APPENDIX
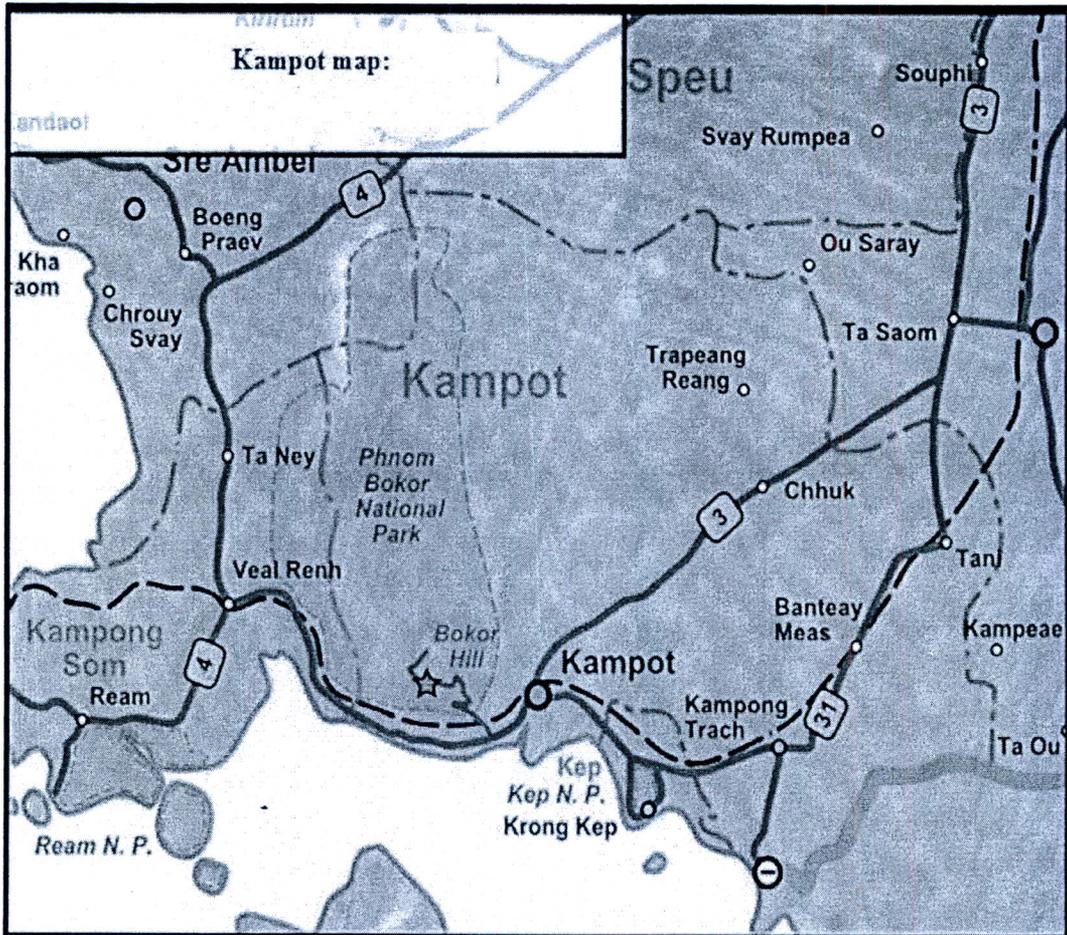
APPENDIX A: MAP OF KAMPOT PROVINCE

Kampot map:

07 KAMPOT

* Commune Code consists of District Code and two digits.

0701 Angkor Chey
070101	Angk Phnum Touch
070102	Ankor Chey
070103	Champei
070104	Dambouk Khpos
070105	Dan Koum
070106	Daeum Doung
070107	Mroum
070108	Phnum Kong
070109	Praphnum
070110	Samlanh
070111	Tani

0702 Banteay Meas
070201	Banteay Meas Khang Kaeut
070202	Banteay Meas Khang lech
070203	Prey Tonle
070204	Samraong Kraom
070205	Samraong Leu
070206	Sdach Kong Khang Cheung
070207	Sdach Kong Khang lech
070208	Sdach Kong Khang Tboung
070209	Tnoat Chong Srang
070210	Trapeang Sala Khang Kaeut
070211	Trapeang Sala Khang Lech
070212	Tuk Meas Khang Kaeut
070213	Tuk Meas Khang Lech
070214	Voat Angk Khang Cheung
070215	Voat Angk Khang Tboung

0703 Chhuk
070301	Baniev
070302	Takaen
070303	Boeng Nimol
070304	Chhuk
070305	Doun Yay
070306	Krang Sbov
070307	Krang Snay
070308	Lbaeuk
070309	Trapeang Phleang
070310	Mean Chey
070311	Neareay
070312	Satr Pong
070313	Trapeang Bei
070314	Tramaeng

0704 Chum Kiri
070401	Chres
070402	Chumpu Voan
070403	Snay Anhchit
070404	Srae Chaeng
070405	Srae Knong
070406	Srae Samraong
070407	Trapeang Reang

0705 Dang Tong
070501	Damnak Sokram
070502	Dang Tong
070503	Khcheay Khang Cheung
070504	Khcheay Khang Tboung
070505	Mean Ritth
070506	Srae Chea Khang Cheung
070507	Srae Chea khang Tboung
070508	Totung
070509	Angkor Meas
070510	L'ang

0706 Kampong Trach
070601	Boeng Sala Khang Cheung
070602	Boeng Sala Khang Tboung
070603	Damnak Kantuot Khang Cheung
070604	Damnak Kantuot Khang Tboung
070605	Kampong Trach Khang Kaeut
070606	Kampong Trach Khang Lech
070607	Kanthaor Khang Cheung
070608	Kanthaor Khang Kaeut
070609	Kanthaor Khang Lech
070612	Preaek Kroes
070613	Ruessei Srok Khang Kaeut
070614	Ruessei Srok Khang Lech
070615	Svay Tong Khang Cheung
070616	Svay Tong Khang Tboung

0707 Kampot
070701	Boeng Tuk
070702	Chum Kriel
070703	Kampong Kraeng
070704	Kampong Samraong
070705	Kandal
070707	Kaoh Touch
070708	Koun Satv
070709	Makprang
070711	Preaek Tnoat
070712	Prey Khmum
070713	Prey Thnang
070715	Stueng Kaev
070716	Thmei
070717	Trapeang Pring
070718	Trapeang Sangkae
070719	Trapeang Thum

0708 Kampong Bay
070801	Kampong Kandal
070802	Krang Ampil
070803	Kampong Bay
070804	Andoung Khmaer
070805	Traeuy Kaoh

* Codes and boundaries are as of February 9, 2009.

APPENDIX B: POPULATION OF CAMBODIA AND KAMPOT PROVINCE

Province	Population 1998	Population 2008
Banteay Meanchey	577,772	678,033
Battambang	793,129	1,024,663
Kampong Cham	1,608,914	1,680,694
Kampong Chhnang	417,693	471,616
Kampong Speu	598,882	716,517
Kampong Thom	569,060	630,803
Kampot	528,405	585,110
Kandal	1,075,125	1,265,085
Koh Kong	132,106	139,722
Kratie	263,175	318,523
Mondul Kiri	32,407	60,811
Phnom Penh	999,804	1,325,681
Preah Vihear	119,261	170,852
Prey Veng	946,042	947,357
Pursat	360,445	397,107
Ratanak Kiri	94,243	149,997
Siemreap	696,164	896,309
Sihanoukville	155,690	199,902
Stung Treng	81,074	111,734
Svay Rieng	478,252	482,785
Takeo	790,168	843,931
Oddar Meanchey	68,279	185,443
Kep	28,660	35,753
Pailin	22,906	70,482

Provisional Table 1. Number of Households and Population by Province and Sex						
Province	Number of Households	Population			Sex Ratio	Average Household Size (*)
		Both Sexes	Males	Females		
Cambodia – Total	2,832,691	13,388,910	6,495,512	6,893,398	94.2	4.7
Banteay Meanchey	144,400	678,033	331,289	346,744	95.5	4.6
Battambang	210,327	1,024,663	504,974	519,689	97.2	4.8
Kampong Cham	368,871	1,680,694	817,251	863,443	94.7	4.5
Kampong Chhnang	101,122	471,616	226,357	245,259	92.3	4.6
Kampong Speu	149,132	716,517	347,594	368,923	94.2	4.8
Kampong Thom	134,123	630,803	306,547	324,256	94.5	4.7
Kampot	129,745	585,110	283,604	301,506	94.1	4.5
Kandal	257,857	1,265,085	609,810	655,275	93.1	4.9
Koh Kong	28,853	139,722	70,665	69,057	102.3	4.8
Kratie	65,632	318,523	158,365	160,158	98.9	4.8
Mondul Kiri	12,296	60,811	31,128	29,683	104.9	4.9
Phnom Penh	257,828	1,325,681	622,197	703,484	88.4	5.1
Preah Vihear	33,260	170,852	84,909	85,943	98.8	5.1
Prey Veng	226,764	947,357	451,875	495,482	91.2	4.2
Pursat	83,515	397,107	192,354	204,753	93.9	4.7
Ratanak Kiri	27,396	149,997	75,827	74,170	102.2	5.5
Siemreap	180,097	896,309	437,994	458,315	95.6	5.0
Sihanoukville	40,478	199,902	99,226	100,676	98.6	4.9
Stung Treng	21,179	111,734	55,635	56,099	99.2	5.2
Svay Rieng	115,282	482,785	231,129	251,656	91.8	4.2
Takeo	183,905	843,931	409,799	434,132	94.4	4.6
Oddar Meanchey	38,642	185,443	93,193	92,250	101	4.8
Kep	7,234	35,753	17,603	18,150	97	4.9
Pailin	14,753	70,482	36,187	34,295	105.5	4.7

Based on Normal or Regular Households
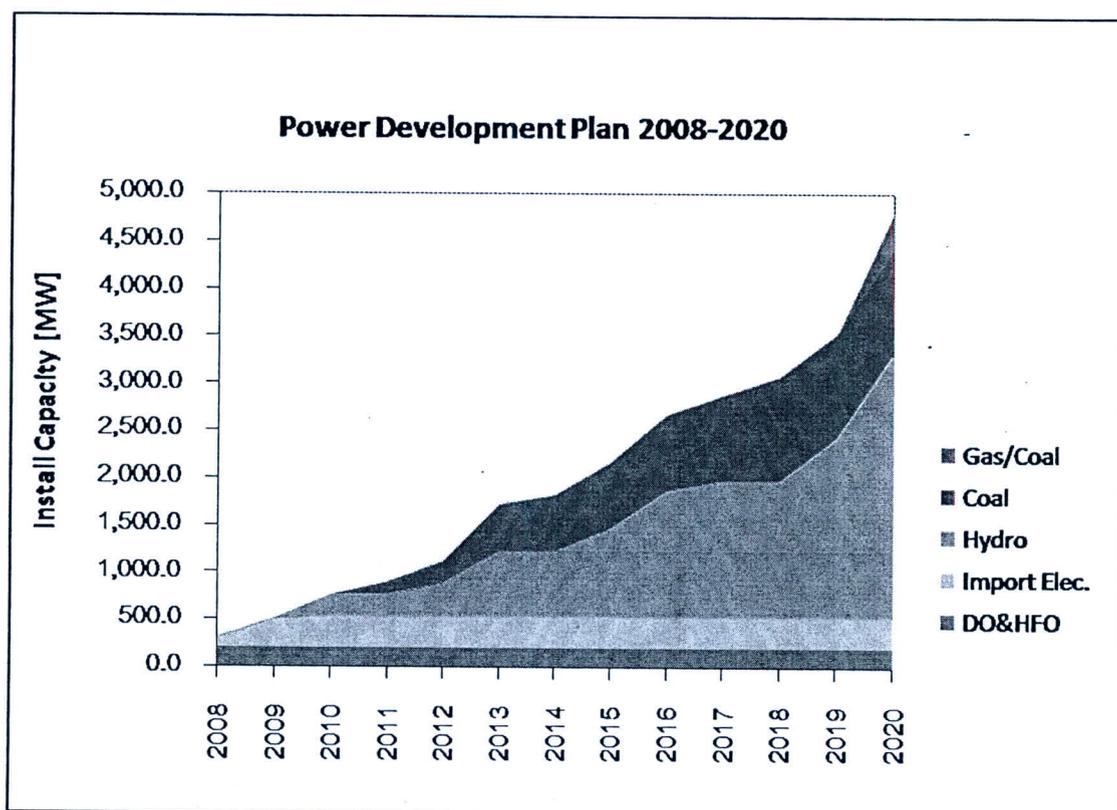
Population of Kampot province from 1998-2012

Province	1998	2004	2008	2012
Kampot	528,405	554,825	585,110	620,217

Source: National Institute of Statistics, Ministry of Planning in 2012 and
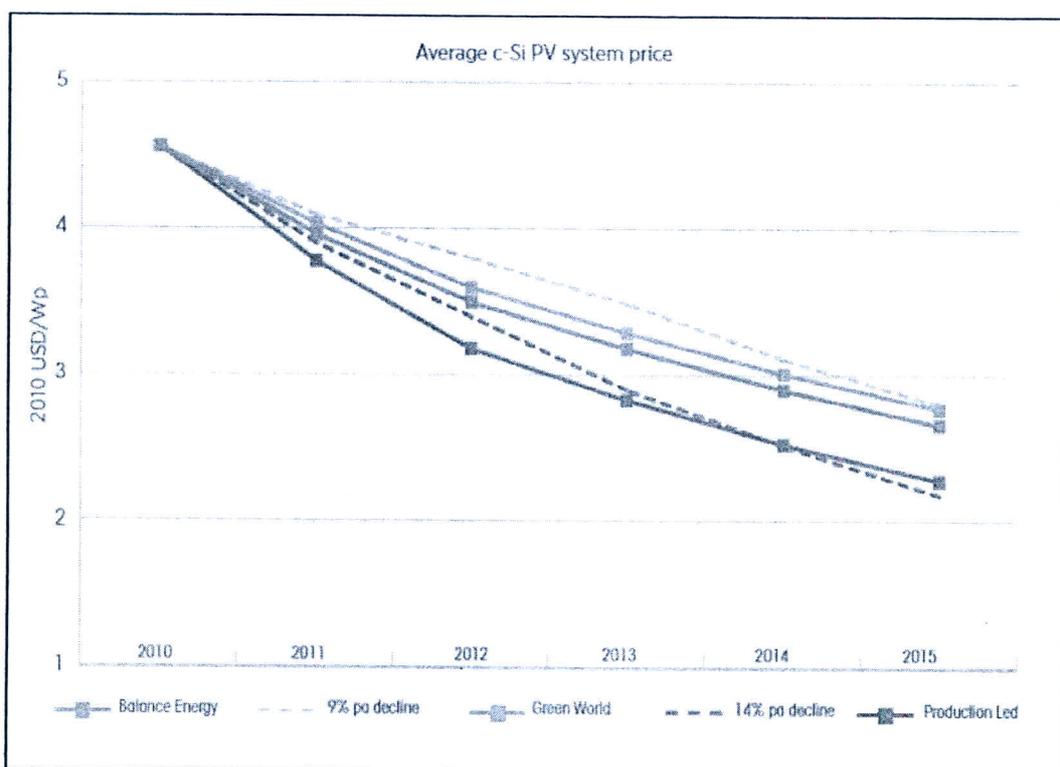(http://www. nis.gov.kh)

APPENDIX C: ELECTRICITY POWER PRODUCTION AND OTHER COSTS IN KAMPOT PROVINCE FROM 2004-2011 (KW)

Year	2004	2005	2006	2007	2008	2009	2010	2011
Capacity	427	611	3,691	6,173	27,076	51,616	75,860	78,246

Source: Annual report of EAC, 2012

Power Development Plan 2008-2020

Source: Ministry of Industry, Mines and Energy, 2008

Average c-Si PV system price

Legend: Balance Energy · · · 9% pa decline — Green World — — 14% pa decline — Production Led

Table 32: Diesel generation costs for different capacities of diesel gensets, and associated competitive PV/hybrid option

Capacity (kW)	Unit cost (USD/kW)	Specific consumption (L/kWh)	Diesel generation cost (Uscts/kWh)	Competitive PV/Hybrid option
20	450	0.40	44	100% storage (42 UScts/kWh)
30	337	0.38	42	
40	296	0.37	40	50% storage (34 UScts/kWh)
50	271	0.36	39	
60	255	0.35	38	
70	237	0.35	37	
80	218	0.34	36	
90	204	0.33	35	
100	192	0.33	35	
150	158	0.31	33	0% storage (27 UScts/kWh)
200	140	0.30	31	
250	130	0.29	30	
300	123	0.28	29	
400	114	0.27	28	

APPENDIX D: SOLAR RADIATION OF FIVE STATIONS IN CAMBODIA, 2010 (kWh/m²/d)

The solar energy potential of Cambodia can be determined from the geographical distribution of long-term average solar radiation which has been obtained from satellites. To investigate quantitatively this geographical distribution of solar radiation, the percentages of that area which receive different levels of solar radiation were shown the yearly radiation as table below.

Solar Radiation of five stations in Cambodia, 2010 (kWh/m²/day)

| Station	Sept	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug
Phnom Penh	5.39	4.77	4.86	5.10	4.75	5.12	5.18	5.23	5.39	5.13	5.61	5.29
Sihanouk Ville	3.94	4.56	4.86	5.35	5.25	4.67	5.18	5.23	4.08	4.09	4.35	4.12
Kampot	4.95	5.11	4.97	4.88	4.90	5.02	5.77	5.50	5.01	4.98	4.97	5.19
Kampong Thom	5.17	4.47	4.68	5.13	4.85	5.23	5.69	5.66	5.80	5.45	5.64	5.37
Siem Reap	4.95	4.35	4.77	4.95	4.84	4.91	5.66	5.89	5.48	5.35	5.52	5.18

Source: MOWRAM, 2010

APPENDIX E: PHOTOVOLTAIC TECHNOLOGY

1. Types of PV cells

Most commercially available solar cells have a lifespan of at least twenty to twenty-five years. Out of the following types of PV cells, only the first two are commercially available globally:

- Crystalline silicon (c-Si) modules represent 85 to 90% of the global annual market today. These are subdivided into: i) mono crystalline (mono-Si); and ii) polycrystalline (poly-Si). Metallurgical grade silicon is refined to form close to 99% pure silicon. Silicon ingots are obtained from molten poly silicon. Wafers are made by wire-sawing block-cast silicon ingots into very thin (180 to 350 micro-meter) slices. Two sides of the wafer are doped with two different dopants – one side is left electron deficient (the p-layer) and the other side has an excess of electrons (the n-layer). This forms a P–N junction a few hundred nanometers below the surface, which creates an electric field across the junction (PN junction).

- Thin films currently account for 10 to 15% of global PV module sales. These are subdivided into three main families: i) amorphous (a-Si); ii) cadmium telluride (CdTe); and iii) copper indium diselenide (CIS) and copper indium gallium dieselenide (CIGS). Thin film modules are created by coating entire sheets of glass or steel (called substrate) with thin layers of semiconductor materials rather than growing, slicing and treating a crystalline ingot. Emerging technologies include advanced thin films, dye-sensitized cells and organic cells. Concentrator photovoltaic (CPV) technologies use an optical concentrator system that focuses solar radiation onto a small high-efficiency cell. Multi-junction cells are a subclass of photovoltaic cells developed for higher efficiency. These use multiple layers of semiconductor material (from the group III and V elements of the periodic table) to absorb and convert more of the solar spectrum into electricity than is converted by single-junction cells. Hetero-junction with intrinsic thin layer (HIT) solar cells is composed of mono thin crystalline silicon wafer surrounded by ultra-thin amorphous silicon layers.
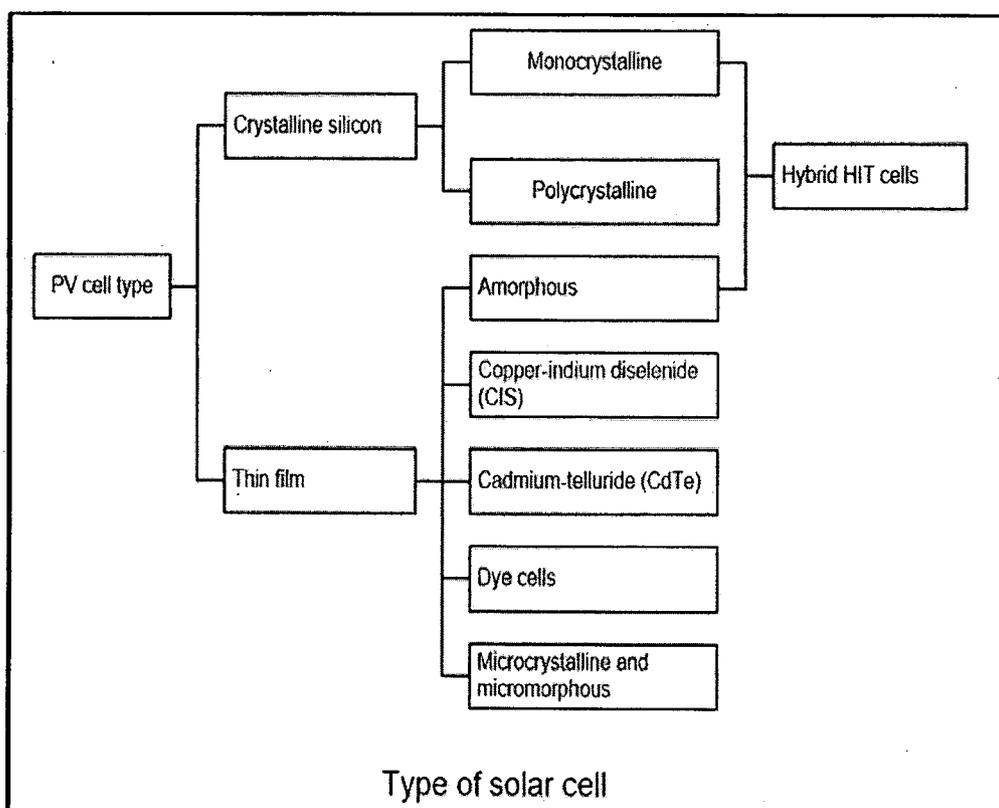
Type of solar cell

• Comparison of solar cell types

Solar cell	Cell efficiency (laboratory) η_{cell}	Cell efficiency (production) η_{cell}	Module efficiency (series production) η_{module}
Monocrystalline silicon	24.7%	18.0%	14.0%
Polycrystalline silicon	19.8%	16.0%	13.0%
Ribbon silicon	19.7%	14.0%	13.0%
Crystalline thin film silicon	19.2%	9.5%	7.9%
Amorphous silicon[a]	13.0%	10.5%	7.5%
Micromorphous silicon[a]	12.0%	10.7%	9.1%
Hybrid HIT solar cell	20.1%	17.3%	15.2%
CIS, CIGS	18.8%	14.0%	10.0%
Cadmium telluride	16.4%	10.0%	9.0%
III-V semiconductor	35.8%[b]	27.4%	27.0%
Dye-sensitized cell	12.0%	7.0%	5.0%

[a] in stabilized state
[b] measured with concentrated irradiance
[c] small production runs

APPENDIX F: POLICIES PROMOTING ON RENEWABLE ENERGY IN CAMBODIA

The Royal Government of Cambodia has set up the renewable energy policies as following:

1. Endeavor to provide access to reliable, safe electricity services, with insignificant impact on the environment and at an affordable price for rural communities;

2. Provide effective legal, regulatory frameworks and various to an encouragements and train the private sector to participate in providing electricity services by renewable energy to the rural areas;

3. Act as a market enable, through various incentives, for enabling equity in access to reliable and safe electricity services, with insignificant impact on the environment, at an affordable price for the rural communities;

4. Encourage the efficient generation, transmission and distribution of electricity using the renewable energy technologies, through tariffs, which are in conformity with the Electricity Authority of Cambodia (EAC)'s regulation;

5. Promote electricity systems by renewable energy at least cost for rural communities, through research and pilot development, as part of the Royal Government of Cambodia's portfolio on grid and off-grid technologies;

6. Ensure adequate resources, appropriate institutional mechanism and training to empower the poor involving in rural electrification to participate.

Source: Master Plan on Renewable Energy of the Ministry of Industry, Mines and Energy (MIME, 2005).

APPENDIX G: ECONOMIC CALCULATION OF C-Si PV WITH ORIGINAL ELECTRICITY PRICE OF 0.27 US$/KWH AND DIESEL BATTERY CHARGING STATION WITH CAPACITY OF 10 KW$_P$ WITH ORIGINAL ELECTRICITY PRICE OF 0.34 US$/KWH

PV battery charging station in Kampot province can calculate as below:

Charge controller (10 kW$_p$)			$1,500	Solar radiation =	5.2 kWh/m^2/day	(5 hrs/day)	
Investment cost of PV BCS (3US$/W$_p$)			$30,000	Annual Gen. =	14,045.20 kWh		
Electricity Cost from EAC, 2012 (kWh)			$0.27				
O & M		0.0005	$16				
Envir. Benefits		10.42US$/tonCO$_2$		0.01 US$/kgCO$_2$		DR =	6%
CO$_2$ Reduction Emission		0.43 kgCO$_2$/kWh		0.43			

Year	DF (6%)	Direct Benefit Annual Gen (kWh)	Electricity Cost (US$)	CO$_2$ Emission (US$)	Total Benefit (US$)	Total Investment Cost of system (US$)	O & M Cost	Total Cost	Benefit	Cost	NPV
0	1.00	0.00	0.00	0.00	0.00	31,500.00	0.00	31,860.00	0.00	31,860.00	-31,860.00
1	0.94	14,045.20	3,792.20	62.93	3,855.13		15.75	1,335.75	3,636.92	1,260.14	2,376.78
2	0.89	14,044.08	3,867.74	62.93	3,930.66		16.07	1,336.07	3,498.28	1,189.09	2,309.18
3	0.84	14,042.95	3,944.78	62.92	4,007.70		16.39	1,336.39	3,364.94	1,122.06	2,242.89
4	0.79	14,041.83	4,023.35	62.92	4,086.27		16.71	1,336.71	3,236.71	1,058.80	2,177.90
5	0.75	14,040.71	4,103.49	62.91	4,166.40	1,500.00	17.05	2,837.05	3,113.38	2,120.01	993.37
6	0.70	14,039.58	4,185.23	62.91	4,248.13		17.39	1,337.39	2,994.76	942.81	2,051.96
7	0.67	14,038.46	4,268.59	62.90	4,331.49		17.74	1,337.74	2,880.69	889.67	1,991.02
8	0.63	14,037.34	4,353.61	62.90	4,416.51		18.09	1,338.09	2,770.97	839.54	1,931.44
9	0.59	14,036.21	4,440.33	62.89	4,503.22		18.45	1,338.45	2,665.45	792.23	1,873.22
10	0.56	14,035.09	4,528.77	62.89	4,591.66		18.82	1,338.82	2,563.96	747.59	1,816.37
11	0.53	14,033.97	4,618.98	62.88	4,681.86	1,500.00	19.20	2,839.20	2,466.35	1,495.65	970.69
12	0.50	14,032.85	4,710.98	62.88	4,773.86		19.58	1,339.58	2,372.46	665.73	1,706.73
13	0.47	14,031.72	4,804.82	62.87	4,867.69		19.97	1,339.97	2,282.16	628.23	1,653.93
14	0.44	14,030.60	4,900.52	62.87	4,963.39		20.37	1,340.37	2,195.31	592.85	1,602.46
15	0.42	14,029.48	4,998.13	62.86	5,060.99	1,500.00	20.78	2,840.78	2,111.78	1,185.36	926.42
16	0.39	14,028.36	5,097.69	62.86	5,160.54		21.20	1,341.20	2,031.43	527.96	1,503.47
17	0.37	14,027.23	5,199.22	62.85	5,262.07		21.62	1,341.62	1,954.15	498.23	1,455.92
18	0.35	14,026.11	5,302.78	62.85	5,365.63		22.05	1,342.05	1,879.81	470.18	1,409.63
19	0.33	14,024.99	5,408.41	62.84	5,471.25		22.49	1,342.49	1,808.32	443.71	1,364.61
20	0.31	14,023.87	5,516.13	62.84	5,578.97	1,500.00	22.94	2,842.94	1,739.55	886.44	853.11
21	0.29	14,022.74	5,626.01	62.83	5,688.84		23.40	1,343.40	1,673.40	395.17	1,278.23
22	0.28	14,021.62	5,738.07	62.83	5,800.89		23.87	1,343.87	1,609.78	372.93	1,236.85
23	0.26	14,020.50	5,852.36	62.82	5,915.18		24.35	1,344.35	1,548.58	351.95	1,196.63
24	0.25	14,019.38	5,968.93	62.82	6,031.75		24.84	1,344.84	1,489.71	332.15	1,157.57
25	0.23	14,018.26	6,087.82	62.81	6,150.63		25.33	1,345.33	1,433.09	313.46	1,119.63
Total		350,793.12	121,338.94	1,571.76	122,910.70	37,500.00	504.48	71,364.48	59,321.92	51,981.94	7,339.98

Labor	$1,320.00
Transportation	$0.00
Land	$360.00
Total	$1,680.00

4,916.43	20.18

IRR	19.19%
Benefit/Cost	1.14
LGOE	0.15	US$/kWh
Simple Payback Period	10.57	Years

O & M 0.05% of investment cost (Ketjoy N., 2005)

Note: Replaced charge controller every 5 years.

Charge controller cost = 1,500 US$.

Diesel battery charging station in Kampot province can be calculated as:

Annual Gen 13,200.00 kWh (4 hrs/day)

Investment cost of diesel system $3,000
Original Electricity Cost from EAC, 2012 (kWh) $0.34
O & M 7% $630.00
Diesel engine operation [(4h/day), 330/year] = 13,200.00 kWh

DR = 6%

| Year | DF (6%) | Direct Benefit | | Total Benefit (US$) | Total Investment Cost of system (US$) | Present Value @ 6% DR | | | | NPV |
		Annual Gen (kWh)	Electricity Cost (US$)			O & M Cost	Total Cost	Benefit	Cost	
0	1.00	0.00	0.00	0.00	3,000.00	0.00	4,100.00	0.00	4,100.00	-4,100.00
1	0.94	13,200.00	4,488.00	4,488.00		630.00	4,617.90	4,233.96	4,356.51	-122.55
2	0.89	13,200.00	4,577.76	4,577.76		642.60	4,630.50	4,074.19	4,121.13	-46.94
3	0.84	13,200.00	4,669.32	4,669.32		655.45	4,643.35	3,920.45	3,898.65	21.80
4	0.79	13,200.00	4,762.70	4,762.70		668.56	4,656.46	3,772.51	3,688.35	84.15
5	0.75	13,200.00	4,857.96	4,857.96		681.93	4,669.83	3,630.15	3,489.57	140.58
6	0.70	13,200.00	4,955.11	4,955.11		695.57	4,683.47	3,493.16	3,301.66	191.50
7	0.67	13,200.00	5,054.22	5,054.22		709.48	4,697.38	3,361.34	3,124.03	237.32
8	0.63	13,200.00	5,155.30	5,155.30		723.67	4,711.57	3,234.50	2,956.10	278.40
9	0.59	13,200.00	5,258.41	5,258.41		738.15	4,726.05	3,112.44	2,797.34	315.10
10	0.56	13,200.00	5,363.58	5,363.58	3,000.00	752.91	7,740.81	2,994.99	4,322.43	-1,327.43
11	0.53	13,200.00	5,470.85	5,470.85		767.97	4,755.87	2,881.97	2,505.33	376.64
12	0.50	13,200.00	5,580.26	5,580.26		783.33	4,771.23	2,773.22	2,371.15	402.07
13	0.47	13,200.00	5,691.87	5,691.87		798.99	4,786.89	2,668.57	2,244.28	424.29
14	0.44	13,200.00	5,805.71	5,805.71		814.97	4,802.87	2,567.87	2,124.31	443.55
15	0.42	13,200.00	5,921.82	5,921.82		831.27	4,819.17	2,470.97	2,010.87	460.10
16	0.39	13,200.00	6,040.26	6,040.26		847.90	4,835.80	2,377.72	1,903.59	474.13
17	0.37	13,200.00	6,161.06	6,161.06		864.85	4,852.75	2,288.00	1,802.14	485.86
18	0.35	13,200.00	6,284.28	6,284.28		882.15	4,870.05	2,201.66	1,706.19	495.47
19	0.33	13,200.00	6,409.97	6,409.97		899.80	4,887.70	2,118.58	1,615.45	503.13
20	0.31	13,200.00	6,538.17	6,538.17	3,000.00	917.79	7,905.69	2,038.63	2,465.03	-426.40
21	0.29	13,200.00	6,668.93	6,668.93		936.15	4,924.05	1,961.70	1,448.43	513.27
22	0.28	13,200.00	6,802.31	6,802.31		954.87	4,942.77	1,887.68	1,371.64	516.03
23	0.26	13,200.00	6,938.36	6,938.36		973.97	4,961.87	1,816.44	1,299.00	517.44
24	0.25	13,200.00	7,077.12	7,077.12		993.45	4,981.35	1,747.90	1,230.29	517.61
25	0.23	13,200.00	7,218.67	7,218.67		1,013.32	5,001.22	1,681.94	1,165.28	516.66
Total		330,000.00	143,751.99	143,751.99	9,000.00	20,179.09	129,976.59	69,310.55	67,418.77	1,891.78

Fuel dies	$2,187.90	
Labor	$1,800.00	5,750.08
Transportation	$950.00	
Land	$150.00	
Total	$5,087.90	

807.16

IRR =	2.15%
Benefit Cost =	1.03
LCOE =	0.20 US$/Wh
Simple Payback Period =	11.72 Years

O & M 7% of investment costs

Note: Replaced generator every 10 years.
Small-scale project = 0.45 L/kWh.