Ministry of Environment
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Institute for Global
Environmental Strategies

**IGES Clean Development Mechanism**

**Capacity Building Programme**

# Grid Emission Factor of the Phnom Penh Electricity Grid

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## Table of Contents

## Abbreviations

BM: Build Margin
CER: Certified Emission Reduction
CDM: Clean Development Mechanism
CM: Combined Margin
DOE: Designated Operational Entity
DO: Diesel Oil
EAC: The Electricity Authority of Cambodia
EDC: Électricité du Cambodge
GHG: Greenhouse Gas
HFO: Heavy Fuel Oil
IGES: Institute for Global Environmental Strategies
OM: Operating Margin
PDD: Project Design Document
UNFCCC: United Nations Framework Convention on Climate Change

# 1. Introduction

The IGES Clean Development Mechanism (CDM) Capacity Building Programme is a facilitative project for CDM host countries, with financial support provided by the Ministry of the Environment, Japan. The objectives of the IGES CDM Capacity Building Programme are to provide information on and raise awareness of the CDM in both the public and private sectors, to support the institutional framework, to train human resources to operationalise CDM projects and to support the CDM project's identification, development and implementation activities.

To achieve these objectives, IGES has been implementing several activities in Cambodia in collaboration with the Cambodian Ministry of Environment since the launch of the project in the late 2003. As part of these activities, the IGES CDM Capacity Building Programme team also identified the need to provide publicly available data for developing baselines for CDM projects. Some CDM project developers in Cambodia face difficulties in accurate estimation for the amount of Certified Emission Reductions (CERs) generated from their projects, which is a task of crucial importance for them in carrying out their CDM projects. By establishing publicly available baseline data, CDM project developers can utilize this information to set up credible baseline emissions in order to make more accurate Greenhouse Gas (GHG) emission reduction projections, which are in turn needed to calculate the CERs generated from the projects.

In this regard, the IGES CDM Capacity Building Programme, in cooperation with Cambodia Designated National Authority, decided to formulate a CDM baseline for the Phnom Penh Electricity Grid in FY 2010, and to this end the IGES CDM Capacity Building Programme held expert consultation meetings with Électricité du Cambodge, a public power company in Cambodia. This report presents a summary of the preliminary results of the above activities.

## 2. Current Status of Electricity Generation in the Phnom Penh Grid System

The Electricity Authority of Cambodia (EAC), which is an autonomous body set up to regulate and monitor the electric power sector throughout the country, defines the Phnom Penh Grid System as follows:

*"In 2009, The Phnom Penh Grid System was connected to the Vietnam Grid by double circuit 230kV line from Chau Doc in Vietnam to grid substation at Takeo and GS4 in Phnom Penh. By the end of 2009, the sources of power connected to Phnom Penh Grid System are Vietnam system at 230kV, CETIC Hydro station at Kirirom, Khmer Electrical Power Co. Ltd and (Cambodia) Electricity Private Co. Ltd at Phnom Penh at 115kV and Cambodia Utilities Pte Ltd., City Power Group Corporation, Colben Energy (Cambodia) Limited, SL Garment Processing (Cambodia) Ltd at Phnom Penh at 22kV. The Phnom Penh Grid System supplies power to Phnom Penh, parts of Kandal, Kampong Speu and Takeo Provinces".* (Page 45, EAC 2010)

In addition, Électricité du Cambodge (EDC), comprised of one diesel power plant (C3) and two thermal power plants (C5 and C6) and small three diesel generator plants, supplies electricity to the Phnom Penh Grid System[1].

[1] According to the data obtained from EDC.

**Table 1: Electrical output from each power plant connected to the Phnom Penh Grid System**

| Name of generator and power plant | Year commissioned | Installed Capacity, MW ** | Energy Sent Out, MWh | | |
|---|---|---|---|---|---|
| | | | 2007 | 2008 | 2009 |
| Electricité du Cambodge | | | | | |
| C3 | 1995 | 15.4 | 21,770 | 43,410 | 22,610 |
| C5 | 1995 | 13.0 | 20,130 | 24,440 | 19,840 |
| C6 | 1996 | 18.6 | 51,820 | 75,990 | 43,700 |
| Cambodia Utilities Pte. Limited | 1996 | 37.1 | 258,490 | 258,713 | 182,224 |
| CETIC International Hydropower Development Co., Ltd | 2002 | 12.0 | 46,498 | 43,292 | 44,380 |
| Khmer Electrical Power Co., Ltd | 2005 | 48.2 | 277,991 | 317,848 | 256,247 |
| City Power Group Corporation | 2005 | 8.1 | 38,238 | 41,816 | 34,113 |
| Colben Energy (CAMBODIA) Ltd | 2006 | 2007:14.8 2008-:21.4 | 54,019 | 45,696 | 53,235 |
| SHC (Cambodia) International Pte Ltd | 2006 | 10.9 | 14,700 | 34,501 | 17,307 |
| (Cambodia) Electricity Private Co, Ltd | 2006 | 48.2 | 315,550 | 325,883 | 269,480 |
| SL Garment Processing (Cambodia) Ltd | 2006 | 4.5 | 5,134 | 4,406 | 5,758 |
| Sovanna Phum Investment Co., Ltd | 2008 | 13.0 | - | 23,359 | 28,033 |
| Colben Energy (Cambodia) PPSEZ Limited | 2008 | 13.0 | - | 35,658 | 45,061 |
| Imported from Vietnam | * | 100.0 | - | - | 374,166 |
| Electricity Tramkhnar | 2004* | | - | - | 537 |
| Mr. Bun Huy | 2007* | | - | - | 8 |
| Mr. Toeng Samouv | 2007* | | - | - | 176 |

Source: EAC 2010,2009 and 2008.
EDC, 2010

*Generator started supply of electricity to the Phnom Penh Grid in 2009.

** These numbers differ from those of the power units as defined in Annex I. The definitions given in Annex I reflect their respective sources.

**Table 2: Fuel consumption of each fossil power plant connected to the grid (ton/year)**

| Name of generator and power plant | Fuel type | Fuel consumption, t | | |
|---|---|---|---|---|
| | | 2007 | 2008 | 2009 |
| Electricité du Cambodge | | | | |
| C3 | DO | 4,950 | 9,684 | 4,988 |
| C5 | HFO | 4,423 | 5,079 | 4,543 |
| C6 | HFO | 12,042 | 17,085 | 10,267 |
| Cambodia Utilities Pte. Limited | HFO | 61,053 | 60,794 | 43,169 |
| Khmer Electrical Power Co., Ltd | HFO | 63,186 | 72,117 | 57,313 |
| City Power Group Corporation | HFO | 8,904 | 9,773 | 8,124 |
| Colben Energy (Cambodia) Ltd | HFO | 14,097 | 12,362 | 13,851 |
| SHC (Cambodia) International Pte Ltd | DO | 3,675 | 8,625 | 4,324 |
| (Cambodia) Electricity Private Co, Ltd | HFO | 72,522 | 74,840 | 62,337 |
| Sovanna Phum Investment Co., Ltd | Coal | - | 27,727 | 35,041 |
| Colben Energy (Cambodia) PPSEZ Limited | HFO | - | 8,915 | 11,567 |

Source: EDC 2010

## 3. CDM Baseline Construction for the Phnom Penh Grid System

The rules indicate that "baseline emissions include only $CO_2$ emissions from electricity generation in fossil fuel fired power plants that are displaced due to the project activity. The methodology assumes that all project electricity generation above the baseline levels would have been generated by existing grid-connected power plants and the addition of new grid-connected power plants. The baseline emissions are to be calculated as follows:

$$BE_y = EG_{PJ,y} * EF_{grid,CM,y}$$

where:

$BE_y$ = Baseline emissions in year y (t-$CO_2$/yr)

$EG_{PJ,y}$ = Quantity of net electricity generation that is produced and fed into the grid as a result of the implementation of the CDM project activity in year y (MWh/yr)

$EF_{grid,CM,y}$ = Combined margin $CO_2$ emission factor for grid connected power generation in year y calculated using the latest version of the 'Tool to calculate the emission factor for an electricity system' (t-$CO_2$/MWh)"

Further, the rules specified in I.D. Type I (Renewable Energy Projects) for small scale project activity categories of the UNFCCC indicate that "the baseline scenario is the electricity delivered to the grid by the project activity that otherwise would have been generated by the operation of grid-connected power plants and by the addition of new generation sources. The baseline emissions are the product of electrical energy baseline $EG_{BL,y}$ expressed in MWh of electricity produced by the renewable generating unit multiplied by the grid emission factor.

$$BE_y = EG_{BL,y} * EF_{CO2,grid,y}$$

where:

$BE_y$ = Baseline Emissions in year y (t-$CO_2$)

$EG_{BL,y}$ = Quantity of net electricity supplied to the grid as a result of the implementation of the CDM project activity in year y (MWh)

$EF_{CO2,grid,y}$ = $CO_2$ emission factor of the grid in year y (t-$CO_2$/MWh)

The Emission Factor can be calculated in a transparent and conservative manner as follows:

(a) A combined margin (CM), consisting of the combination of operating margin (OM) and build margin (BM) according to the procedures prescribed in the 'Tool to calculate the Emission Factor for an electricity system'

OR

(b) The weighted average emissions (in t-$CO_2$/MWh) of the current generation mix. The data of the year in which project generation occurs must be used".

For this study, the emission grid factor for baseline emissions applies a combined margin (CM) calculated by use of the 'Tool to calculate the Emission Factor for an electricity system'. The tool for calculating the baseline is comprised of the following seven steps;

STEP 1. Identify the relevant electricity systems.

STEP 2. Choose whether to include off-grid power plants in the project electricity system (optional).

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

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

STEP 5. Identify the group of power units to be included in the build margin (BM).

STEP 6. Calculate the build margin emission factor.

STEP 7. Calculate the combined margin (CM) emissions factor.

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

The electricity system is identified in Section 2 and Annex I.

***STEP 2. Choose whether to include off-grid power plants in the project electricity system (optional).***

Option I: 'Only grid power plants are included in the calculation', is chosen.

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

The calculation of the operating margin emission factor ($EF_{grid,OM,y}$) is 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 (option a) can only be used if low-cost/must-run resources constitute less than 50% of total grid generation in: 1) average of the five most recent years, or 2) based on long-term averages for hydroelectricity production.

**Table 3: Electrical output from low-cost/must-run sources in the Phnom Penh Grid System**

| Name of generator and power plant | Fuel type | Energy Sent Out / Input, MWh | | | | |
|---|---|---|---|---|---|---|
| | | 2005 | 2006 | 2007 | 2008 | 2009 |
| CETIC International Hydropower Development Co., Ltd | Hydro power | 40,854 | 47,653 | 46,498 | 43,292 | 44,380 |
| SL Garment Processing (Cambodia) Ltd | Wood | | 1,669 | 5,134 | 4,406 | 5,758 |
| Average generation from low-cost/must-run resources | | 47,929 | | | | |
| Total grid generation | | 752,542 | 911,188 | 1,105,548 | 1,270,024 | 1,021,075 |
| Average of total grid generation | | 1,012,075 | | | | |
| Low-cost/must-run resources share | | 4.74% < 50% | | | | |

Source: EAC 2010, 2009, 2008, 2007 and 2006.

*Imported electricity to the grid is excerpted in 2009

As the share of low-cost/must-run sources in the Phnom Penh Grid System is 4.74%, the simple OM method can be applied.

For the simple OM, the emissions factor can be calculated using either of the two data vintages: *Ex ante* option or *Ex post* option. The Ex ante option is chosen.

*Ex ante* option: If the *ex ante* option is chosen, the emission factor is determined once at the validation stage, thus no monitoring and recalculation of the emissions factor during the crediting period is required. For grid power plants, use a 3-year generation-weighted average, based on the most recent data available at the time of submission of the CDM-PDD to the DOE for validation

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

***(a) Simple OM***

The simple OM may be calculated:

Option A: Based on the net electricity generation and $CO_2$ 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.

Option A is available and chosen.

***Option A - Calculation based on average efficiency and electricity generation of each plant***

Under this option, the simple OM emission factor is calculated based on the net electricity generation of each power unit and an emission factor for each power unit, as follows:

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

where:

$EF_{grid,OMsimple,y}$ = Simple operating margin $CO_2$ emission factor in year *y* (t-$CO_2$/MWh)

$EG_{m,y}$ = Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)

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

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

units

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

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

The emission factor of each power unit *m* should be determined as follows:

**Option A1.** If for a power unit *m* data on fuel consumption and electricity generation is available, the emission factor ($EF_{EL,m,y}$) should be determined as follows:

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

where:

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

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

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

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

$EG_{m,y}$ = Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)

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

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

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

**Option A2.** If for a power unit *m* only data on electricity generation and the fuel types used is available, the emission factor should be determined based on the $CO_2$ emission factor of the fuel type used and the efficiency of the power unit, as follows:

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

where:

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

$EF_{CO2,m,i,y}$ = Average $CO_2$ emission factor of fuel type *i* used in power unit *m* in year *y*(t-$CO_2$/GJ)

$\eta_{m,y}$ = Average net energy conversion efficiency of power unit *m* in year *y* (ratio)

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

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

**Option A3.** If for a power unit *m* only data on electricity generation is available, an emission factor of 0 t-$CO_2$/MWh can be assumed as a simple and conservative approach.

For imports from connected electricity systems located in another host country(ies), the emission factor is 0 t-$CO_2$ per MWh.

**Table 4: Calculation of the operating margin**

| Plant | 2007 | | 2008 | | 2009 | |
|---|---|---|---|---|---|---|
| | Electricity generated | $CO_2$ emission factor | Electricity generated | $CO_2$ emission factor | Electricity generated | $CO_2$ emission factor |
| | MWh | t-$CO_2$ /MWh | MWh | t-$CO_2$ /MWh | MWh | t-$CO_2$ /MWh |
| Electricité du Cambodge | | | | | | |
| C3 | 21,770 | 0.6834 | 43,410 | 0.6705 | 22,610 | 0.6631 |
| C5 | 20,130 | 0.6602 | 24,440 | 0.6245 | 19,840 | 0.6881 |
| C6 | 51,820 | 0.6983 | 75,990 | 0.6756 | 43,700 | 0.7060 |
| Cambodia Utilities Pte. Limited | 258,490 | 0.7097 | 258,713 | 0.7061 | 182,224 | 0.7119 |
| Khmer Electrical Power Co., Ltd | 277,991 | 0.6830 | 317,848 | 0.6818 | 256,247 | 0.6721 |
| City Power Group Corporation | 38,238 | 0.6997 | 41,816 | 0.7023 | 34,113 | 0.7156 |
| Colben Energy (CAMBODIA) Ltd | 54,019 | 0.7842 | 45,696 | 0.8129 | 53,235 | 0.7818 |
| SHC (Cambodia) International Pte Ltd | 14,700 | 0.7514 | 34,501 | 0.7514 | 17,307 | 0.7509 |
| (Cambodia) Electricity Private Co, Ltd | 315,550 | 0.6906 | 325,883 | 0.6901 | 269,480 | 0.6951 |
| Sovanna Phum Investment Co., Ltd | | | 23,359 | 0.5934 | 28,033 | 0.6249 |
| Colben Energy (Cambodia) PPSEZ Limited | | | 35,658 | 0.7513 | 45,061 | 0.7713 |
| Imported from Vietnam | | | | | 374,166 | 0.0000 |
| Electricity Tramkhnar | | | | | 537 | 0.6702 |
| Mr. Bun Huy | | | | | 8 | 0.6702 |
| Mr. Toeng Samouv | | | | | 176 | 0.6702 |
| Annual Electricity generation in total | 1,052,708 | | 1,227,315 | | 1,346,739 | |
| **Simple operating margin $CO_2$ emission factor (t-$CO_2$ /MWh)** | **0.6989** | | **0.6951** | | **0.5236** | |
| **OM (t-$CO_2$ /MWh)** | | | | | **0.6257** | |

***STEP 5. Identify the group of power units to be included in the build margin***

The sample group of power units *m* used to calculate the build margin consists of either:

(a) The set of five power units that have been built most recently; or

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

Project participants should use the set of power units that comprises the larger annual generation.

In this case, (b), which is 269,348MWh, is larger than (a), which is 79,037MWh from Colben Energy (Cambodia) PPSEZ Limited, Sovanna Phum Investment Co., Ltd, Mr. Toeng Samouv, Mr. Bun Huy and SL Garment Processing (Cambodia) Ltd. As this set of five power units and (Cambodia) Electricity Private Co, Ltd comprises 20% of the system generation, these are adopted for the calculation.

***STEP 6. Calculate the build margin emission factor***

The build margin emissions factor is the generation-weighted average emission factor (t-$CO_2$/MWh) of all power units *m* during the most recent year *y* for which power generation data is available, calculated as follows:

$$EF_{grid,BMsimple,y} = \frac{\sum_m EG_{m,y} \times FE_{EL,m,y}}{\sum_m EG_{m,y}}$$

where:

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

$EG_{m,y}$ = Net quantity of electricity generated and delivered to the grid by power unit *m* in year *y* (MWh)

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

m = Power units included in the build margin

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

**Table 5: Calculation of the build margin for 2009**

| Power Plant | Year of operation | Fuel Type | Electricity Generated, MWh | $CO_2$ Emission Factor, t-$CO_2$/MWh |
|---|---|---|---|---|
| Colben Energy (Cambodia) PPSEZ Limited | 2008 | HFO | 45,061 | 0.7713 |
| Sovanna Phum Investment Co., Ltd | 2008 | Coal | 28,033 | 0.6249 |
| Mr. Toeng Samouv | 2007 | DO | 176 | 0.6702 |
| Mr. Bun Huy | 2007 | DO | 8 | 0.6702 |
| SL Garment Processing (Cambodia) Ltd | 2006 | Wood | 5,758 | 0.0000 |
| (Cambodia) Electricity Private Co, Ltd | 2006 | HFO | 269,480 | 0.6951 |
| **Total** | | | **348,517** | |
| **BM (t-$CO_2$/MWh)** | | | | **0.6878** |

***STEP 7. Calculate the combined margin emissions factor***

The combined margin emissions factor is calculated as follows:

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

where:

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

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

$w_{OM}$ = Weighting of operating margin emissions factor (%)

$w_{BM}$ = Weighting of build margin emissions factor (%)

The following default values should be used for $w_{OM}$ and $w_{BM}$:

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

• All other projects: $w_{OM}$ = 0.5 and $w_{BM}$ = 0.5 for the first crediting period, and $w_{OM}$ = 0.25 and $w_{BM}$ = 0.75 for the second and third crediting period, unless otherwise specified in the approved methodology which refers to this tool.

Based on Tables 4 and 5, the emission factors for the renewable energy CDM project supplying power to the grid are shown below:

**Table 6: Summary of the CDM Baseline Construction for the Phnom Penh Electricity Grid**

($t\text{-}CO_2/MWh$)

| | |
|---|---|
| Operating margin from 2007-2009 | 0.6257 |
| Build margin 2009 | 0.6878 |
| **Combined margin :**<br>Wind and solar power generation project activities for the first crediting period and for subsequent crediting periods | **0.6413** |
| **Combined margin:**<br>All other projects for the first crediting period | **0.6568** |
| **Combined margin:**<br>All other projects for the second and third crediting periods | **0.6723** |

# Annex I

Descriptions of the electricity generation plants supplying power to the Phonon Penh Grid System[2]

- The C3 power station is located in the Boeng Tumpun commune, Mean Chey district, with an installed capacity of 15.4MW. The electricity is generated from diesel generators, and the electrical output was 21.8GWh, 43.4GWh and 22.6GWh in 2007, 2008 and 2009 respectively.

- The C5 power station has two 5MW generators with a total installed capacity of 13MW. The plant was granted by Japan in 1995 and commissioned in 1996. The electrical output of the plant was 20.1GWh, 24.4GWh and 19.8GWh in 2007, 2008 and 2009 respectively.

- The C6 power station is adjacent to C5 and is comprised of three generator sets which were recently converted from Diesel Oil (DO) to Heavy Fuel Oil (HFO). The total installed capacity of the plant is 18.6MW. It was commissioned in 1996. The plant generated 51.8GWh, 76.0GWh and 43.7GWh of electricity in 2007, 2008 and 2009 respectively.

- The Cambodia Utilities Pte Ltd. (CUPL) is comprised of seven 5 MW generators operating on HFO. This plant was commissioned in 1996/97 and is located at the Chak Angrae Leu commune in the Mean Chey district. The electricity output generated was 258.5GWh, 258.7GWh and 182.2GWh in 2007, 2008 and 2009 respectively.

- The Kirirom 1 Hydropower Plant is operated by CETIC (China Electric Power Technology Import & Export Corporation) International Hydropower Development Co., Ltd. The company obtained permission to rebuild the project which was recommissioned in May 2002 with a capacity of 12MW and an upgraded 115kV

[2] EAC

transmission line to Phnom Penh. The project generated about 46.5GWh, 43.3GWh and 44.4GWh in 2007, 2008 and 2009, respectively.

- Khmer Electrical Power Co., Ltd. operates an electrical power generating plant of total capacity of 48 MW, consisting of six Wartsila-type diesel generator units rated at 8 MW, located in Phum Dam Nak Thom, Sangkat Steung Mean Chay, Khan Mean Chay, Phnom Penh for supplying electricity to the distribution system of EDC. It was commissioned in 2005. The normal fuel for the plant is HFO. The electrical output of the plant was 278.0GWh, 317.8GWh and 256.2GWh in 2007, 2008 and 2009 respectively

- City Power Group Corporation operates an HFO Power Plant of total capacity of 8.1 MW, consisting of three 9H25/33-type diesel generator units rated at 2.7MW, in Phum Tror Peang Chrey, Sangkat Kar Kap, Khan Dang Kor, Phnom Penh for supplying electricity to the distribution system of EDC. It was commissioned in 2005. The normal fuel for the Plant is HFO. The electrical output of the plant was 38.2GWh, 41.8GWh and 34.1GWh in 2007, 2008 and 2009 respectively

- Colben Energy (Cambodia) Limited operates an HFO power plant with a total installed capacity of 14.8MW, consisting of two diesel generators (SEMT Pielstick) rated at 5.4MW and one diesel generator (IHI-SEMT Pielstick) rated at 4MW, located in land lot No. 283, Phum Boung Salang, Sangkat Russey Keo, Khan Russey Keo, Phnom Penh for supplying electricity to EDC's distribution system in Phnom Penh. It was commissioned in 2006. The normal fuel for the Plant is HFO. The electrical output of the plant was 54.0GWh, 45.7GWh and 53.2GWh in 2007, 2008 and 2009 respectively

- SHC (Cambodia) International Pte Ltd. operates a diesel power plant of total capacity of 13.639 MVA, consisting of 18 diesel generator Units with:-21 diesel engines with installed capacity of 619 kVA each -1 diesel engine with installed capacity of 640 kVA, located in the EDC's Power Plant Nº 1, Nº 3 and Nº 5 in Phnom Penh for supplying electricity to the distribution system of EDC. It was commissioned in 2006.

The normal fuel for the operation of the Power Plant is DO. The electrical output of the plant was 14.7GWh, 34.5GWh and 17.3GWh in 2007, 2008 and 2009 respectively

- (Cambodia) Electricity Private Co., Ltd operates an electrical power generating plant with a total installed capacity of 60.2MW and contracted capacity of 45MW, consisting of six Wartsila-type diesel generator units rated at 10.040MVA, located in Phum Tuol Pongro, Sangkat Chom Chao, Khan Dang Kor, Phnom Penh for supplying electricity to the distribution system of EDC. It was commissioned in 2006. The normal fuel for the Plant is HFO. The electrical output of the plant was 315.6GWh, 325.9GWh and 269.5GWh in 2007, 2008 and 2009 respectively.

- SL Garment Processing (Cambodia) Ltd operates a thermal generating plant of a total installed capacity of 4.5MW, consisting of two thermal generators rated at 3MW and 1.5MW, located in Phum Russey, Sangkat Steungmeanchhey, Khan Meanchhey, Phnom Penh for supplying electricity to the distribution system of EDC. It was commissioned in 2006. The normal fuel for the Plant is wood. The electrical output of the plant was 5.1GWh, 4.4GWh and 5.8GWh in 2007, 2008 and 2009 respectively.

- Sovannaphum Investment Co., Ltd operates a thermal generating plant of total installed capacity 13MW, and consists of two thermal generators (10MW and 3MW), located in Khum Samrong Thom, Keansvay District, Kandal Province for supplying electricity to distribution system of EDC. It was commissioned in 2008. The normal fuel for the plant is coal. The electrical output of the plant was 23.4GWh in 2008 and 28GWh in 2009.

- Colben Energy (Cambodia) PPSEZ Limited operates a power generating plant of total installed capacity of 13MW, consisting of two generators (6.5MW each), located in Phnom Penh Special Economic Zone for supplying electricity to EDC. It was commissioned in 2008. The normal fuel for the Plant is HFO. The electrical output of the plant was 35.7GWh in 2008 and 45.1GWh in 2009.

Three small generator houses, Electricity Tramkhnar (DO), Mr. Bun Huy (DO) and Mr. Toeng Samouv (DO), started to supply electricity to the Phnom Penh Grid System in 2009, due to the grid extension.

# Annex Ⅱ

**Table 7: Worksheet for the estimation of $CO_2$ emissions from Power Plants in the Phnom Penh Grid System in 2007**

| **Worksheet** | | **$CO_2$ emissions from Power Plants in Phnom Penh in 2007** | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **A** | **B** | **C** | **D** | **E** | **F** | **G** |
| M | | i | $EG_m$ | $FC_{i,m}$ | $NCV_i$ | $EF_{CO2,i}$ | $\eta_m$ | $EF_{EL,m}$ | |
| Name of Power Plant | Option | Fuel Type | Electricity Generated MWh | Fuel Consumption t | Net Calorific Value* GJ/t | $CO_2$ Emission Factor* t-$CO_2$/GJ | Ave.Net Energy Conversion Efficiency % | $CO_2$ Emission Factor t-$CO_2$/MWh | $CO_2$ Emissions t-$CO_2$ |
| | | | | | | | | A1: F=(BxCxD)/A A2: F=Dx3.6/E | G=AxF |
| Electricité du Cambodge | | | | | | | | | |
| C3 | A1 | DO | 21,770 | 4,950 | 41.4 | 0.0726 | | 0.6834 | 14,878 |
| C5 | A1 | HFO | 20,130 | 4,423 | 39.8 | 0.0755 | | 0.6602 | 13,291 |
| C6 | A1 | HFO | 51,820 | 12,042 | 39.8 | 0.0755 | | 0.6983 | 36,185 |
| Cambodia Utilities Pte. Limited | A1 | HFO | 258,490 | 61,053 | 39.8 | 0.0755 | | 0.7097 | 183,458 |
| Khmer Electrical Power Co., Ltd | A1 | HFO | 277,991 | 63,186 | 39.8 | 0.0755 | | 0.6830 | 189,868 |
| City Power Group Corporation | A1 | HFO | 38,238 | 8,904 | 39.8 | 0.0755 | | 0.6997 | 26,756 |
| Colben Energy (CAMBODIA) Ltd | A1 | HFO | 54,019 | 14,097 | 39.8 | 0.0755 | | 0.7842 | 42,360 |
| SHC (Cambodia) International Pte Ltd | A1 | DO | 14,700 | 3,675 | 41.4 | 0.0726 | | 0.7514 | 11,046 |
| (Cambodia) Electricity Private Co, Ltd | A1 | HFO | 315,550 | 72,522 | 39.8 | 0.0755 | | 0.6906 | 217,921 |
| | | | | | | | **$EF_{grid, OMsimple,2007}$** | | **0.6989** |

*IPCC2006

**Table 8: Worksheet for the estimation of $CO_2$ emissions from Power Plants in the Phnom Penh Grid System in 2008**

| Worksheet | | $CO_2$ emissions from Power Plants in Phnom Penh in 2008 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G |
| M | | i | $EG_m$ | $FC_{i,m}$ | $NCV_i$ | $EF_{CO2,i}$ | $\eta_m$ | $EF_{EL,m}$ | |
| Name of Power Plant | Option | Fuel Type | Electricity Generation<br>MWh | Fuel Consumption<br>t | Net Calorific Value*<br>GJ/t | $CO_2$ Emission Factor *<br>t-$CO_2$/GJ | Ave. Net Energy Conversion Efficiency<br>% | $CO_2$ Emission Factor<br>t-$CO_2$/MWh | $CO_2$ Emissions<br>t-$CO_2$ |
| | | | | | | | | A1: F=(BxCxD)/A<br>A2: F=Dx3.6/E | G=AxF |
| Electricité du Cambodge | | | | | | | | | |
| C3 | A1 | DO | 43,410 | 9,684 | 41.4 | 0.0726 | | 0.6705 | 29,107 |
| C5 | A1 | HFO | 24,440 | 5,079 | 39.8 | 0.0755 | | 0.6245 | 15,262 |
| C6 | A1 | HFO | 75,990 | 17,085 | 39.8 | 0.0755 | | 0.6756 | 51,339 |
| Cambodia Utilities Pte. Limited | A1 | HFO | 258,713 | 60,794 | 39.8 | 0.0755 | | 0.7061 | 182,680 |
| Khmer Electrical Power Co., Ltd | A1 | HFO | 317,848 | 72,117 | 39.8 | 0.0755 | | 0.6818 | 216,704 |
| City Power Group Corporation | A1 | HFO | 41,816 | 9,773 | 39.8 | 0.0755 | | 0.7023 | 29,367 |
| Colben Energy (CAMBODIA) Ltd | A1 | HFO | 45,696 | 12,362 | 39.8 | 0.0755 | | 0.8129 | 37,147 |
| SHC (Cambodia) International Pte Ltd | A1 | DO | 34,501 | 8,625 | 41.4 | 0.0726 | | 0.7514 | 25,924 |
| (Cambodia) Electricity Private Co, Ltd | A1 | HFO | 325,883 | 74,840 | 39.8 | 0.0755 | | 0.6901 | 224,887 |
| Sovanna Phum Investment Co., Ltd | A1 | Coal | 23,359 | 27,727 | 5.5 | 0.0909 | | 0.5934 | 13,862 |
| Colben Energy (Cambodia) PPSEZ Limited | A1 | HFO | 35,658 | 8,915 | 39.8 | 0.0755 | | 0.7513 | 26,789 |
| | | | | | | | **$EF_{grid, OMsimple,2008}$** | | **0.6951** |

*IPCC 2006

**Table 9: Worksheet for the estimation of $CO_2$ emissions from Power Plants in the Phnom Penh Grid System in 2009**

| Worksheet | | $CO_2$ emissions from Power Plants in Phnom Penh in 2009 | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | A | B | C | D | E | F | G |
| M | | i | $EG_m$ | $FC_{i,m}$ | $NCV_i$ | $EF_{CO2,i}$ | $\eta_m$ | $EF_{EL,m}$ | |
| Name of Power Plant | Option | Fuel Type | Electricity Generated<br>MWh | Fuel Consumption<br>t | Net Calorific Value*<br>GJ/t | $CO_2$ Emission Factor *<br>t-$CO_2$/GJ | Ave.Net Energy Conversion Efficiency<br>% | $CO_2$ Emission Factor<br>t-$CO_2$/MWh | $CO_2$ Emissions<br>t-$CO_2$ |
| | | | | | | | | A1: F=(BxCxD)/A<br>A2: F=Dx3.6/E | G=AxF |
| Electricité du Cambodge | | | | | | | | | |
| C3 | A1 | DO | 22,610 | 4,988 | 41.4 | 0.0726 | | 0.6631 | 14,992 |
| C5 | A1 | HFO | 19,840 | 4,543 | 39.8 | 0.0755 | | 0.6881 | 13,651 |
| C6 | A1 | HFO | 43,700 | 10,267 | 39.8 | 0.0755 | | 0.7060 | 30,851 |
| Cambodia Utilities Pte. Limited | A1 | HFO | 182,224 | 43,169 | 39.8 | 0.0755 | | 0.7119 | 129,719 |
| Khmer Electrical Power Co., Ltd | A1 | HFO | 256,247 | 57,313 | 39.8 | 0.0755 | | 0.6721 | 172,220 |
| City Power Group Corporation | A1 | HFO | 34,113 | 8,124 | 39.8 | 0.0755 | | 0.7156 | 24,412 |
| Colben Energy (CAMBODIA) Ltd | A1 | HFO | 53,235 | 13,851 | 39.8 | 0.0755 | | 0.7818 | 41,621 |
| SHC (Cambodia) International Pte Ltd | A1 | DO | 17,307 | 4,324 | 41.4 | 0.0726 | | 0.7509 | 12,996 |
| (Cambodia) Electricity Private Co, Ltd | A1 | HFO | 269,480 | 62,337 | 39.8 | 0.0755 | | 0.6951 | 187,316 |
| Sovanna Phum Investment Co., Ltd | A1 | Coal | 28,033 | 35,041 | 5.5 | 0.0909 | | 0.6249 | 17,519 |
| Colben Energy (Cambodia) PPSEZ Limited | A1 | HFO | 45,061 | 11,567 | 39.8 | 0.0755 | | 0.7713 | 34,758 |
| Imported from Vietnam | Imported | | 374,166 | | | 0 | | 0.0000 | 0 |
| Electricity Tramkhnar | A2 | DO | 537 | | 41.4 | 0.0726 | 39% | 0.6702 | 360 |
| Mr. Bun Huy | A2 | DO | 8 | | 41.4 | 0.0726 | 39% | 0.6702 | 5 |
| Mr. Toeng Samouv | A2 | DO | 176 | | 41.4 | 0.0726 | 39% | 0.6702 | 118 |
| | | | | | | | **$EF_{grid, OMsimple,2009}$** | | **0.5053** |

*IPCC 2006

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