ/mass or volume unit] | | [tCO2/GJ] | [tCO2/MWh] |
| Bobô-Fôrro 1 - Group 7 | 2011 | 1,354 | 1.83% | 351 | 1 | 34.7760 | 1 | 0.0726 | 0.6540 |
| Bobô-Fôrro 1 - Group 6 | 2011 | 1,123 | 3.35% | 279 | 1 | 34.7760 | 1 | 0.0726 | 0.6275 |
| Bobô-Fôrro 1 - Group 5 | 2011 | 479 | 3.99% | 124 | 1 | 34.7760 | 1 | 0.0726 | 0.6529 |
| Bobô-Fôrro 1 - Group 4 | 2011 | 920 | 5.24% | 238 | 1 | 34.7760 | 1 | 0.0726 | 0.6528 |
| Bobô-Fôrro 1 - Group 3 | 2011 | 1,000 | 6.59% | 241 | 1 | 34.7760 | 1 | 0.0726 | 0.6089 |
| Bobô-Fôrro 1 - Group 2 | 2011 | 732 | 7.58% | 188 | 1 | 34.7760 | 1 | 0.0726 | 0.6482 |
| Bobô-Fôrro 1 - Group 1 | 2011 | 1,206 | 9.21% | 311 | 1 | 34.7760 | 1 | 0.0726 | 0.6508 |
| Santo Amaro - HIMSEN#2 | 2010 | 8,930 | 21.27% | 2,236 | 1 | 34.7760 | 1 | 0.0726 | 0.6322 |

**Note:** The source for the disaggregated power plant data is (Empresa de Água e Electricidade, 2013) and (Directorate-General for Energy, 2013), for power units' electricity generation and fuel consumption, respectively. The last reference also presents the values for power units' electricity generation, which are similar to those presented in the annual report of EMAE.

**Table 6 Combined Margin Emission Factor.**

| Parameter | SI Unit | $W_{OM}$ | $W_{BM}$ | Description | Value |
|---|---|---|---|---|---|
| EFgrid,CM,y | tCO2/MWh | 0.5 | 0.5 | Combined margin CO2 emission factor for the project electricity system applicable to all project activities other than wind and solar for the first crediting period | 0.6514 |

| | | | | | |
|---|---|---|---|---|---|
| EFgrid,CM,y | tCO2/MWh | 0.75 | 0.25 | Combined margin CO2 emission factor for the project electricity system applicable to the wind and solar power generation | 0.6590 |
| EFgrid,CM,y | tCO2/MWh | 0.25 | 0.75 | Combined margin CO2 emission factor for the project electricity system applicable to all project activities other than wind and solar for the second or third crediting period | 0.6438 |
| EFgrid,BM,y | tCO2/MWh | n.a. | n.a. | Build margin CO2 emission factor for the project electricity system | 0.6363 |
| EFgrid,OM,y | tCO2/MWh | n.a. | n.a. | Operating margin CO2 emission factor for the project electricity system | 0.6666 |

# ANNEX 2 – CALCULATION SPREADSHEET

Please, refer to the *MS Excel* file attached – *GEF20102012_STP.xlsx.*

# GRID EMISSION FACTOR

*Of*

São Tomé and Príncipe

**2010-2012**

UNEP RISØ Centre

With Coordination & technical support from RCC Lomé

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