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2015

ACP MEAs

CUBAENERGÍA
Centro de Gestión de la Información y Desarrollo de la Energía

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This report was developed with the support of the European Commission Programme for Capacity Building related to Multilateral Environmental Agreements (MEAs) in African, Caribbean and Pacific (ACP) Countries.

Acknowledgements
This publication benefitted from a collaboration of regional institutions in LAC. We would like to thank Byron Chiliquinga from the Latin American Energy Organization (OLADE) and Karla Solis Garcia from the UNFCCC Regional Collaboration Centre for the Caribbean, for providing us with regional insights, national data, and regional coordination.
The authors

CONTENTS

GLOSSARY

ACP	Africa, Caribbean and Pacific
BM	Build margin
CCGT	Closed Cycle Gas Turbines
CDM	Clean Development Mechanism
CER	Certified Emissions Reduction (equivalent to 1 tonne CO_{2e})
CM	Combined margin
CO_2e	Carbon dioxide equivalent
EC	European Commission
DOE	Designated Operational Entity
EUA	European Union Allowances (equivalent to 1 tonne CO_{2e})
GEF	Grid Emission Factor
GWh	Gigawatt hour
IAEA	International Atomic Energy Agency
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
LAC	Latin America and the Caribbean
MEAs	Multilateral Environmental Agreements
MWh	Megawatt hour
OLADE	Latin American Energy Organization
OM	Operating Margin
PDD	Project Design Document
PIN	Project Identification Note
PoA	Program of Activities
PV	Photovoltaic
SIDS	Small Island Developing States
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change

INTRODUCTION

As part of their capacity development efforts to promote mitigation actions, the UNEP DTU Partnership, together with the UNFCCC Regional Collaborating Centre in the Caribbean, UNDP and OLADE, agreed to collaborate with Caribbean countries willing to update or establish their grid emission factors by undertaking a study to calculate standardized grid emission factors (GEF) for sixteen independent nations or groups of countries in the Caribbean region as a basis to the further identification of mitigation activities such as CDM PoAs or any other market-related instrument to be approved by the UNFCCC.

The study analyses the following topics:

– Status of the calculation and adoption of grid emission factors for each country in the region.
– Characteristics of electricity generation units in the different Caribbean countries.
– Application of the CDM methodological tool for calculating a standardized grid emission factor for countries with generation units with similar characteristics.

Data on the power systems of the different countries have been collected from several centres and institutions, including the UNEP DTU Partnership, the Latin American Energy Organization (OLADE), the Caribbean Community Climate Change Centre, the Caribbean Regional Collaboration Centre of the UNFCCC, the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA) and the Observatory for Renewable Energy in Latin America and the Caribbean. In addition, data have been collected from CDM projects, studies of the electricity sector in the region and public information issued by electric utilities.

1. EXISTING GRID EMISSION FACTORS FOR THE DIFFERENT CARIBBEAN COUNTRIES

1.1. CHARACTERIZATION OF THE STUDY AREA

The Caribbean region covers a wide area connecting the southern, central and northern portions of Latin America. Its waters, which are adjacent to the coasts of several Latin American countries, embrace a number of islands ranging from Trinidad & Tobago to Bahamas and the Cuban archipelago. This region is commonly considered to consist of the Arch of the Greater Antilles and the Lesser Antilles, but other countries, members of regional bodies such as OLADE or the Community of Latin-American and Caribbean Countries (CELAC), can be included in the socio-economic analysis of the area.

The Caribbean region encompasses sixteen independent nations (Figure 1): Antigua & Barbuda, the Bahamas, Barbados, Belize, Cuba, Dominica, Dominican Republic, Granada, Guyana, Haiti, Jamaica, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & the Grenadines, Suriname, and Trinidad & Tobago.

1.2. CHARACTERIZATION OF THE ELECTRICITY SECTOR IN THE REGION

The Caribbean Small Island States are characterized by their high reliance on fossil fuels for electricity generation. 93.2% of installed capacity in the Carib-

Figure 1. The Caribbean region

Table 1. Grid Emission Factor considered in CDM projects for the Bahamas, Dominican Republic, Guyana, Jamaica and Trinidad & Tobago ($EF_{grid, CM,}$ tCO_2/MWh). All the values are from the UNEP DTU Partnership CDM pipeline, except where otherwise stated.

Country	Types of CDM projects						
	Wind	Cement	Combined cycle	PV	Biomass	Landfill waste	Associated gas recovery PoA
Bahamas	n.a	n.a	n.a	n.a	n.a	0.723	n.a
DominicanRepublic	0.730	0.631	0.6535	0.654	0.614	n.a	n.a
Guyana	n.a	n.a	n.a	n.a	0.9483[a]	n.a	n.a
Jamaica	0.7324	0.7034[b]	n.a	n.a	n.a	n.a	n.a
Trinidad & Tobago	n.a	n.a	n.a	n.a	n.a	n.a	0.666[c]

[a] From the Project Design Document form: Guyana Skeldon Bagasse Cogeneration Project. Version 03. November 7, 2007.

[b] From the Project Design Document form: Blend increasing in the cement production of Caribbean Cement Company Ltd. Version 01. December 19, 2007.

[c] From Programme Design Document form for CDM Programmes of Activities: Petrotrin Oil Fields Associated Gas Recovery and Utilization. Version 07. December 26, 2012.

bean comes from thermal energy, and the remaining 6.8% from hydro and wind power.

In recent years, the Caribbean Small Island States have been facing a rapid increase in the demand for electricity due to several factors, including strong economic growth, population growth and the expansion of rural electrification. In addition, in most of these countries the use of fossil fuels has increased over time as the economy has shifted from agriculture to industry and services. The high rates of fossil fuel consumption, the reliance on fuel imports and the increase in fuel prices have created major challenges for Caribbean states regarding energy use.

Although Caribbean countries may differ in terms of the relative size of installed capacity in the electricity sector, most of them have similar dynamics with regard to the rapid growth in demand for electricity, the historical path dependent technologically on oil-based fuels, and the technological bias towards small-capacity power plants based on gas-oil.

1.3. PARTICIPATION OF THE REGION IN TRADITIONAL CDM PROJECTS

According to the UNEP DTU Partnership CDM pipeline[1], 13.2% of CDM projects (not including those that have been rejected or withdrawn) are located in the Latin American and Caribbean (LAC) region. The LAC region comes in second place after the Asia–Pacific region (81.7%).

However, statistics for the LAC region show that only 29 projects from the Caribbean have entered into the CDM project cycle, accounting for only 2% of the projects in the LAC region and about 0.3 % of all CDM projects worldwide.

Of the sixteen Caribbean countries considered in this study, only seven account for all the 29 CDM projects: twenty from the Dominican Republic, three from Cuba, two from Jamaica, and one each from Belize, Guyana, the Bahamas and Trinidad & Tobago. Of the 29 projects, nineteen have been registered, but only four are issuing CERs.

[1] UNEP DTU Partnership CDM pipeline: http://cdmpipeline.org/ (last accessed November 2014).

Table 2. Combined grid emission factor for Belize. (UNEP Risø Centre, 2013)

Option	WOM	WBM	$EF_{grid,\ CM}$ (tCO_2/MWh)
All Project Activities (Except wind and solar)	0.5	0.5	0.1519
Wind and Solar	0.75	0.25	0.2278
All Project Activities 2nd and 3rd Crediting Period	0.25	0.75	0.0759

Table 3. Grid emission factor for Cuba. (Padrón, 2012)

Emission factor	2009	2010	2011
$EF_{grid,OM,}$ tCO_2/MWh	0.826	0.819	0.817
$EF_{grid,BM,}$ tCO_2/MWh		0.662	
$EF_{grid,CM,}$ tCO_2/MWh wind and solar projects		0.781	
$EF_{grid,CM,}$ tCO_2/MWh 1st crediting period		0.741	
$EF_{grid,CM,}$ tCO_2/MWh 2nd and 3st crediting period		0.702	

1.4. EXISTING GRID EMISSION FACTORS FOR THE DIFFERENT COUNTRIES IN THE REGION

Among the sixteen Caribbean countries considered for this study, seven have grid emission factors that have been calculated previously, namely the Bahamas, Belize, Cuba, Dominican Republic, Guyana, Jamaica, and Trinidad & Tobago.

In the case of the Bahamas, Dominican Republic, Guyana and Jamaica, combined grid emission factors ($EF_{grid,CM}$) have been calculated under their respective CDM projects and can be found in the UNEP DTU Partnership CDM pipeline. The combined grid emission factors may be used to determine the baseline of any CDM project that displaces electricity generated by power plants in an electricity system or that reduces electricity consumption. Table 1 shows the combined grid emission factors calculated in the CDM projects at validation or registered by the CDM Executive Board for the Bahamas, Dominican Republic, Guyana, Jamaica and Trinidad & Tobago.

In the case of Belize, a combined grid emission factor has been calculated for the period 2009-2011 in a study conducted under the EC ACP MEAs program (UNEP Risø Centre, 2013). The combined grid emission factor for Belize is shown in Table 2.

In the case of Cuba, a grid emission factor has been calculated by Padrón (2012). Table 3 shows the grid emission factor for Cuba.

2. CHARACTERISTICS OF ELECTRICITY GENERATION UNITS IN THE DIFFERENT CARIBBEAN COUNTRIES

For nine of the 16 Caribbean countries considered for this study, no grid emission factor has been calculated: Antigua & Barbuda, Barbados, Dominica, Grenada, Haiti, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & the Grenadines, and Suriname. These countries are further analysed below.

Of these nine countries, Antigua & Barbuda, Barbados, Grenada, Saint Kitts & Nevis, and Saint Lucia rely for more than 98% of their electricity generation (from 98% to 100%) on fossil fuels.

The other countries are less dependent on fossil fuels for electricity generation, although their is still higher than 50% (68% for Dominica, 72% for Haiti, 83% for Saint Vincent & Grenadines, and 52% for Suriname) (APUA, 2010; BEC, 2013; BL&P, 2013; DOMLEC, 2013; ENERDATA, 2012; GBLC, 2012; GRENCEL, 2013; IRENA, 2013; LUCELEC, 2013; Mehairjan, 2010; NEXANT, 2010; NREL, 2012; NEVLEC, 2013; OAS, 2012; OLADE, 2012; SKELEC, 2013). It should be noted that for some of these countries such as Suriname, hydropower is an important source of electricity generation, though the relative contributions of fossil fuels compared to hydropower can vary from one year to another, according to the occurrence of dry seasons.

The sections below give a brief overview of the electricity systems for each of the nine countries for which a grid emission factor has been calculated in this publication: Antigua & Barbuda, Barbados, Dominica, Grenada, Haiti, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & Grenadines, and Suriname.

2.1. ANTIGUA & BARBUDA

The Antigua Public Utilities Authority operates three power plants: Wadadli, Barbuda and Friar's Hill. The most important is Wadadli, which generates 99.9% of the electricity in the country. Total installed capacity in 2008 was 90.2 MW of diesel engines using gas oil. Total electricity generation was 222 GWh using 231 TOE of fuel/MWh (Annex 2, Annex 3) (NEXANT, 2010; Author's calculation from APUA, 2013).

2.2. BARBADOS

The Barbados Light & Power Company Limited is the sole electricity provider. In 2008, 2009 and 2010, Barbados had an installed capacity of 257.8 MW, including two steam turbines of 20 MW per turbine using fuel oil, four low-speed diesel engines of 12.5 MW each, two low-speed diesel engines of 30 MW each, and six gas turbines rated from 13.3 MW to 20 MW each (total 104.1 MW). Four of these six gas turbines used gas oil, the two other used jet fuel (Annex 2). In addition there were two waste heat turbines of 1.5 MW and 2.2 MW. In 2010 total electricity generation was 1040 GWh using 245.1 TOE of fuel/MWh (Annex 2, Annex 3) (BL&P, 2013).

2.3. DOMINICA

Dominica Electricity Services Limited (DOMLEC) is the sole electricity utility in the Commonwealth of Dominica. The company operates three run-of-the-river hydro plants on the Roseau River. These plants are the Laudat plant, the Trafalgar plant and the Padu plant, with installed capacities of 1.24 MW, 3.52 MW and 1.8 MW respectively. In 2010, hydro capacity was 24.5% of the total installed capacity in the country and generated 32% of its electricity.

In 2010, DOMLEC operated also two diesel stations, one in Fond Cole and the other in Sugar Loaf, with installed capacities of 13.3 MW and 6.8 MW respectively (Annex 2). Thermal generation was 68% of total generation (DOMLEC, 2013). Total electricity generation was 87.04 GWh in 2008 and 92.9 GWh in 2009 and 2010 using 230TOE of fuel/MWh (Annex 2, Annex 3).

2.4. GRENADA

Grenada Electricity Services Limited (GRENLEC) is the sole provider of electricity in Grenada. GRENLEC is a private company located in the capital of St George's. The company's total thermal installed capacity was 25.7 MW, 33 MW and 49 MW in 2008, 2009 and 2010 respectively, and total electricity generation was 194.2 GWh, 200.2 GWh and 205.8 GWh (Annex 2) (GRENLEC, 2013). In this study, specific fuel consumption was assumed to be similar to that using the same technologies as in Jamaica, namely 275 TOE per MWh (Annex 3).

2.5. HAITI

Electricité d'Haiti (EDH) is an autonomous, state-owned, vertically integrated enterprise, which has a monopoly on the production, transmission, distribution and marketing of electricity throughout the country. Independent Power Producers (IPP) have also been operating in the electricity sector in Haiti since 1996.

In 2010 EDH's installed capacity was 216.11 MW, of which 154.36 MW was in thermal technology and 61.75 MW in hydro power plants. The thermal units were diesel motors using mainly gas oil and sometimes fuel oil (NEXANT, 2010; BME, 2006). In addition to EDH, the power system included the medium and small power plants of the IPP with installed capacities of between 300 kW and 9850 kW.

The country's total installed thermal capacity was 162 MW, 236 MW and 276 MW in 2008, 2009 and 2010 respectively, and total electricity generation 486 GWh, 721 GWh and 645.2 GWh (Annex 2). On average hydro capacity represents 18% of total installed capacity, but generates 28%-37% of the electricity.

In this study, the specific fuel consumption was assumed to be similar to that produced by the same technologies as those used in Jamaica, namely 275 TOE per MWh (Annex 3).

It should be noted that EDH's total available capacity is much less than its installed capacity due to serious problems of maintenance, which leads to frequent scheduled and unscheduled outages.

2.6. SAINT KITTS & NEVIS

Until 2008 Saint Kitts & Nevis was entirely reliant on imported oil for electricity generation. Since 2008, the government has been diversifying the generation mix with the use of renewable energy resources such as bioenergy, wind, geothermal and solar.

The electric utility on St. Kitts is the St. Kitts Electricity Company (SKELEC), and on Nevis the Nevis Electricity Company Limited (NEVLEC).

In 2009, SKELEC had a power station located at Needsmust made of ten diesel generators operating in droop and with a total capacity of 37.5 MW. NEVLEC had 13.2 MW of installed capacity (SKELEC, 2013; NEVLEC, 2013, LCCC, 2012). Total installed thermal capacity in the country was 50.7 MW. Electricity generation was 221 GWh (Annex 2).The fuel specific consumption was assumed to be 230 TOE per MWh (Annex 3).

2.7. SAINT LUCIA

LUCELEC's Cul De Sac Power Station (CDSPS) is the sole power plant on the island. In 1990, the CDSPS was commissioned with 3 MAK engines with a capacity of 6 to 7 MW by engine.

Between 2008 and 2010, in addition to the three MAK units, CDSPS was operating six large Wärtsilä units: four of 9.3 MW and two of 10.3 MW. CDSPS had 77.2 MW of installed generating capacity using gas oil, but the available generating capacity was 76 MW. With the installation of these last units, fuel efficiency has been increased to 19.4 kWh per gallon. 217.8 TOE of fuel are used to produce 1 MWh (LUCELEC, 2013) (Annex 3).

2.8. SAINT VINCENT & THE GRENADINES

The public electricity utility, St. Vincent Electricity Services Limited (VINLEC), is the sole provider of electricity. Between 2008 and 2010, the company was operating two diesel plants with a total installed capacity of 28 MW located at Cane Hall and at Lowmans Bay (Annex 2). Thermal generation was 83% of total electricity generation (139.1 GWh, 147.3 GWh and 156.5 GWh from 2008 to 2010 respectively). The specific fuel consumption was assumed to be 230 TOE per MWh (Annex 3).

VINLEC also operated hydropower plants located at South Rivers, Cumberland and Richmond (8 MW).

2.9. SURINAME

The power sector in Suriname is made up of individual thermal power plants and hydropower plants.

The installed capacity connected to the system includes generation from different grids: the EPAR grid, which includes generation by N.V. Energie Bedrijven Suriname (EBS) and by the hydropower plant; the ENICK grid; and the rural districts' own power systems.

N.V. Energie Bedrijven Suriname (EBS), the Dutch translation of Energy Companies of Suriname, is the national power company. It mainly supplies the coastal areas, where a large part of the population lives, and some interior areas of Suriname, through diesel generators. The ENICK System uses diesel engines. In addition, small power systems exist in the interior of Suriname, providing electric power to rural districts. These power systems are owned and operated by the Department for Rural Energy of the Ministry of Natural Resources (DEV). They operate as isolated power system with one or more diesel generators (Mehairjan, 2010; Jharap, 2014).

Total installed thermal capacity was 200 MW in 2008 and 2009, and 221 MW in 2010 (Annex 2). The specific fuel consumption was 270 TOE per MWh (Annex 3).

It should be noted that the hydropower plants had an installed capacity of 190 MW, representing 46-48% of total installed capacity in Suriname. However, the relative contribution of hydropower to electricity generation can vary strongly from one year to another, according to the occurrence of dry seasons.

3. METHODOLOGY FOR CALCULATING THE STANDARDIZED EMISSION FACTOR FOR COUNTRIES WITH GENERATION UNITS WITH SIMILAR CHARACTERISTICS

The grid emission factor (GEF) for the nine countries dealt with in this study have been calculated following the 'Tool to calculate the emission factor for an electricity system, Version 04.0' developed by the UNFCCC for the Clean Development Mechanism.[2] The official definitions adopted by the UNFCCC have been used (Annex 1).

The aim of the methodology is to determine the combined margin emissions factor ($EF_{grid,CM,}$ tCO_2/MWh) characterizing electric power generation in the national system. The combined margin emissions factor is used to determine the baseline of any CDM project that displaces electricity from the electricity system or reduces electricity consumption. This factor is the combination of the operating margin emission factor (OM) and the build margin emission factor (BM).

This study shows the calculation of the combined margin emissions factor in the national grids of the different countries. The parameters used in the calculations are for the period 2008-2010. Where data were not available for specific parameters and countries, data from other countries with similar technologies have been used.

3.1 STEP 1: IDENTIFY THE RELEVANT ELECTRICITY SYSTEM

The CDM methodological tool defines a grid/project electricity system as the 'spatial extent of the power plants that are physically connected through transmission and distribution lines to the project activity'. Annex 2 shows the characteristics of the power plants or units connected to the electricity system for each country under analysis in this report. Annex 3 shows the fuel type and the specific fuel consumption for each power system. It should be noted that in some Caribbean countries, two or more power systems are operating on different islands. In this case, the country was considered as having one power system in the absence of desegregated data.

In all countries considered in the study, isolated grids or isolated power units supply electricity in places not connected to the chosen electricity system. There are no imports or exports with any other electricity system. Thus, no connected electricity system is considered in the calculation.

3.2 STEP 2: CHOOSE WHETHER TO INCLUDE OFF-GRID POWER PLANTS IN THE PROJECT ELECTRICITY SYSTEM

According to the CDM methodological tool, there are two options for calculating the operating margin (OM) and build margin (BM) emission factors:

- **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.

In some of the countries considered in this study, the lack of grid reliability and stability has led some enterprises and consumers to invest in their own generating units to balance the frequent grid shortages and blackouts. Off-grid power plants are also used in the electrification of rural areas, isolated places and small islands. Despite the importance of these off-grid power plants, the lack of data related to the amount of electricity generation and fuel consumption of these plants does not allow them to be taken into consideration in the calculations. Therefore, **Option 1** is chosen.

[2] https://cdm.unfccc.int/methodologies/PAmethodologies/tools/am-tool-07-v4.0.pdf

3.3 STEP 3: SELECT A METHOD TO DETERMINE THE OPERATING MARGIN (OM)

The CDM methodological tool offers four different methods with which to calculate the OM emission factor ($EF_{grid,OM,y}$):

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

The data used in the calculations are for the period 2008-2010 (Annex 2) and were collected from different sources (APUA, 2013; BEC, 2013; BL&P, 2013; CARICOM, 20013; CEEBIP, 2013; DOMLEC, 2013; ENERDATA, 2012; GBPC, 2012; GRENCEL, 2013; IRENA, 2013; LUCELEC, 2013; Mehairjan, 2010; NEXANT, 2010; NREL, 2012; OIEA, 2012; ONEI, 2012; OLADE, 2010, 2012; PDD, 2007; SKELEC, 2013; VINLEC, 2013; WB, 2011).

It should be noted that the use of simple adjusted OM (method b) requires hourly data. As such data were not available for the countries considered in the study, method b) has been excluded. The use of dispatch data analysis OM (method c) has also been discarded, as this approach is not applicable to historical data and requires *ex-post* annual monitoring of data.

In Antigua & Barbuda, Barbados, Grenada, Saint Kitts & Nevis, and Saint Lucia more than 98% of electricity is generated using fossil fuels, specifically gas oil, fuel oil and natural gas. For the period covered by this study, in Dominica, Haiti, Saint Vincent & the Grenadines, and Suriname, 68%, 72%, 83% and 52% of electricity respectively was generated by gas oil or fuel oil.

In the case of Dominica, Haiti, Saint Vincent & the Grenadines, and Suriname, low-cost/must-run refers to hydro resources only. Average electricity generation from hydroelectric power plants for these countries was below 32%, 28%, 17% and 48% respectively.

In the case of Antigua & Barbuda, Barbados, Grenada, Saint Kitts & Nevis, and Saint Lucia, low-cost/must run resources refers to solar photovoltaic panels and wind turbines, but they represent less than one per cent of the total grid electricity generation in all countries.

Low-cost/must run resources thus constitute less than fifty per cent of total grid generation in all the countries considered in this study. Therefore the Simple OM (method a) could be used to determine the operating margin emission factor. However, as described in section 3.5, the data needed to calculate the build margin emission factor for these countries were not available. For this reason, in accordance with the CDM methodological tool, the **Average OM (method d)** has to be used to calculate the operating margin emission factor.

3.4 STEP 4: CALCULATE THE OPERATING MARGIN EMISSION FACTOR ACCORDING TO THE SELECTED METHOD

The average OM emission factor ($EF_{grid,\ OM\text{-}ave,y}$) is calculated *ex-ante* according to method d) for the calendar years 2008, 2009 and 2010 – the most recent years for which data are available for the countries under consideration at the time this study was carried out.

In accordance with the CDM methodological tool, the average OM emission factor ($EF_{grid,\ OM\text{-}ave,y}$) is calculated as the average emission rate of all power plants serving the grid, using the methodological guidance as described for the simple OM, but also including the low-cost/must-run power plants in all equations. Annex 2 includes the data for hydropower generation for Dominica, Haiti, St. Vincent & the Grenadines, and Suriname.

The simple OM may be calculated using one of the following two options:

Option A: based on the net electricity generation and a CO_2 emission factor of each power unit; or

Option B: based on the total net electricity generation of all power plants serving the system and the fuel types and total fuel consumption of the project electricity system.

According to the CDM methodological tool for the average OM emission factor, when following the guidance for calculation of the simple OM, Option B should only be used if the necessary data for Option A are not available.

For this study, in the absence of the data needed to use **Option A** for all countries considered here, **Option B** was used.

Using Option B, the average OM emission factor is calculated based on the net electricity supplied to the grid by all power plants serving the system, including low-cost/must-run power plants/units, and based on the fuel types and total fuel consumption of the project electricity system, as follows:

$$EF_{grid,\,OM\text{-}ave,\,y} = \frac{\sum_i FC_{i,y} X\ NCV_{i,y} X\ EF_{co_2,i,y}}{EG_y}$$

Equation (1)

Where:

- $EF_{grid,OM\text{-}ave,y}$: average operating margin CO_2 emission factor in year y (t CO_2/MWh)
- $FC_{i,y}$: amount of fuel type i consumed in the project electricity system in year y (ton)
- $NCV_{i,y}$: net calorific value (energy content) of fuel type i in year y (GJ/ton)
- $EF_{CO_2,i,y}$: CO_2 emission factor of fuel type i in year y (t CO_2/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)
- $_i$: all fuel types combusted in power sources in the project electricity system in year y
- $_y$: relevant year in accordance with the data vintage chosen in Step 3

The IPCC default values for $NCV_{i,y}$, 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 the IPCC Guidelines on National GHG Inventories, Vol. 2 (Energy) (IPCC, 2006). In this study, gas oil, fuel oil and natural gas are the fossil fuel types that are considered. The equations 2, 3 and 4 are applied:

$NCV_{gasoil,y}$= 41.4 GJ/ton,y
Equation (2)

$NCV_{fueloil,y}$ = 39.8 GJ/ton,y
Equation (3)

$NCV_{naturalgas,y}$= 46.5 GJ/ton,y
Equation (4)

The data on fuel consumption are in litres, barrels or imperial gallons. These values are converted to tons by using the density of gas oil, fuel oil and natural gas (OIEA, 2012). The equations 5, 6 and 7 are applied:

$\rho_{gasoil,y}$ = 0.84 kg/l,y
Equation (5)

$\rho_{fueloil,y}$ = 0.96 kg/l,y
Equation (6)

$\rho_{naturalgas,y}$ = 0.78 kg/m^3,y
Equation (7)

The IPCC default values for $EF_{CO_2,i,y}$, 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 the IPCC Guidelines on National GHG Inventories, Vol. 2 (Energy) (IPCC, 2006). The equations 8, 9 and 10 are applied for gas oil, fuel oil and natural gas respectively:

$EF_{CO_2,gasoil,y}$ =72.6 kgCO_2/TJ,y
Equation (8)

$EF_{CO_2,fueloil,y}$ =75.5 kgCO_2/TJ,y
Equation (9)

$EF_{CO_2,naturalgas,y}$ =54.3 kgCO_2/TJ,y
Equation (10)

Annex 4 shows the results of the calculations of the average operating margin CO_2 emission factor ($EF_{grid,OM\text{-}ave}$) for each power system by country. Grenada and Barbados have the highest $EF_{grid,OM\text{-}ave}$ values. These results reflect the complete dependence of these two countries on fossil fuels. Suriname has the lowest $EF_{grid,OM\text{-}ave}$ value, reflecting the high contribution of hydropower in electricity generation in this country. It has to be noted that 2010 was a dry year in Suriname, explaining the increase in the $EF_{grid,OM\text{-}ave}$

value due to the higher contribution of thermal power generation for this year.

3.5 STEP 5: CALCULATE THE BUILD MARGIN (BM) EMISSION FACTOR

In accordance with the CDM methodological tool, in terms of the vintage of data, the BM emission factor may be calculated using one of the following two options:

(a) Option 1. For the first crediting period, calculate the build margin emission factor *ex-ante* based on the most recent information available on units already built for sample group *m* at the time of CDM-PDD submission to the DOE for validation. For the second crediting period, the build margin emission factor should be updated based on the most recent information available on units already built at the time of submission of the request for renewal of the crediting period to the DOE. For the third crediting period, the build margin emission factor calculated for the second crediting period should be used. This option does not require monitoring the emission factor during the crediting period.

(b) Option 2. For the first crediting period, the build margin emission factor should be updated annually, *ex-post*, including those units built up to the year of registration of the project activity, or, if information up to the year of registration is not yet available, including those units built up to the latest year for which information is available. For the second crediting period, the build margin emission factor should be calculated *ex-ante*, as described in Option 1 above. For the third crediting period, the build margin emission factor calculated for the second crediting period should be used.

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

The CDM methodological tool provides a procedure for determining the sample group of power units *m* used to calculate the build margin emission factor (Step 5, paragraph 71, from (a) to (f), p. 20 of the CDM methodological tool). However, in this study, it has not been possible to apply the procedure in the absence of data on the power units that started to supply electricity to the grid most recently in the countries considered here.

3.6 STEP 6: CALCULATE THE COMBINED MARGIN (CM) EMISSION FACTOR

In accordance with the CDM methodological tool, the calculation of the CM emission factor ($EF_{grid,CM,y}$) is based on one of the following methods:

(a) weighted average CM; or
(b) simplified CM.

In this study, the simplified CM method (b) is used, as the following conditions are met, in accordance with the CDM methodological tool: the project activity is located in a Small Island Developing State (SIDS), and the data requirements for the application of Step 5 above cannot be met.

The CM emissions factor ($EF_{grid,CM,y}$) is calculated as follows:

$$\mathrm{EF}_{grid,CM,y} = \mathrm{EF}_{grid,OM,y} \times w_{OM} + \mathrm{EF}_{grid,BM,y} \times w_{BM}$$

Equation (11)

Where:

$EF_{grid,OM,y}$: 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 build margin emission factor (%).

In the case of the simplified CM method, the following conditions are applied to the equation (11): w_{BM}=0 and w_{OM} = 1.

The CM emission factor ($EF_{grid,CM,y}$) is thus equal to the OM emission factor, which has been calculated in this study as the average OM emission factor ($EF_{grid,\ OM\text{-}ave,y}$) in STEP 3. The final results are shown in Annex 4.

4. CONCLUSIONS

- The study covers the analysis of grid emission factors for the electricity sector in Caribbean countries. Nine out of sixteen countries with similar characteristics in terms of fuel types (gas oil and fuel oil) and technology used for electricity generation were considered in the study.
- The lack of reliable and recent grid data/information, among the Caribbean countries remains one of the main challenges in calculating grid emission factors.
- The grid emission factors were already available in the case of seven countries: Bahamas, Belize, Cuba, Dominican Republic, Guyana, Jamaica, and Trinidad & Tobago.
- The grid emission factors have been calculated by using the CDM methodological tool developed under the Clean Development Mechanism for Antigua & Barbuda, Barbados, Dominica, Grenada, Haiti, Saint Kitts & Nevis, Saint Lucia, Saint Vincent & Grenadines, and Suriname.
- In the absence of data to calculate the BM emission factor, the CM emission factors have been considered as equal to the OM emission factors. Therefore, the CM emission factors calculated in this study are probably overestimated.
- Barbados and Grenada have the highest CM emission factors (0.7906 tCO_2/MWh and 0.8027 tCO_2/MWh respectively), reflecting their complete dependence on fossil fuels for electricity generation. Antigua & Barbuda, Saint Kitts & Nevis, and Saint Lucia have emission factors ranging from 0.6943 tCO_2/MWh to 0.6526 tCO_2/MWh. Saint Vincent & the Grenadines and Haiti have emission factors of 0.5537 tCO_2/MWh to 0.5493 tCO_2/MWh. Suriname and Dominica have the lowest emission factors, 0.4895 tCO_2/MWh and 0.4711 tCO_2/MWh respectively, reflecting the low dependence of these countries on fossil fuels for electricity generation.

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ANNEX 1.
UNFCC OFFICIAL DEFINITIONS

Power plant/unit. A power plant or unit is a facility that generates electric power. Several power units at one site comprise one power plant, though a power unit can also operate independently from other power units at the same site. Where several identical power units (i.e. with the same capacity, age and efficiency) are installed at one site, they may be considered to be one single power unit.

Grid power plant/unit. A power plant or unit that supplies electricity to an electricity grid and, if applicable, to specific consumers. This means that power plants supplying electricity to the grid and specific captive consumers at the project are considered to be a grid power plant/unit, while power plants that serve only captive consumers and do not supply electricity to the grid are not.

Off-grid power plant/unit. A power plant or unit that supplies electricity to specific consumers through a dedicated distribution network which is not used by any other power plants. For a power plant to be categorized as off-grid, the following conditions need be fulfilled:

I. There must be a grid (or grids) capable of supplying power to the specific consumer(s) to which the off-grid facility is connected;
II. The off-grid facility is not connected to the grid(s) and cannot supply power to the grid(s), but only to the consumer(s) to which it is connected;
III. Under normal conditions, the consumer(s) are supplied with their power requirements from the grid only, that is, the off-grid plant(s) which is connected to the consumer(s) is a standby on-site facility(ies) that is only used when the power supply from the grid fails (or in many cases, when the quality of the power supply to the end-user is below an acceptable quality);
IV. To ensure a proper shift from the grid supply to the off-grid supply, the consumer has in place a change-over switch system (which may be manual or automatic).

Net electricity generation. This refers to the difference between the total quantity of electricity generated by the power plant/unit and its auxiliary electricity consumption (also known as parasitic load, e.g. for pumps, fans, controlling etc.).

A grid/project electricity system. This is defined by 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.

Connected electricity system. This is an electricity system that is connected by transmission lines to the project electricity system. Power plants within the connected electricity system can be dispatched without significant transmission constraints, but transmission to the project electricity system has significant transmission constraints, and/or the transmission capacity of the transmission line(s) that is connecting electricity systems is less than ten per cent of the installed capacity either of the project electricity system or of the connected electricity system, whichever is smaller.

Low-cost/must-run resources. These are defined as power plants with low marginal generating costs or dispatch independently of the daily or seasonal load of the grid. They include hydro, geothermal, wind, low-cost biomass, nuclear and solar generation. If a fossil fuel plant is dispatched independently of the daily or seasonal load of the grid, and if this can be demonstrated based on the publicly available data, it should be defined as low-cost/must-run.

ANNEX 2.
LIST AND CHARACTERISTICS OF THERMAL POWER PLANTS/UNITS BY COUNTRY

LIST OF THERMAL POWER PLANTS/UNITS USING FOSSIL FUEL BY COUNTRY

Power system	Power plants/ units	Year started	Technology	Fuel type	Installed thermal capacity, MW[a]		
					2008	2009	2010
Antigua & Barbuda	Wadadli PS	ND	Diesel Engine	Gas Oil/ HFO	90.2	ND	ND
	Barbuda PS	ND					
	Friar's Hill PS	ND					
Barbados	CG01	1976	Steam Turbine	Fuel Oil	20	257.8	257.8
	Steam S2	1976			20		
	Diesel EngineD10	1982	Low Speed Diesel	Gas Oil	12.5		
	Diesel EngineD11	1982			12.5		
	Diesel EngineD12	1987			12.5		
	Diesel EngineD13	1990			12.5		
	CG01	1985	Waste Heat Turbine	–	1.5		
	Diesel EngineD14	2005	Low Speed Diesel	Gas Oil	30		
	Diesel EngineD15	2005			30		
	CG01	2005	Waste Heat Turbine	–	2.2		
	Gas TurbineGT1	1973	Gas Turbine	Gas Oil	17.5		
	Gas TurbineGT2	1996			13.3		
	Gas TurbineGT3	1996			13.3		
	Gas TurbineGT4	1999			20		
	Gas TurbineGT5	2000		Jet Fuel	20		
	Gas TurbineGT6	2001			20		
Dominica	Fond Cole	ND	Diesel Engine	Gas Oil	16.6	19.46	20.06
	Sugar Loaf	ND					
Grenada	Queen's Park PS	1960	Diesel Engine	Gas Oil	1.7	33	49
		1961			1.2		
		1961			0.75		
		1962			1		
		1968			1.425		
		1971			1.425		
		1984			3.64		
		1986			1.82		
		1987			2.04		
		1991			5.2		
		2002			5.5		

Haiti	Varreux	ND	Steam Turbine	Gas Oil	162	236	276
	Carrefour	ND					
	North	ND	Diesel Engine	Gas Oil			
	Artibonite	ND					
	South	ND					
	Centre-West	ND					
	Jacmel	ND					
St. Kitts & Nevis	Needsmust PS	ND	Diesel Engine	Gas Oil	48	50.7	52.4
	Prospect PS	1983-2003	Diesel Engine				
St. Lucia	MAK	1990	Diesel Engine	Gas Oil	76	76	76
	Cul De Sac PS	ND					
St. Vincent & Grenadines	Cane Hall PS	ND	Diesel Engine	Gas Oil	28	28	28
	Lowmans Bay PS	2006					
Suriname	EPAR System	ND	Diesel Engine	HFO	200	200	221
	ENICK System	ND					
	Rural Distric Power System	ND					

[a] Installed thermal capacity was disaggregated by power plants/units when data were available. ND means that no data were available.

CHARACTERISTICS OF THERMAL POWER PLANTS/UNITS USING FOSSIL FUEL BY COUNTRY

Power system	Fuel type	$EF_{CO2,i,y}$, tCO_2/GJ[a]	$EG_{m,y}$, GWh[q]			$NCV_{i,y}$, GJ/ton[a]	$\eta_{m,y}$[b]	$EF_{EL,m,y}$, tCO_2/MWh[c]
			2008	2009	2010			
Antigua & Barbuda[d]	Gas Oil	0.0726	222.0	318.0	315.0	41.4	0.375	0.66
Barbados[e,f,i]	Gas Oil	0.0726	948.0	1023.0	1047.0	41.4	0.395	0.66
Dominica[h,i,j]	Gas Oil	0.0726	87.04	92.9	92.9	41.4	0.300	0.66
Grenada[k,l]	Gas Oil	0.0726	194.2	200.2	205.8	41.4	0.300	0.66
Haiti[f,l]	Gas Oil	0.0726	486.0	721.0	645.2	41.4	0.300	0.87
St. Kitts & Nevis[d,m]	Gas Oil	0.0726	210.0	221.0	233.0	41.4	0.375	0.66
St. Lucia[d,n]	Gas Oil	0.0726	352.3	363.0	380.9	41.4	0.300	0.66
St. Vincent & Grenadines[o]	Gas Oil	0.0726	139.1	147.3	156.5	41.4	0.395	0.66
Suriname[f,l,p]	Fuel Oil	0.0755	1616.9	1633.1	1634.7	39.8	0.300	0.69

[a] IPCC, 2006.
[b] Appendix 1 of the CDM methodological tool.
[c] Is the same for power systems in 2008, 2009 and 2010, calculated by the CDM methodological tool.
[d] LCCC, 2012.
[e] BL&P, 2013. The power station use fuel oil, gas oil and jet fuel. In the absence of detailed data, gas oil is assumed as fuel because has a lower emission factor.
[f] OLADE, 2010; OLADE, 2012.
[h] DOMLEC, 2013.
[i] OAS, 2012.
[j] NREL, 2012.
[k] GRENLEC, 2012.
[l] ENERDATA, 2012.
[m] IRENA, 2013.
[n] LUCELEC, 2013.
[o] VINLEC, 2013.
[p] Mehairjan, 2010.
[q] Electricity generation data includes generation from low cost/must run plants in the case of Dominica, Haiti, St. Vincent & Grenadines, and Suriname (hydropower plants).

ANNEX 3.
SPECIFIC FUEL CONSUMPTION AND $FC_{i,m,y}$

Country	Tech-nology	Fuel type	Specific fuel consumption, TOE /MWh			$FC_{i,m,y}$, ton		
			2008	2009	2010	2008	2009	2010
Antigua & Barbuda	Diesel engine	Gas Oil/ Fuel Oil	231	231	231	51282.0	73458.0	72765.0
Barbados	Steam turbine	Fuel Oil	272	272	245	248435.6	256732.2	236609.7
	Diesel engine/ Gas turbine	Gas Oil/ Jet fuel						
Dominica	Diesel engine	Gas Oil	230	230	230	13021.0	14467.9	15317.8
Grenada	Diesel engine	Gas Oil	275	275	275	51901.9	53383.8	55000.0
Haiti	Steam turbine/ Diesel engine	Gas Oil	275	275	275	80575.0	136675.0	124446.9
St Kitts & Nevis	Diesel engine	Gas Oil	230	230	230	48300.0	50830.0	53590.0
St Lucia	Diesel engine	Gas Oil	217.8	217.8	217.8	73633.6	80195.9	84355.3
St Vincent & Gren-adines	Diesel engine	Gas Oil	230	230	230	25329.0	27132.0	29172.7
Suriname	Steam turbine/ Diesel engine	Fuel Oil	270	270	270	214904.6	217050.8	364414.7

Source: For Antigua & Barbuda, Barbados, Guyana and St. Lucia, $FC^{i,m,y}$ has been found in the literature or has been calculated by the authors from primary data. For the remaining countries, specific fuel consumption was assumed to be the same as in countries with similar technologies (Belize, Cuba, Dominican Republic and Jamaica).

ANNEX 4.
GRID OM AND CM EMISSION FACTORS

Power System	OPTION B				
	$EF_{grid,OM-ave,y}$ (tCO_2/MWh)			$EF_{grid,OM-ave}$ (tCO_2/MWh)	$EF_{grid,CM}$ (tCO_2/MWh)
	2008	2009	2010		
Antigua & Barbuda	0.6943	0.6943	0.6943	0.6943	0.6943
Barbados	0.8175	0.8169	0.7374	0.7906	0.7906
Dominica	0.4496	0.4681	0.4956	0.4711	0.4711
Grenada	0.8033	0.8015	0.8033	0.8027	0.8027
Haiti	0.4983	0.5698	0.5797	0.5493	0.5493
St. Kitts & Nevis	0.6913	0.6913	0.6913	0.6913	0.6913
St. Lucia	0.6282	0.6640	0.6656	0.6526	0.6526
St. Vincent& Grenadines	0.5473	0.5536	0.5603	0.5537	0.5537
Suriname	0.3994	0.3994	0.6699	0.4895	0.4895

Source: Calculated by the authors following the methodology described in Section 3.