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IGES Clean Development Mechanism

Capacity Building Programme

Grid Emission Factor of the Phnom Penh Electricity Grid

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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 : Wind and solar power generation project activities for the first crediting period and for subsequent crediting periods	**0.6413**
Combined margin: All other projects for the first crediting period	**0.6568**
Combined margin: 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	$EF_{CO2,i}$	η_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.

**Both default Net Calorific Value (NCV) and CO_2 Emission Factor for Heavy Fuel Oil (HFO) refers to the values equivalent to those with Residual Fuel Oil.

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	$EF_{CO2,i}$	η_m	$EF_{EL,m}$	
Name of Power Plant	Option	Fuel Type	Electricity Generation 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	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.
**Both default Net Calorific Value (NCV) and CO_2 Emission Factor for Heavy Fuel Oil (HFO) refers to the values equivalent to those with Residual Fuel Oil.
***Coal refers to the values of Lignite.

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

Worksheet		CO₂ 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	$EF_{CO2,i}$	η_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	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.

**Both default Net Calorific Value (NCV) and CO_2 Emission Factor for Heavy Fuel Oil (HFO) refers to the values equivalent to those with Residual Fuel Oil.

***Coal refers to the values of Lignite.

Table 10: Default net calorific values (NCVs) and lower and upper limits of the 95% confidence intervals[1], 2006 IPCC Guidelines for National Greenhouse Gas Inventories, page 1.18

Fuel type English description		Net calorific value (TJ/Gg)	Lower	Upper
	Crude Oil	42.3	40.1	44.8
	Orimulsion	27.5	27.5	28.3
	Natural Gas Liquids	44.2	40.9	46.9
Gasoline	Motor Gasoline	44.3	42.5	44.8
	Aviation Gasoline	44.3	42.5	44.8
	Jet Gasoline	44.3	42.5	44.8
	Jet Kerosene	44.1	42	45
	Other Kerosene	43.8	42.4	45.2
	Shale Oil	38.1	32.1	45.2
	Gas/Diesel Oil	43	41.4	43.3
	Residual Fuel Oil	40.4	39.8	41.7
	Liquefied Petroleum Gases	47.3	44.8	52.2
	Ethane	46.4	44.9	48.8
	Naphtha	44.5	41.8	46.5
	Bitumen	40.2	33.5	41.2
	Lubricants	40.2	33.5	42.3
	Petroleum Coke	32.5	29.7	41.9
	Refinery Feedstocks	43	36.3	46.4
Other Oil	Refinery Gas [2]	49.5	47.5	50.6
	Paraffin Waxes	40.2	33.7	48.2
	White Spirit and SBP	40.2	33.7	48.2
	Other Petroleum Products	40.2	33.7	48.2
	Anthracite	26.7	21.6	32.2
	Coking Coal	28.2	24	31
	Other Bituminous Coal	25.8	19.9	30.5
	Sub-Bituminous Coal	18.9	11.5	26
	Lignite	11.9	5.5	21.6
	Oil Shale and Tar Sands	8.9	7.1	11.1
	Brown Coal Briquettes	20.7	15.1	32
	Patent Fuel	20.7	15.1	32
Coke	Coke Oven Coke and Lignite Coke	28.2	25.1	30.2
	Gas Coke	28.2	25.1	30.2
	Coal Tar [3]	28	14.1	55
Derived Gases	Gas Works Gas [4]	38.7	19.6	77
	Coke Oven Gas [5]	38.7	19.6	77
	Blast Furnace Gas [6]	2.47	1.2	5
	Oxygen Steel Furnace Gas [7]	7.06	3.8	15
	Natural Gas	48	46.5	50.4
	Municipal Wastes (non-biomass fraction)	10	7	18
	Industrial Wastes	NA	NA	NA
	Waste Oil [8]	40.2	20.3	80
	Peat	9.76	7.8	12.5

Fuel type English description		Net calorific value (TJ/Gg)	Lower	Upper
Solid Biofuels	Wood/Wood Waste [9]	15.6	7.9	31
	Sulphite lyes (black liquor) [10]	11.8	5.9	23
	Other Primary Solid Biomass [11]	11.6	5.9	23
	Charcoal [12]	29.5	14.9	58
Liquid Biofuels	Biogasoline [13]	27	13.6	54
	Biodiesels [14]	27	13.6	54
	Other Liquid Biofuels [15]	27.4	13.8	54
GasBiomass	Landfill Gas [16]	50.4	25.4	100
	Sludge Gas [17]	50.4	25.4	100
	Other Biogas [18]	50.4	25.4	100
Other non-fossil fuels	Municipal Wastes (biomass fraction)	11.6	6.8	18

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

Table 11: Default CO_2 emission factors for combustion, 2006 IPCC Guidelines for National Greenhouse Gas Inventories[1], page 1.23

Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/ 12*1000	Lower	Upper
	Crude Oil	20	1	73300	71100	75500
	Orimulsion	21	1	77000	69300	85400
	Natural Gas Liquids	17.5	1	64200	58300	70400
Gasoline	Motor Gasoline	18.9	1	69300	67500	73000
	Aviation Gasoline	19.1	1	70000	67500	73000
	Jet Gasoline	19.1	1	70000	67500	73000
	Jet Kerosene	19.5	1	71500	69700	74400
	Other Kerosene	19.6	1	71900	70800	73700
	Shale Oil	20	1	73300	67800	79200
	Gas/Diesel Oil	20.2	1	74100	72600	74800
	Residual Fuel Oil	21.1	1	77400	75500	78800
	Liquefied Petroleum Gases	17.2	1	63100	61600	65600
	Ethane	16.8	1	61600	56500	68600
	Naphtha	20	1	73300	69300	76300
	Bitumen	22	1	80700	73000	89900
	Lubricants	20	1	73300	71900	75200
	Petroleum Coke	26.6	1	97500	82900	115000
	Refinery Feedstocks	20	1	73300	68900	76600
Other Oil	Refinery Gas	15.7	1	57600	48200	69000
	Paraffin Waxes	20	1	73300	72200	74400
	White Spirit & SBP	20	1	73300	72200	74400
	Other Petroleum Products	20	1	73300	72200	74400
	Anthracite	26.8	1	98300	94600	101000
	Coking Coal	25.8	1	94600	87300	101000
	Other Bituminous Coal	25.8	1	94600	89500	99700
	Sub-Bituminous Coal	26.2	1	96100	92800	100000
	Lignite	27.6	1	101000	90900	115000
	Oil Shale and Tar Sands	29.1	1	107000	90200	125000
	Brown Coal Briquettes	26.6	1	97500	87300	109000
	Patent Fuel	26.6	1	97500	87300	109000
Coke	Coke oven coke and lignite Coke	29.2	1	107000	95700	119000
	Gas Coke	29.2	1	107000	95700	119000
	Coal Tar	22	1	80700	68200	95300
Derived Gases	Gas Works Gas	12.1	1	44400	37300	54100
	Coke Oven Gas	12.1	1	44400	37300	54100
	Blast Furnace Gas [4]	70.8	1	260000	219000	308000
	Oxygen Steel Furnace Gas [5]	49.6	1	182000	145000	202000

Fuel type English description		Default carbon content (kg/GJ)	Default carbon oxidation factor	Effective CO2 emission factor (kg/TJ) [2]		
				Default value [3]	95% confidence interval	
		A	B	C=A*B*44/ 12*1000	Lower	Upper
	Natural Gas	15.3	1	56100	54300	58300
	Municipal Wastes (non-biomass fraction)	25	1	91700	73300	121000
	Industrial Wastes	39	1	143000	110000	183000
	Waste Oil	20	1	73300	72200	74400
	Peat	28.9	1	106000	100000	108000
Solid Biofuels	Wood/Wood Waste	30.5	1	112000	95000	132000
	Sulphite lyes (black liquor)	26	1	95300	80700	110000
	Other Primary Solid Biomass	27.3	1	100000	84700	117000
	Charcoal	30.5	1	112000	95000	132000
Liquid Biofuels	Biogasoline	19.3	1	70800	59800	84300
	Biodiesels	19.3	1	70800	59800	84300
	Other Liquid Biofuels	21.7	1	79600	67100	95300
Gas biomass	Landfill Gas	14.9	1	54600	46200	66000
	Sludge Gas	14.9	1	54600	46200	66000
	Other Biogas	14.9	1	54600	46200	66000
Other non-fossil fuels	Municipal Wastes (biomass fraction)	27.3	1	100000	84700	117000

Notes:
1 The lower and upper limits of the 95 percent confidence intervals, assuming lognormal distributions, fitted to a dataset, based on national inventory reports, IEA data and available national data. A more detailed description is given in section 1.5
2 TJ = 1000GJ
3 The emission factor values for BFG includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas.
4 The emission factor values for OSF includes carbon dioxide originally contained in this gas as well as that formed due to combustion of this gas
5 Includes the biomass-derived CO2 emitted from the black liquor combustion unit and the biomass-derived CO2 emitted from the kraft mill lime kiln.

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