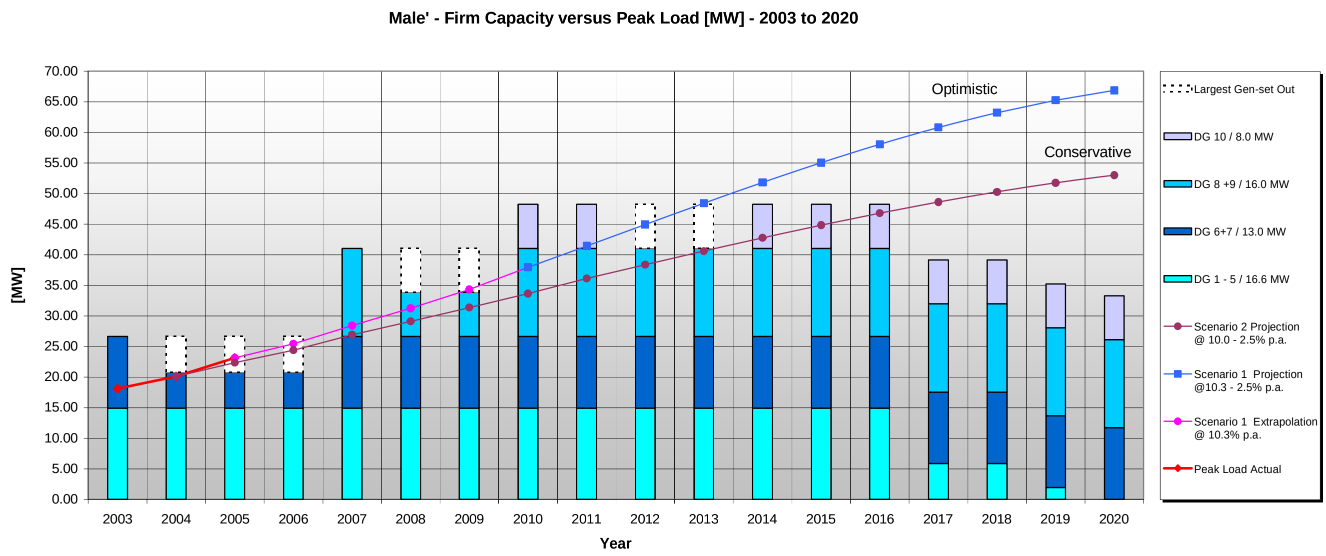
CHAPTER 4　TECHNICAL FEASIBILITY STUDY

4.1　Power Demand Projection

4.1.1　Male' Island

In the aftermath of the Tsunami disaster caused by Sumatra earthquake of December 2004, there has been steady migration of people from outer islands to Male' Island and the demand for electricity here has increased rapidly. The latest power demand projection conducted by STELCO was the Power Extension Study that was conducted by German consultant OLP in 2004, and this made a forecast of peak demand on Male' and Hulhumale' Islands up to 2020. For Male' Island, this study estimated two scenarios: a high growth case and a low growth case; however, even in the low growth case, peak load is expected to exceed the firm capacity of generator facilities (the capacity obtained after deducting the largest generator capacity from the 85% of total rated capacity) in 2013, indicating an urgent need to reinforce generating facilities. Accordingly, STELCO commenced the Fourth Power System Development Project under support from DANIDA (Denmark) in 2009. This entails the procurement and installation of two DEGs (8 MW) with construction of foundations for three units and is scheduled for completion in 2010. It is planned to procure and install the third unit under this project in 2011.



Source：STELCO

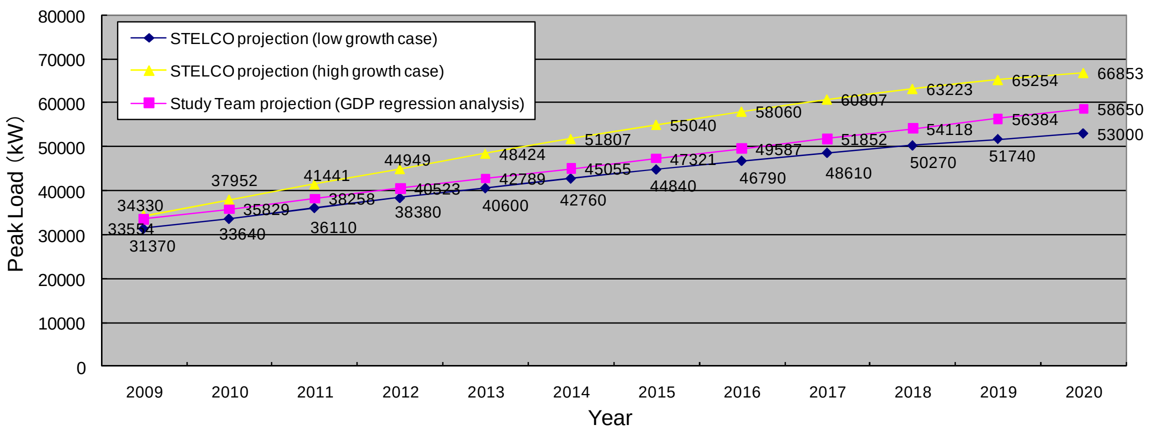
Figure 4.1.1-1　Power Demand Projection for Male' Island (STELCO)

The Study Team conducted regression analysis based on the minimum square method utilizing GDP values (by the Ministry of Finance) from 1997 to 2007 and GDP projections from 2008 to 2011 as the first parameter and population statistics from 2000 to 2007 as the second parameter, and compared the findings with the above projection by STELCO. The prediction model was constructed on the econometric simulation software Simple EE, which is used for projecting power demand in East Asia. Generally speaking, since econometric models are constructed as an aggregate of numerous estimation expressions and definitional expressions, it is necessary to verify the model validity. In the Study, model validity was verified through using the following indicators:

Coefficient of determination (R^2) (expressing overall model certainty): 0.85 or more

Value t (estimated coefficient assessing reference accuracy): Absolute value of 2 or more

As a result of conducting regression analysis on peak load, R^2 = 0.979 and t = 2.57 were obtained and the validity of the constructed model was verified. In the future, these projection findings will be used to project peak load on each distribution line feeder and estimate the maximum PV capacity that can be connected to each feeder.

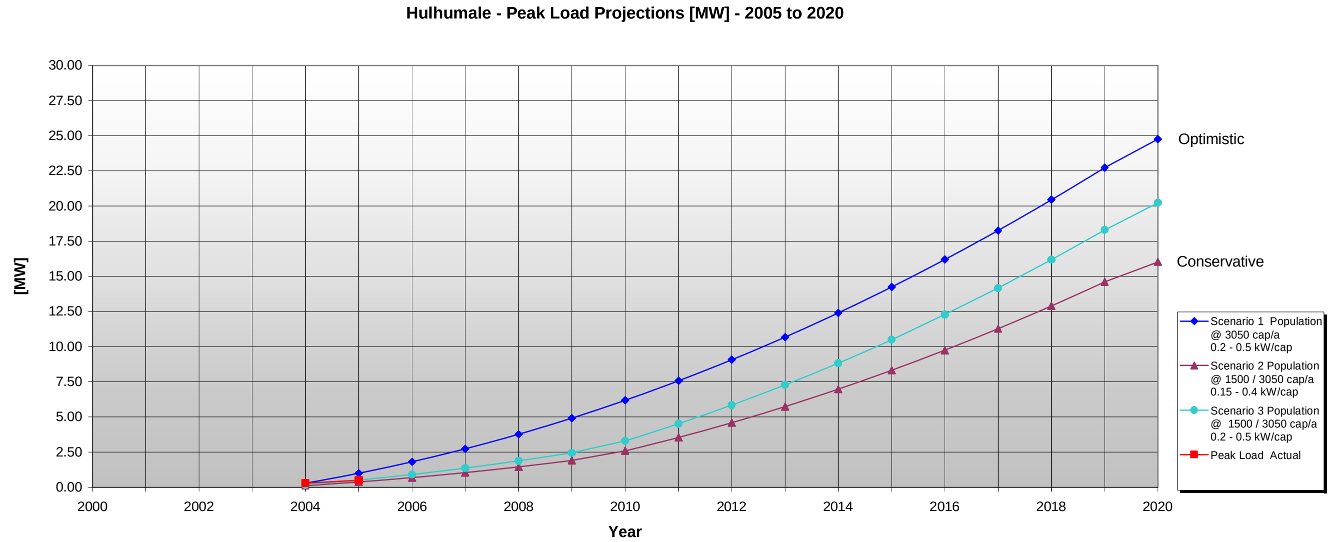


Source: Prepared by the Study Team

Figure 4.1.1-2 Power Demand Projection for Male' Island
(Comparison with the Study Team's Projection)

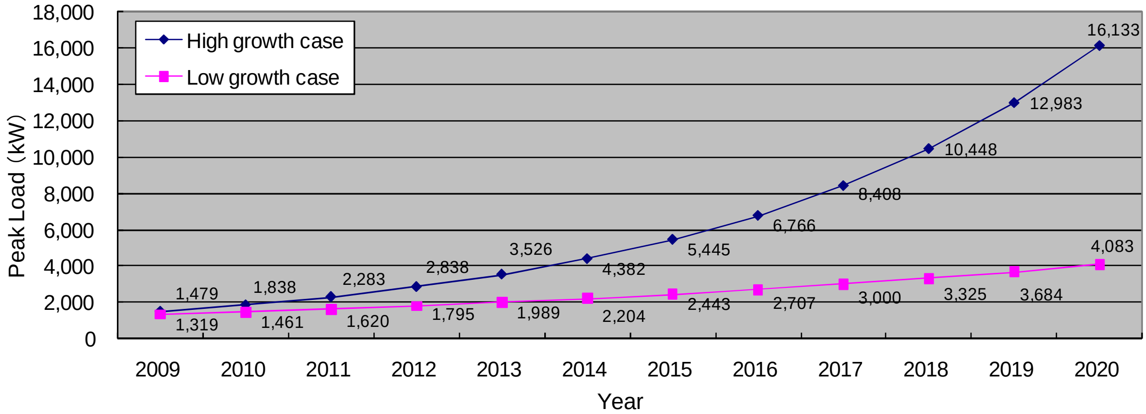
4.1.2 Hulhumale' Island

As in the case of Male' Island, the latest demand projection (Figure 4.1.2-1) is the one that was implemented in 2004, however, because values from 2004 onwards are not reflected in this forecast, the Study Team conducted a separate demand projection involving analysis of peak power from 2004 to 2008. According to the Hulhumale' Development Corporation (HDC), although plans aiming for the relocation of 60,000 residents by 2020 are being sustained by the new government, future trends regarding the large-scale development of residential areas and industrial and business districts are unclear. Accordingly, demand projection was implemented for two cases, i.e. 1) the population growth rate (24.3%) required to achieve the target population proposed under the relocation program, and 2) the case assuming the peak load growth rate (10.8%) between 1987~2008 on Male' Island. As is shown in Figure 4.1.2-2, power demand in the high growth case is estimated to be approximately 16 MW in 2020, which is close to the findings of the low growth case by STELCO. Therefore, detailed analysis in the following sections will be carried out based on the high growth case estimated by the Study Team.



Source： STELCO

Figure 4.1.2-1 Estimated Power Demand on Hulhumale' Island (STELCO)



Source： Prepared by the Study Team

Figure 4.1.2-2 Estimated Power Demand on Hulhumale' Island (Study Team)

4.2 Collection and Analysis of Solar Irradiation Data, etc.

During the first field survey, the Study Team visited the Department of Meteorology and calculated monthly solar irradiation utilizing data measured in a joint effort between the former Ministry of Communication Science & Technology (MCST) and UNDP between August 1, 2003 and July 31, 2004.

Solar irradiation observations are not currently implemented due to breakdown of the data logger, however, the Study Team found that the pyranometer is operating independently. In order to confirm the reliability of the data, in the second field survey the Study Team took a calibrated pyranometer (Table 4.2-1), installed it in the same place and compared the resulting data with data from the existing instrument. As is shown in Figure 4.2-2 and Figure 4.2-3, since both meters give almost the same data, reliability of the local pyranometer was confirmed and it was decided to adopt the measurements from August 1, 2003 to July 31, 2004 as the basic data.

Month	Daily Avg. Grobal Irradiation [$kWh/m^2/day$]
1	5.30
2	5.69
3	6.08
4	5.31
5	4.92
6	5.12
7	4.57
8	5.67
9	4.63
10	6.15
11	4.05
12	5.17
AVE	5.22

Source： Prepared by the Study Team

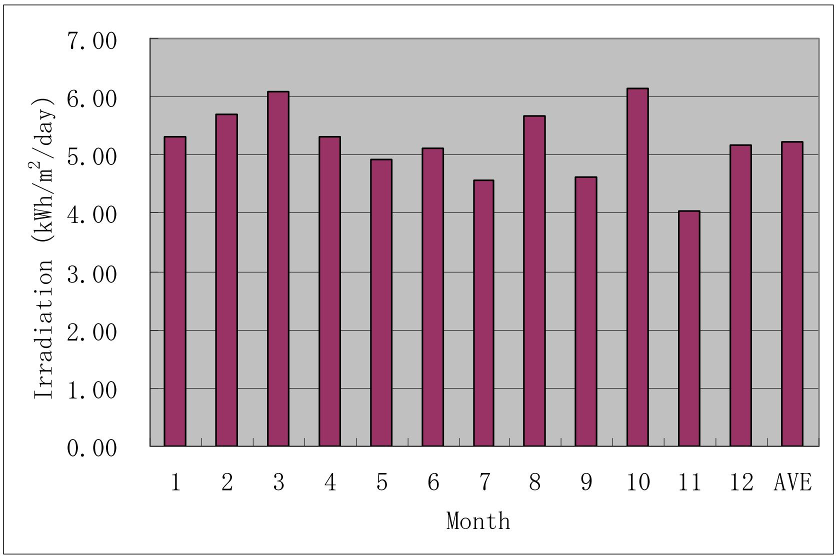
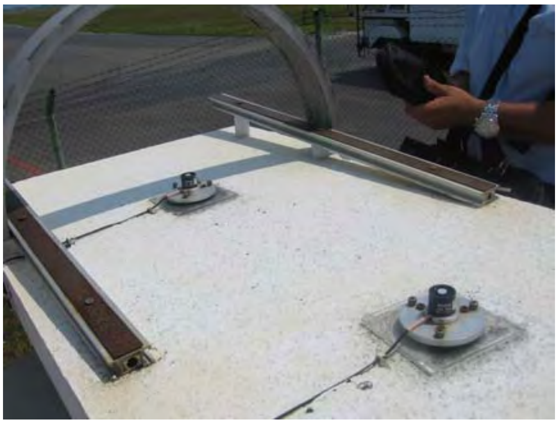


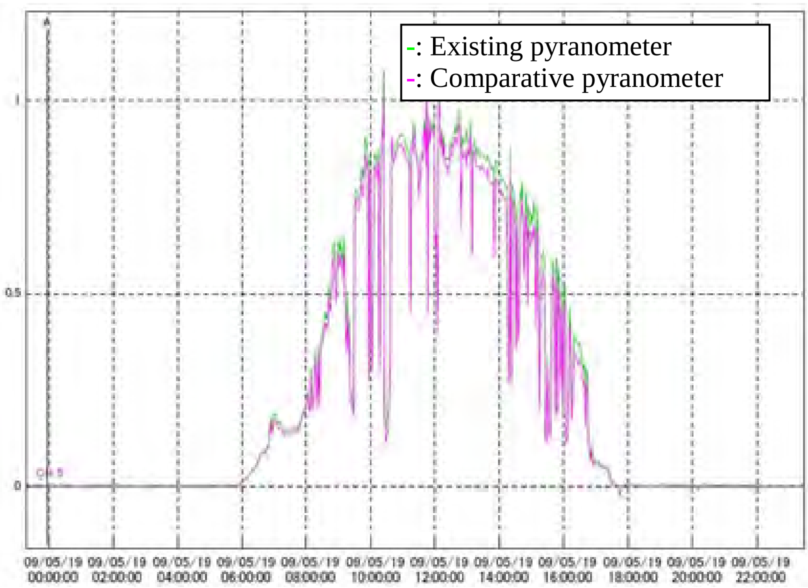
Figure 4.2-1 Hulhumale' Island Solar Irradiation Data Analysis Findings



Pyranometer (data logger not working) installed in the Meteorological Agency on Hulhumale' Island

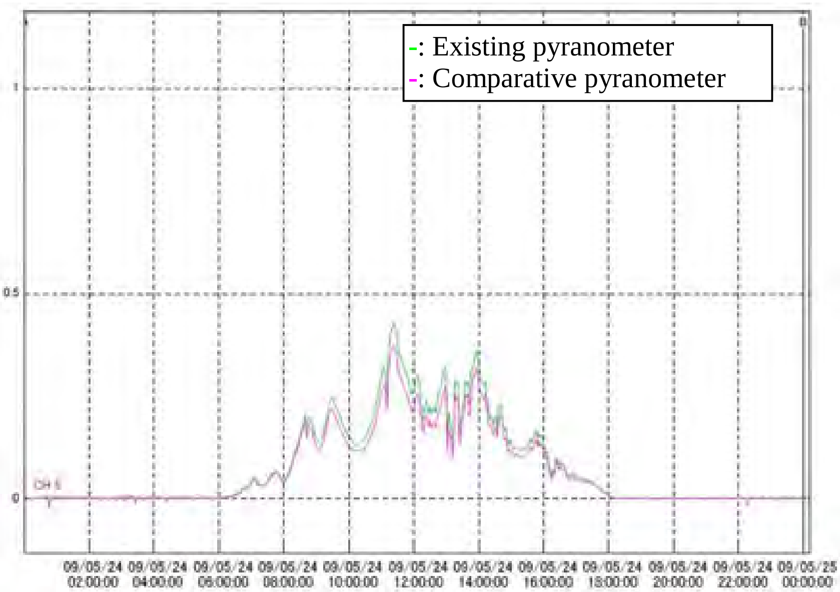
Table 4.2-1　Specifications of the Pyranometer and Data Logger Used for Comparison

Instrument	Specifications	
Irradiation sensor	Manufacturer	Prede Co., Ltd.
	Model	PCM-01(L)
	Wavelength scope	305～2800nm
	Sensitivity	7mV/kW▪m^{-2}
	Accuracy	±3%
Data logger	Manufacturer	Hioki E.E. Corporation
	Model	UIZ3635-50ｍV
	Input	Voltage 1ch
	Measured scope	±50mV resolution: 0.01mV
	Certainty	±0.8%rdg. ±5 dgt.



Source： Prepared by the Study Team

Figure 4.2-2　Pyranometer Accuracy Confirmation Findings (May 19, clear skies)



Source： Prepared by the Study Team

Figure 4.2-3　Pyranometer Accuracy Confirmation Findings (May 24, rain)

This global solar irradiation data were divided into direct solar irradiation and scattered solar irradiation using the solar irradiation estimation method devised by the New Energy and Industrial Technology Development Organization (NEDO) based on survey by the Japan Weather Association. The findings of these calculations shall be used as design parameters for projecting power generation in the grid-connected PV system.

Month	Daily Avg. Grobal Irradiation [kWh/m^2/day]
1	5.23
2	5.61
3	5.99
4	5.24
5	4.86
6	5.06
7	4.51
8	5.60
9	4.56
10	6.06
11	4.00
12	5.10
AVE	5.15

Source： Prepared by the Study Team

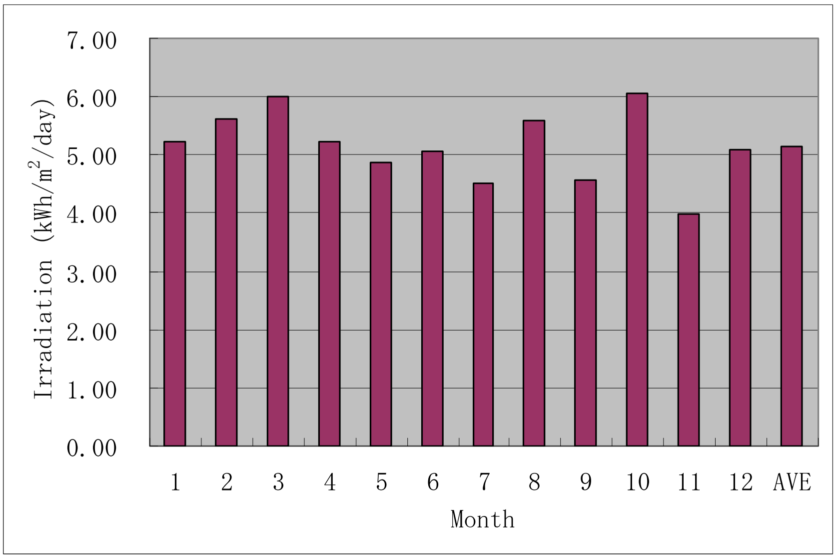
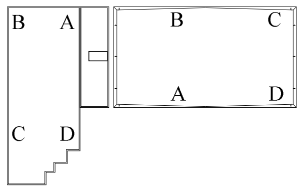
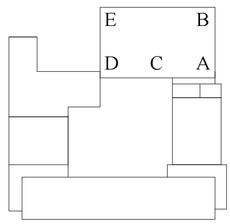
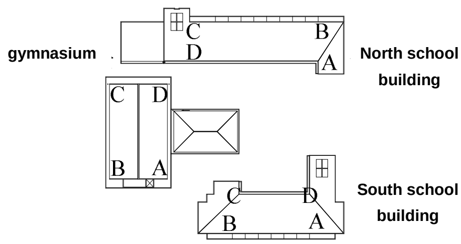


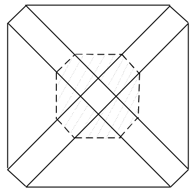
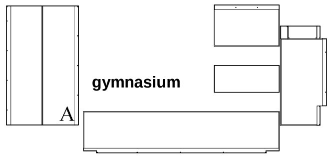
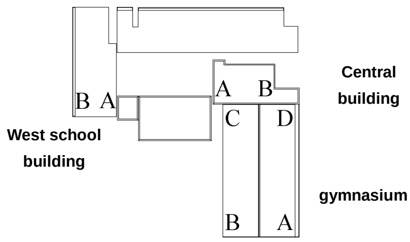
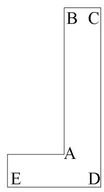
Figure 4.2-4 Horizontal Plane Solar Irradiation Data Applied in the Study

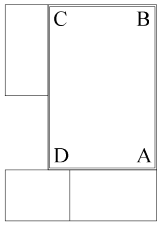
4.3 Examination and Measurement concerning Solar Irradiation Obstruction

The Study Team and counterparts surveyed each potential site and confirmed the areas where sunlight is impeded by surrounding buildings and obstructions, etc. Upon selecting impacted areas on each site, examination of solar irradiation obstruction was conducted with the counterparts using a solar map at the winter solstice on Male' Island and Hulhumale' Island and a transit compass.

Table 4.3-1 Measurement Results concerning Solar Irradiation Obstruction

No	Site	Solar irradiation obstruction (measured site)	Measurement point and impacted time
Male' Island			
1	STELCO Building	None	
2	STELCO Power House	None	
3	Dharubaaruge	Yes (West and east buildings)	West building Points A, B, C, D (17:00-18: 00) East building Points A, B (16:00-18:00), Point C (6:00-9: 00,17:00-18:00), Point D (6:00-7:00) 
4	Velaanaage (Govt. Office)	Unknown (works in progress)	
5	Giyaasudheen School	Yes (Gymnasium)	Point A (6:00-8:10,13: 50-15:10), Point B (6:00-8:10), Point C (6:00-7:40) Point D (6:00-7:30), Point E (6:00-7:10) 
6	Kalaafaanu School	Yes (South and north school buildings and gymnasium)	South school building: Points A, B (17: 10-18: 00), Point C (16:30-18:00), Point D (17:00-18:00) North building: Points A, B (16:50-18:00), Point C (16:30-18:00), Point D (15:30-18:00) Gymnasium Point A (16:30-18:00), Point B (15:40-18:00), Point C (14:50-18:00), Point D (15:30-18:00) 

No	Site	Solar irradiation obstruction (measured site)	Measurement point and impacted time
7	Maldives Center for Social Education	Yes	Range of 6 m viewed from above 
8	Thaajuddeen School	Yes (Gymnasium)	Gymnasium: Point A (6:00-10:00) 
9	New Secondary School for Girls	Yes (Central building, gymnasium, west school building)	Central building: Point A (6:00-7:20, 16:00-18:00), Point B (6:00-7:30, 16:30-18:00) Gymnasium: Point A (6:00-7:50, 15:30-18:00) Point B (15:30-18:00), Point C (15:30-18:00) Point D (6:00-8:00, 16:30-18:00), west school building Point A (6:00-11:00), Point B (6:00-7:30) 
10	Indhira Gandhi Memorial Hospital (IGMH)	Yes (Rooftop terrace)	Point A (6:00-8:00, 16:30-18:00) Point B (6:00-7:50, 16:20-18:00) Point C (6:00-10:00, 16:20-18:00) Point D (6:00-8: 10, 16:50-18:00) Point E (6:00-7: 30, 15:10-18:00) 
11	Faculty of Engineering	None	
12	National Stadium	Yes	Impossible to measure (the west stand is affected in the afternoon)
13	Majeedhiya School	None	

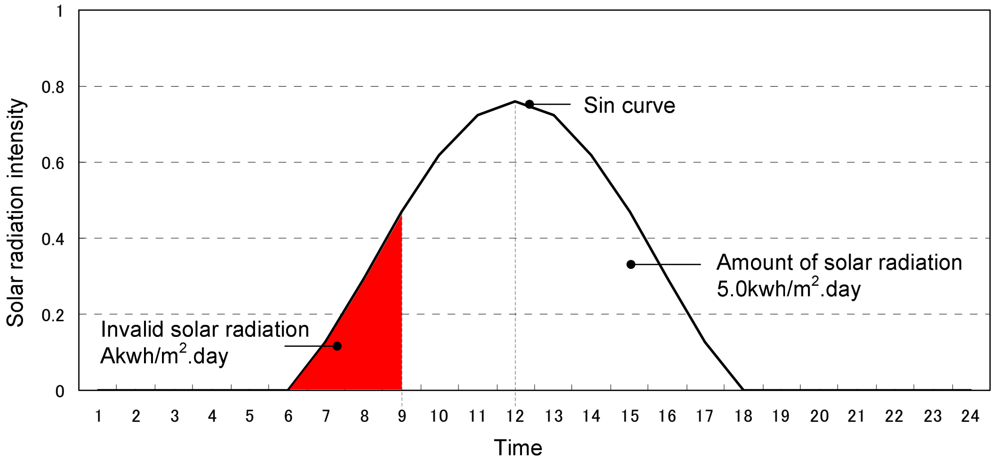
No	Site	Solar irradiation obstruction (measured site)	Measurement point and impacted time
14	Dharumavantha School	Yes	Omitted from the solar irradiation study because of numerous surrounding obstructions.
15	Fen Building	Yes (Rooftop terrace)	Point A (14:00-18:00), Point B (17:00-18:00), Point C 13:50-18:00), Point D (6:00-18:00) 
16	Water Tank (MWSC)	None	
17	Faculty Education	None	
18	Sports Grounds	None	
19	Male' South West Harbour Parking	None	
20	Grand Friday Mosque	None	
21	Jumhooree Maidhan	None	
22	President's Office	None	
Hulhumale' Island			
1	Lale International School	None	
2	Hulhumale Hospital	None	
3	Ghaazee School	None	
4	HDC	None	
5	Housing Flats	None	

Source： Prepared by the Study Team

Figure 4.3-1 OJT on the Solar Irradiation Obstruction Measurement Method

Solar energy comprises direct solar irradiation which directly reaches the earth, as well as scattered solar irradiation (scattered by dirt, dust and clouds, etc. in the air) and reflected solar irradiation. However, reflected solar irradiation shall not be considered here because it varies according to conditions in each area.

Solar energy shall be examined as the sum of direct solar irradiation and scattered solar irradiation, and the hourly intensity of solar irradiation shall be calculated. Accordingly, hourly changes in solar irradiation intensity are approximated in the manner shown in the figure below.



Source : Prepared by the Study Team

Figure 4.3-2 Hourly Changes in Solar Irradiation Intensity

The above figure shows the amount of solar irradiation at the measurement point, assuming that shadow has an impact that invalidates solar irradiation between 06:00 and 09:00 and this invalid solar irradiation is deducted.

The following table shows direct solar irradiation and scattered solar irradiation values calculated by the Study Team upon quoting from the survey and research report on PV systems (survey and research of meteorological data for constructing PV utilization systems) by NEDO. For the purposes of this examination, data are taken from January, the month of the winter solstice, when shadows are the longest.

Table 4.3-2 Solar Irradiation in January on Male' Island

Month	Time	Horizontal Place Direct Arrival	Horizontal Plane Scattering	Horizontal Plane Total
1	1	0.000	0.000	0.000
1	2	0.000	0.000	0.000
1	3	0.000	0.000	0.000
1	4	0.000	0.000	0.000
1	5	0.000	0.000	0.000
1	6	0.000	0.000	0.000
1	7	0.063	0.064	0.127
1	8	0.165	0.130	0.295
1	9	0.281	0.188	0.469
1	10	0.389	0.231	0.620
1	11	0.465	0.259	0.724
1	12	0.492	0.268	0.760
1	13	0.465	0.259	0.724
1	14	0.389	0.231	0.620
1	15	0.281	0.188	0.469
1	16	0.165	0.130	0.295
1	17	0.063	0.064	0.127
1	18	0.000	0.000	0.000
1	19	0.000	0.000	0.000
1	20	0.000	0.000	0.000
1	21	0.000	0.000	0.000
1	22	0.000	0.000	0.000
1	23	0.000	0.000	0.000
1	24	0.000	0.000	0.000
				5.230

Source： Prepared by the Study Team

In cases where shadow occurs at a certain time at the target point, it is conservatively assumed that the intensity of solar irradiation at that time entails neither direct solar irradiation nor scattered solar irradiation. In the case where shadow has an impact between 06:00~08:00 in January in the target area, it is assumed that a total of 0.127 kwh/m^2 of solar energy between 06:00 and 07:00 and a total of 0.295 kwh/m^2 of solar energy between 07:00 and 08:00 cannot be acquired due to the shadow. Therefore, judging from the solar irradiation examination data given in the above table, this means that solar irradiation in January is 5.23 kwh/m^2/day, and the amount of solar irradiation available for power generation is this amount minus 0.127 kwh/m^2 and 0.295 kwh/m^2, i.e. 4.477 kwh/m^2/day.

Based on these findings, the estimated amount of solar irradiation at each site is calculated as follows.

Table 4.3-3 Estimated Solar Irradiation on each Potential Site

No	Site	Solar Irradiation	Invalid Solar Irradiation
Male' Island			
1	STELCO Building	5.23 kwh/m^2/day	No impact because panels will be on a frame supported by pillars at 3 m height
2	STELCO Power House	5.23 kwh/m^2/day	
3	Dharubaaruge	West building: 5.103 kwh/m^2/day East building: 4.386 kwh/m^2/day	West building: Impacted time 17:00-18:00, therefore 0.127 kwh/m^2 East building: Impacted time 6:00-9:00, 16:00-18:00, therefore 0.844 kwh/m^2
4	Velaanaage (Govt. Office)		
5	Giyaasudheen School	South school building: 5.23 kwh/m^2/day Gymnasium: 4.808 kwh/m^2/day	Impacted time 6:00-8:10, therefore 0.422 kwh/m^2
6	Kalaafaanu School	South school building: 4.808 kwh/m^2/day North school building: 4.339 kwh/m^2/day Gymnasium: 3.719 kwh/m^2/day	Impacted time 16:30-18:00, therefore 0.422 kwh/m^2 Impacted time 15:30-18:00, therefore 0.891 kwh/m^2 Impacted time 14:50-18:00, therefore 1.511 kwh/m^2
7	Maldives Center for Social Education	5.23 kwh/m^2/day	
8	Thaajuddeen School	South school building: 5.23 wh/m^2/day Central building: 5.23 kwh/m^2/day North school building: 5.23 kwh/m^2/day Gymnasium: 4.339 kwh/m^2/day	Impacted time 6:00-10:00, therefore 0.891 kwh/m^2
9	New Secondary School for Girls	North school building: 5.23 kwh/m^2/day West school building: 3.917 kwh/m^2/day Gymnasium: 4.386 kwh/m^2/day	Impacted time 6:00-11:00, therefore 1.313 kwh/m^2 Impacted time 6:00-8:00, 15:30-18:00, therefore 0.844 kwh/m^2
10	Indhira Gandhi Memorial Hospital (IGMH)	4.386 kwh/m^2/day	Impacted time 6:00-8:00, 16:30-18:30, therefore 0.844 kwh/m^2
11	Faculty of Engineering	5.23 kwh/m^2/day	
12	National Stadium	East stand: 5.23 kwh/m^2/day South stand: 5.23 kwh/m^2/day West stand: 3.719 kwh/m^2/day	Impacted time assumed as 14: 00-18: 30. 1.511 kwh/m^2
13	Majeedhiya School	5.23 kwh/m^2/day	
14	Dharumavantha School	- (Excluded due to numerous surrounding obstructions)	
15	Fen Building	3.719 kwh/m^2/day	Impacted time 14:00-18:30, therefore 1.511 kwh/m^2
16	Water Tank (MWSC)	5.23 kwh/m^2/day	

No	Site	Solar Irradiation	Invalid Solar Irradiation
17	Faculty Education	5.23 kwh/m^2/day	
18	Sports Grounds	5.23 kwh/m^2/day	
19	Male' South West Harbour Parking	5.23 kwh/m^2/day	
20	Grand Friday Mosque	5.23 kwh/m^2/day	
21	Jumhooree Maidhan	5.23 kwh/m^2/day	
22	President's Office	5.23 kwh/m^2/day	
Hulhumale' Island			
1	Lale International School	5.23 kwh/m^2/day	
2	Hulhumale Hospital	5.23 kwh/m^2/day	
3	Ghaazee School	5.23 kwh/m^2/day	
4	HDC	5.23 kwh/m^2/day	
5	Housing Flats	5.23 kwh/m^2/day	

Source： Prepared by the Study Team

4.4 Selection of Potential Sites for Introducing the Grid-Connected PV System

The Maldives side recommended that the following 27 sites, consisting of 22 on Male' Island and 5 on Hulhumale' Island, be used as survey targets in the Study. Upon discussing with the Maldives side, a number of sites were excluded because of concerns over the impact of shadow, difficulty in implementing survey due to private facilities or difficulty in obtaining drawings, etc., and it was eventually decided to implement technical examination on 14 potential sites.

Table 4.4-1 List of Selected Potential Sites

Island	No.	Site	Selection as Potential Site	Reason for Omission
Male' Island	1	STELCO Building	○	
	2	STELCO Power House	×	Concern that waste heat from the diesel generator will impair PV module efficiency
	3	Dharubaaruge (Public Works Building)	○	
	4	Velaanaag (Government Building)	×	Inability to obtain drawings during the works
	5	Giyaasudheen School	○	
	6	Kalaafaanu School	○	
	7	Maldives Center for Social Education	○	
	8	Thaajuddeen School	○	
	9	New Secondary School for Girls	○	
	10	Indhira Gandhi Memorial Hospital (IGMH)	×	Plans exist for rooftop rehabilitation
	11	Faculty of Engineering	○	
	12	National Stadium	○	
	13	Majeedhiya School	×	Impact of shade from surrounding trees
	14	Dharumayantha School	×	Impact of shade from surrounding buildings and trees
	15	Fen Building	×	Inability to obtain drawings because the building is privately owned
	16	Male' Water Supply	×	The upper part of the water tank cannot be used because of periodic inspections.
	17	Faculty of Education	○	
	18	West Stadium	×	Concerns exist over equipment safety.
	19	Male' South West Harbour Parking	×	The facility is privately owned.
	20	Grand Friday Mosque	○	
	21	Jumhooree Maidhaan	○	
	22	President's Office	○	
Hulhumale' Island	1	Lale International School	×	The school is a private school.
	2	Hospital	○	
	3	Ghaazee School	×	The roof is partly damaged.
	4	HDC Building	×	Installation is difficult on a curved roof.
	5	Housing Flats	×	There is no space for peripheral equipment. There are too many interested parties.

Source：Prepared by the Study Team

4.5 Assessment of Load Responsiveness in the Diesel Generator

The Study Team surveyed STELCO diesel power plants on Male' Island and Hulhumale' Island and confirmed the control method used on existing diesel generators. On both islands, the number of diesel generators in operation is left to the individual discretion of operators. On Male' Island, since a SCADA (Supervisory Control and Data Acquisition) system is used to monitor demand conditions in real time, the system can respond to demand changes relatively quickly, whereas on Hulhumale' Island, operators monitor and record the total generator output every hour and alter the number of units in operation so that spare operating capacity is 20% or more.

The number of governor-free diesel generators can be switched by the SCADA system, however, since the system is configured to trip when engine exhaust heat exceeds 550℃, an alarm is triggered and operation is switched to fixed output operation when 500℃ is reached. The diesel governor speed adjustment rate is stabilized at 4%.

The frequency control standard of STELCO is 50Hz±1.0% and, since the governor speed adjustment rate is 4%, it is possible to hold fluctuations to within the standard range up to 25.0%(1.0% / 4.0%) of the generator rated capacity during governor-free operation.

4.6 Examination and Measurement of Existing Distribution Transformer Capacity and Distribution System

Concerning the potential sites that were selected in 4.4, survey was carried out on the capacity of existing distribution transformers and distribution lines that will link the PV systems with the grid.

Out of the distribution transformers at the interconnection points, No. 61 Tr (Kalaafaanu School) and No. 62 Tr (Maldives Center for Social Education) are owned by the Ministry of Education and Ministry of Human Resources, Youth and Sports, respectively, while the others are all owned by STELCO.

Upon checking against the results of examining PV installation capacity on the potential sites as described in 4.10, it was confirmed that none of the existing transformers will be overloaded. However, concerning No. 61 Tr, since the high voltage power receiving equipment is broken down, it is scheduled to conduct repairs under the budget of the Ministry of Education.

Table 4.6-1 Survey Findings Regarding Capacity of Transformers at Interconnection Points

Island	Site No.	Site Name	PV Capacity [kWp]	Feeder No.	Distribution Tr No.	Tr Capacity [kVA]	Remarks
Male' Island	1	STELCO Building	45	FD9	20B	500	
	3	Dharubaaruge	85	FD3	60	630	
	5	Giyaasudheen School	40	FD6	70	150	
	6	Kalaafaanu School	85	FD3	61	100	High voltage power receiving equipment is broken down.
	7	Maldives Center for Social Education	100	FD6	62	200	
	8	Thaajuddeen School	130	FD6	23	1,000	
	9	New Secondary School for Girls	100	FD6	23	1,000	
	11	Faculty of Engineering	80	FD4	25	800	
	12	National Stadium	400	FD9	41B	1,000	
	17	Faculty of Education	10	FD7	30	630	
	20	Grand Friday Mosque	30	FD2	14	630	
	21	Jumhooree Maidhaan	60 - 160	FD2	14	630	
	22	President's Office	20	FD8	73	1,250	
Hulhumale' Island	2	Hospital	60	FD2	11	315	

Source： Prepared by the Study Team

Furthermore, in order to examine impact on the distribution system, calculation of simulated voltage flows was carried out using the condition shown in Table 4.6.2 based on distribution transformer demand data and line impedance data received from STELCO. In order to check for excessive voltage increase when solar backflows occur, minimum load (demand data) and solar generating capacity were calculated assuming installation of rated output with power factor of 1 at each interconnection point.

As for the bus voltage of power plant, the Team confirmed with STELCO that AVR (Automatic Voltage Regulator) setting of 11kV rated voltage generators is 11kV and tap setting of step-up transformers for 400V rated voltage generators is middle tap (11kV, fix)

Also, the line impedance data were calculated upon considering the most recent reinforcement plans indicated in Table 3.3.5-1.

The simulation results are given below. In the legend given in each figure, V_{base} indicates the voltage on each section before connection of the PV system to the grid, while index numbers are conferred to each branch feeder. On feeders where V_{route} is the same number as V_{base}, voltage following connection of the PV system to the grid is shown (however, V is displayed for feeders that have no branch line).

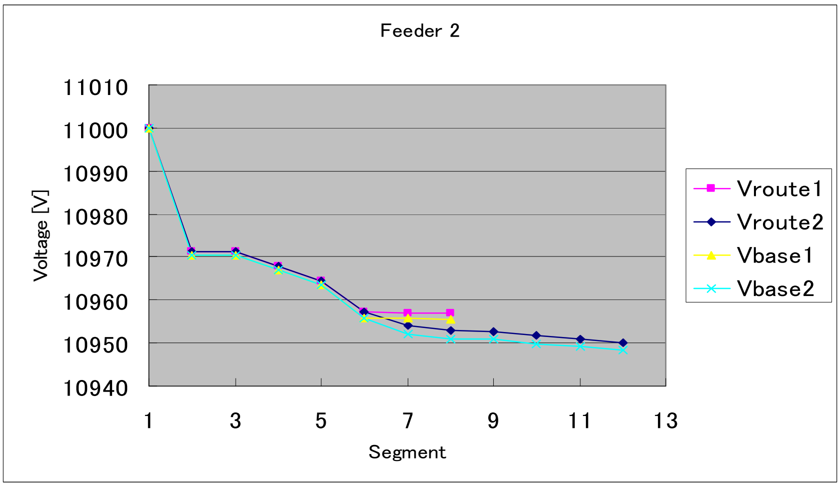
In addition, Segment 1 on horizontal axis means bus of power plant and each connection point of distribution transformer (11kV/230V) is numbered up to the end of distribution lines

Table 4.6- 2 Simulation Condition

	Segment			2	3	4	5	6	7	8	9	10	11	12	13	14
Male' Island	Feeder 2	Route 1	Tr No.	50A	50B	42	34	54A	54B	91						
			Min. Load [kVA]	571	1007	35	552	567	522	65						
			PV Capacity [kW]													
		Route 2	Tr No.						14	17B	17A	21	49	58B		
			Min. Load [kVA]						138	167	98	264	81	819		
			PV Capacity [kW]						190							
	Feeder 3	Route 1	Tr No.	60	13B	13A	61									
			Min. Load [kVA]	45	561	448	0									
			PV Capacity [kW]	85			85									
		Route 2	Tr No.				81	57A	57B	51	41A					
			Min. Load [kVA]				338	262	519	713	704					
			PV Capacity [kW]													
	Feeder 4	Route 1	Tr No.	33	31A	47	39	90	43							
			Min. Load [kVA]	539	201	330	12	8	334							
			PV Capacity [kW]													
		Route 2	Tr No.			25	31B									
			Min. Load [kVA]			35	325									
			PV Capacity [kW]			80										
	Feeder 6	Route 1	Tr No.	20A	32	29	87	88								
			Min. Load [kVA]	435	423	309	24	93								
			PV Capacity [kW]													
		Route 2	Tr No.				70	40	28	72	26	24	24B	24A		
			Min. Load [kVA]				44	486	159	173	196	268	270	187		
			PV Capacity [kW]				40									
		Route 3	Tr No.										23	62		
			Min. Load [kVA]										268	23		
			PV Capacity [kW]										230	100		
		Route 4	Tr No.											44A	44B	46
			Min. Load [kVA]											393	432	706
			PV Capacity [kW]													
	Feeder 7	Route 1	Tr No.	30	56A	66	77	76	59A	59B	84	22	10	79	83	16
			Min. Load [kVA]	412	709	518	127	556	437	547	110	565	594	75	352	217
			PV Capacity [kW]	10												
	Feeder 8	Route 1	Tr No.	75	52	85	67	38	64	36	86	35				
			Min. Load [kVA]	527	340	110	120	388	30	362	415	388				
			PV Capacity [kW]													
		Route 2	Tr No.						15	18						
			Min. Load [kVA]						499	240						
			PV Capacity [kW]													
		Route 3	Tr No.							48	53	73	11	68		
			Min. Load [kVA]							300	271	249	203	16		
			PV Capacity [kW]									20				
	Feeder 9	Route 1	Tr No.	20B	78	41B	19	37	12B	69	82A	12A	65	71		
			Min. Load [kVA]	30	397	0	531	579	385	46	123	473	44	41		
			PV Capacity [kW]	45		400										
Hulhumale' Island	Feeder 2	Route 1	Tr No.	10	11	12	13	14								
			Min. Load [kVA]	60	67	143	131	235								
			PV Capacity [kW]		60											
		Route 2	Tr No.					15								
			Min. Load [kVA]					145								
			PV Capacity [kW]													

Source : Prepared by the Study Team

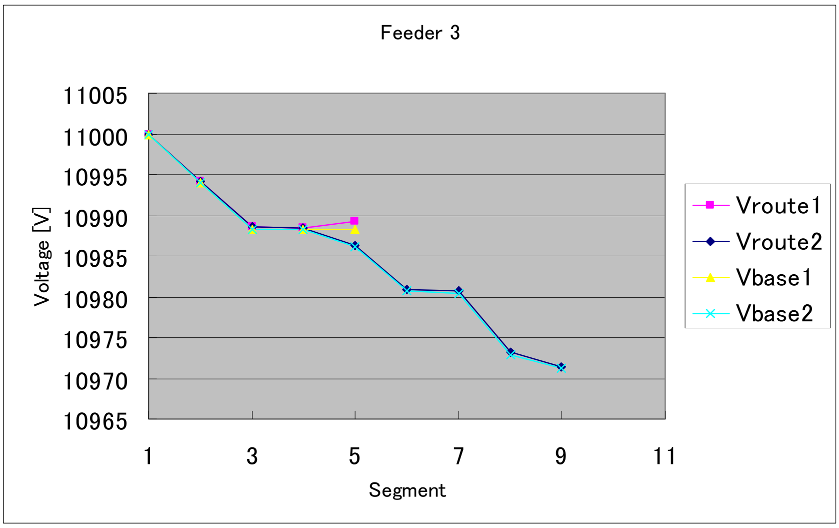
※all load factor are 0.8.



Interconnection Point	PV Capacity ity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 7	190 (Site No. 20+21)	Before connection	10,952	10,725 ~ 11,275	- 48	- 0.47
		After connection	10,954		- 46	- 0.42

Source: Prepared by the Study Team

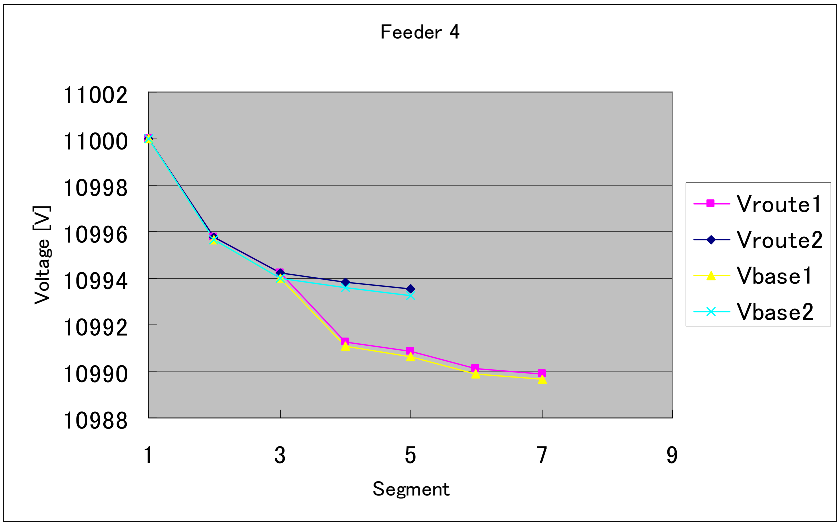
Figure 4.6-1 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 2)



Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 2	85 (Site No. 3)	Before connection	10,994	10,725 ~ 11,275	- 6	- 0.05
		After connection	10,994		- 6	- 0.05
Segment 5	85 (Site No. 6)	Before connection	10,988		- 12	- 0.11
		After connection	10,989		- 11	- 0.10

Source: Prepared by the Study Team

Figure 4.6-2 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 3)



Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 4	80 (Site No. 11)	Before connection	10,994	10,725 ～11,275	- 6	- 0.05
		After connection	10,994		- 6	- 0.05

Source: Prepared by the Study Team

Figure 4.6-3 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 4)

Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 5	40 (Site No. 5)	Before connection	10,964	10,725 ～ 11,275	- 36	- 0.33
		After connection	10,967		- 33	- 0.30
Segment 11	230 (Site No. 8+9)	Before connection	10,901		- 99	- 0.90
		After connection	10,911		- 89	- 0.81
Segment 12	100 (Site No. 7)	Before connection	10,901		- 99	- 0.90
		After connection	10,911		- 89	- 0.81

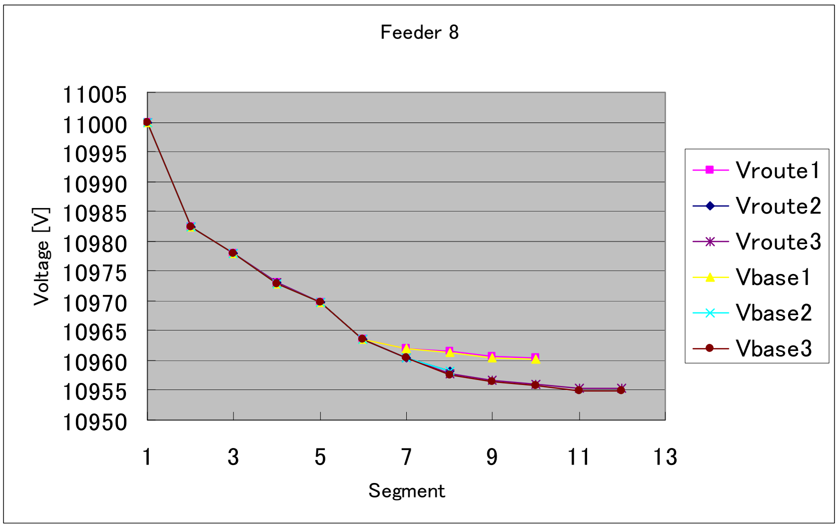
Source: Prepared by the Study Team

Figure 4.6-4 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 6)

Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 2	10 (Site No. 17)	Before connection	10,979	10,725 ～11,275	- 21	- 0.19
		After connection	10,979		- 21	- 0.19

Source: Prepared by the Study Team

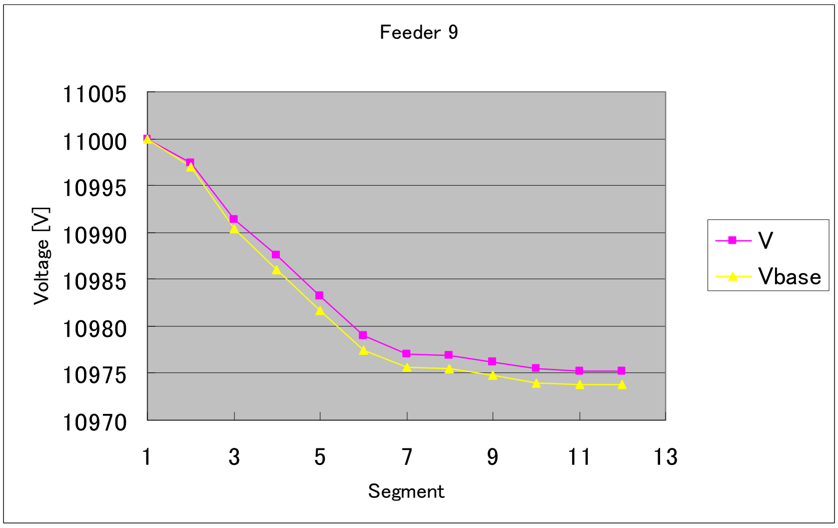
Figure 4.6-5 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 7)



Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 10	20 (Site No. 22)	Before connection	10,956	10,725 ～11,275	- 44	- 0.40
		After connection	10,956		- 44	- 0.40

Source: Prepared by the Study Team

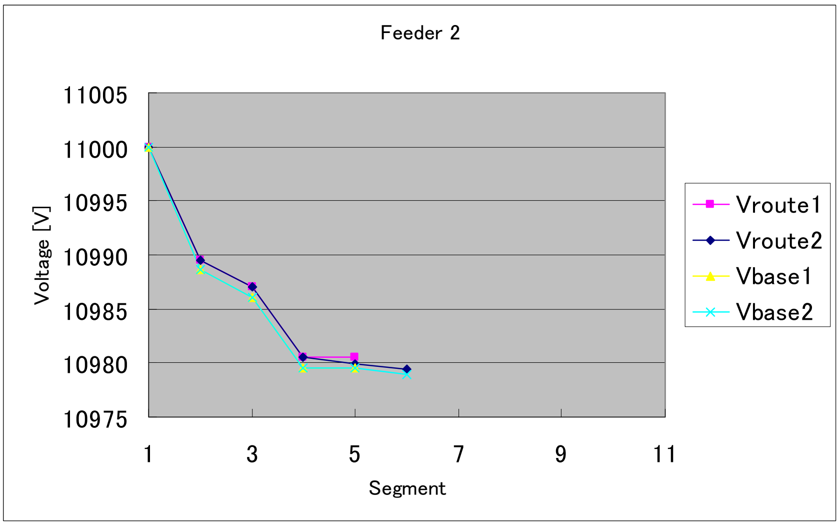
Figure 4.6-6 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 8)



Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 2	45 (Site No. 1)	Before connection	10,997	10,725 ～11,275	- 3	- 0.03
		After connection	10,997		- 3	- 0.03
Segment 2	400 (Site No. 12)	Before connection	10,986		- 14	- 0.13
		After connection	10,987		- 13	- 0.12

Source: Prepared by the Study Team

Figure 4.6-7 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Male' Island, Feeder 9)



Interconnection Point	PV Capacity [kWp]	Interconnection Point Voltage [V]		Standard Range [V]	Voltage Disparity [V]	Voltage Fluctuation Rate [%]
Segment 3	60 (Site No. 2)	Before connection	10,986	10,725 ～ 11,275	- 14	- 0.13
		After connection	10,987		- 13	- 0.12

Source: Prepared by the Study Team

Figure 4.6-8 Calculation Results of Distribution Line Voltage Flow Simulation at Time of PV System Interconnection (Hulhumale' Island, Feeder 2)

Since all the simulation results fell within the standard voltage control scope, it was confirmed that PV interconnection will not have an adverse impact on distribution lines. This can partly be explained by the small capacity of PV interconnection, however, it is also largely down to the fact that the distribution network on Male' Island and Hulhumale' Island is a finely woven mesh, cable lengths are short and distribution line reinforcement works (heavy line conversion) are progressing. Furthermore, Table 4.6-3 shows the results of a survey of problems regarding PV connection to existing distribution lines conducted before the start of the Study. Since the MHTE, MEA and STELCO do not possess the know-how to examine these problems, it will be necessary to continuously implement transfer of technology regarding these issues in the future.

Table 4.6-3 Impacts of PV Interconnection on Existing Distribution Lines

Classification	No	Problem	Outline of Problem and Field Survey Contents	Survey Findings
Quality of electricity	1	Voltage deviation caused by reverse power flow	When there are reverse power flows from PV facilities to substations, there is possibility of system voltage rising around the interconnection points. So it is necessary to survey the existing distribution line capacity and load conditions and check for any reverse power flows.	According to the simulation of voltage flows following PV interconnection, it was confirmed that voltage deviations will not arise.
	2	Malfunction of step voltage regulators due to reverse power flow	When step voltage regulators are installed on distribution lines, reverse power flow may reverse the direction of tap control and deteriorate voltage worse.	Step voltage regulators are not installed in the Maldives.
	3	Voltage fluctuation at times of massive dropout (parallel off) of PV system	When massive dropout occurs due to external disturbance, since there is risk of deviation from the standard voltage range, the limitation of PV introduction level shall be investigated.	According to the simulation of voltage flows following PV interconnection, it was confirmed that voltage deviations will not arise.
	4	Voltage drop at times of PV system start-up	When the PV inverter is paralleled to the grid, there is a risk of sudden voltage drop. Required functions for inverters such as soft start need to be investigated.	The interconnection inverter will be equipped with a soft start function.
	5	Flickering voltage fluctuations	Due to sudden changes in solar irradiation, there are cases where flickering voltage fluctuations occur. The limitation of PV introduction level shall be investigated.	There is no problem because conversion to heavy duty lines is well advanced. It is necessary to verify changes in the power source quality before and after introduction.
	6	Voltage imbalance due to connection of single phase systems	Small inverters for ordinary households are usually single phase systems. However, if they are connected frequently on either phase, phase imbalance will cause equivalent reverse phase current to flow and have an adverse impact on equipment.	Adopt three-phase interconnection as a rule. If allowing single phase interconnection for small capacity inverters, carry out the balancing of the connected phase and rearrangement of load, etc.
	7	System frequency fluctuations caused by fluctuations of PV output	In case the PV output fluctuation exceeds limitation of the adjustment capacity of power system, fluctuation of frequency may cause adverse impact on consumer equipment. The limitation of PV introduction level shall be investigated.	Deal with by increasing the number of governor-free diesel generators in operation. Do not consider the installation of storage batteries with a view to equalizing PV output because of problems surrounding the disposal of batteries.

Classification	No	Problem	Outline of Problem and Field Survey Contents	Survey Findings
	8	Higher harmonics from inverter power source	It is necessary to stipulate the maximum allowed percentage of higher harmonic content as a specification requirement of the interconnected inverter. It is because the inverter interconnection causes higher harmonics which have an adverse impact on consumer equipment.	The Maldives has no current standards or regulations. Stipulations based on grid interconnection guidelines, etc. are required. Since there are no domestically made products, there is no need for a certification system.
	9	Increase in DC outflow	When the distortion by inverter rectification is large, DC content of power grid increases. So it is necessary to review short circuit capacity of circuit breakers. Therefore, the rectification method and distortion factor shall be stipulated as a required specification of the interconnected inverter.	Ditto
	10	Deterioration of Transient Stability	When massive PV systems are interrupted simultaneously at times of failure, transient stability of synchronous generators will be deteriorated. The limitation of PV introduction level shall be investigated considering the stability aspect.	Concerning transient phenomena, it is necessary to implement analysis of the power grid stability, however, this has not been implemented because it was not possible to acquire the transient constant of existing diesel generators in the Study.
Protection	1	Prevention of islanding operation	Survey the method to cut power supply (to prevent electric shock by public) through distributed generators for isolated system loads.	Make it a condition to have isolated operation detection functions (passive system and active system).
	2	Malfunction to detect islanding operation	Deterioration in detection sensitivity due to mutual interference by disturbance of active signals.	Make it a condition to have at least one passive system and one active system.
	3	Ground Fault Protection Ground Fault protection during the contact between medium and low voltage side of transformers	Ground fault detection by earth-fault protection relays is possible in case of mid-voltage interconnection. However, direct detection is not possible in case of low-voltage interconnection.	Adopt over-voltage ground relays as standard function in high voltage systems. In cases of low voltage interconnection, it can be omitted by implementing protection through detection of isolated operation following opening of the circuit breaker on the distribution line side.
	4	Protection against short-circuit faults ① Increase in short-circuit capacity	Since fault currents are also supplied from distributed generators, examine measures to prevent increasing short-circuit currents and causing equipment breakdowns.	Confirm that the shorting capacity of existing distribution line circuit breakers is sufficient with respect to the shorting current.
	5	Protection against short-circuit faults ② Difficulty of detecting short circuit faults at the end of feeders	When short-circuit faults occurs at the end of feeders, fault currents are supplied from distributed generators and it will reduce fault currents from distribution lines especially from higher voltage class. Thus it will make the fault detection difficult.	Make the over-current protection gate-off time of the grid interconnection inverter faster than the existing distribution line relay breaking time.
	6	Protection against short-circuit faults ③ Error trip of sound feeders by incoming current	There is a risk of error trip of sound feeders due to incoming currents from distributed generators. Confirm the composition of substation feeder and relays.	Make the over-current protection gate-off time of the grid interconnection inverter faster than the existing distribution line relay breaking time.

Classification	No	Problem	Outline of Problem and Field Survey Contents	Survey Findings
Operation Management	1	Malfunction of automatic power restoration in case of faults	Overload and voltage deviation may occur in distribution lines in case distribution automation system (or SCADA) is equipped with automatic power restoration system.	There is no automatic power switchover function in the event of failures.
	2	Malfunction of automatic feeder reclose	In case that distribution feeder has automatic reclose, there is a possibility of mismatch of time setting between it and re-interconnection of distributed generators. It is necessary to investigate the measures against this issue.	There is no automatic feeder reclose. It is necessary to equip a condition of receiving voltage confirmation for the restart.
	3	Overload of distribution equipment by switching of distribution lines	Since output of distributed generators cannot be monitored and power flows cannot be predicted, overload of distribution lines may occur after switching operation. It is necessary to confirm the switching operation and monitoring and control of the power distribution company.	Examine installation of monitoring devices that can monitor PV output. -It is necessary to review the demand management method that takes PV output into account.
	4	Difficulty in switching over without interruption	Imbalance of the interconnection capacity of distributed generators causes the phase angle of loop points to increase, and dropout of inverter may occur due to increase in cross current flows and growing change in voltage phase. This problem occurs when the capacity of PV systems is very large.	All loop change-over is conducted as power outage switchover.

Source： Prepared by the Study Team

4.7 Grid-Connected PV System Stability Assessment Technique

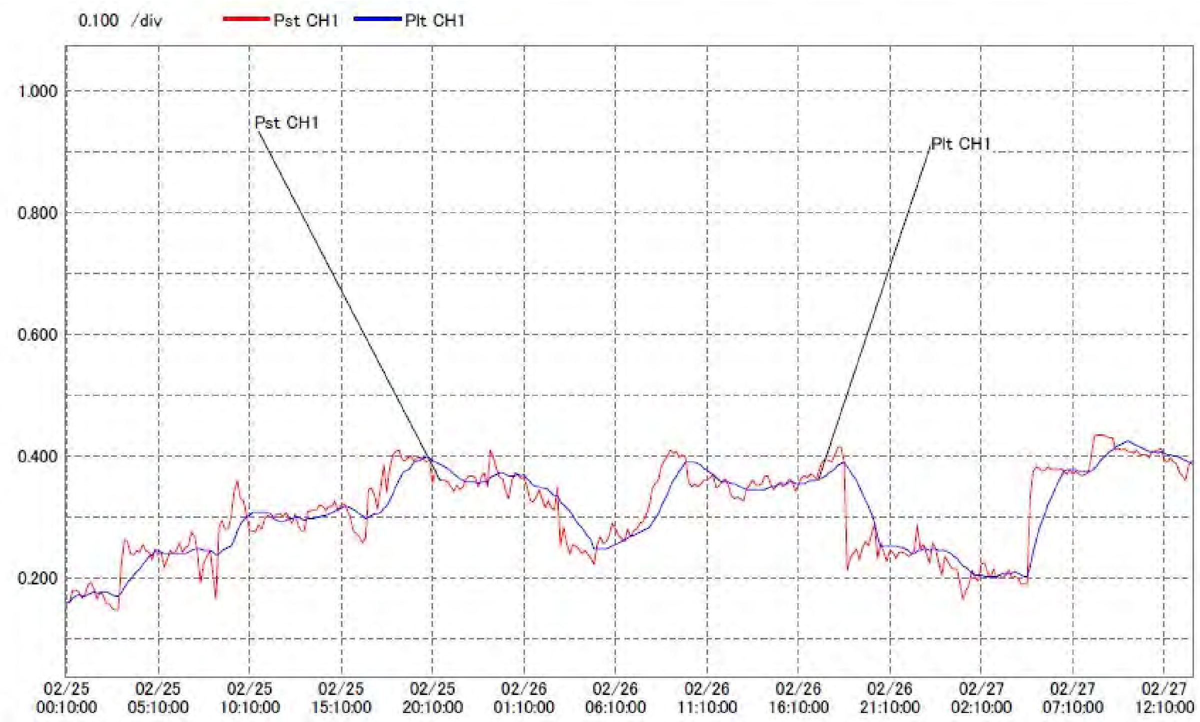
In order to assess the stability of the grid-connected PV system, power source quality of existing distribution lines was measured using the measuring instruments shown in Table 4.7-1. Out of the potential sites, the national stadium, which has the largest potential grid-connected PV capacity, was selected. The measurement results are indicated below.

Table 4.7-1 Specifications of Measuring Instruments

Device	Power supply quality analyzer
Manufacturer	Hioki E.E. Corporation
Model	3196
Measurement line	Single phase 2 wires, single phase 3 wires, 3-phase 3 wires, 3-phase 4 wires
Voltage range	CH1 – 3 : AC 150/300/600V CH4 : AC 60/150/300/600V, DC ±60/600V peak
Current range	Uses a clamp onset 9661 AC 50/500A
Measurement system	Transient over-voltage: 2MS/s High frequency: 2048 points (at times of 10cycle/50Hz, 12cycle/60Hz) Other effective value: 256 points/cycle
Measurement functions	1. Transient over-voltage 2. Voltage swell, voltage dip, voltage instantaneous stop 3. Frequency, voltage, current, voltage-current peak; active, reactive and apparent power, power factor or displacement power factor 4. Voltage imbalance ratio, current imbalance ratio 5. High frequency voltage, current and power, inter-harmonics voltage and current, high frequency voltage and current phase difference, K factor, general high frequency voltage and current distortion factor, general inter-harmonics voltage and current distortion factor 6. ΔV10 flicker or IEC flicker [Pst, Plt] 7. EN50160

Source： Prepared by the Study Team

Concerning the results of flicker measurement, it was confirmed that the IEC standard Pst<1, Plt<0.65 is satisfied.



Pst	:	Short-term flicker value	(flicker characteristic value measured over 10 minutes) Pst is a statistically sought index number. Pst = 1 indicates the voltage fluctuation where flickering of an incandescent light bulb thought to be unpleasant by 50% of people is generated.
Plt	:	Long-term flicker value	(flicker characteristic value measured over 2 hours)

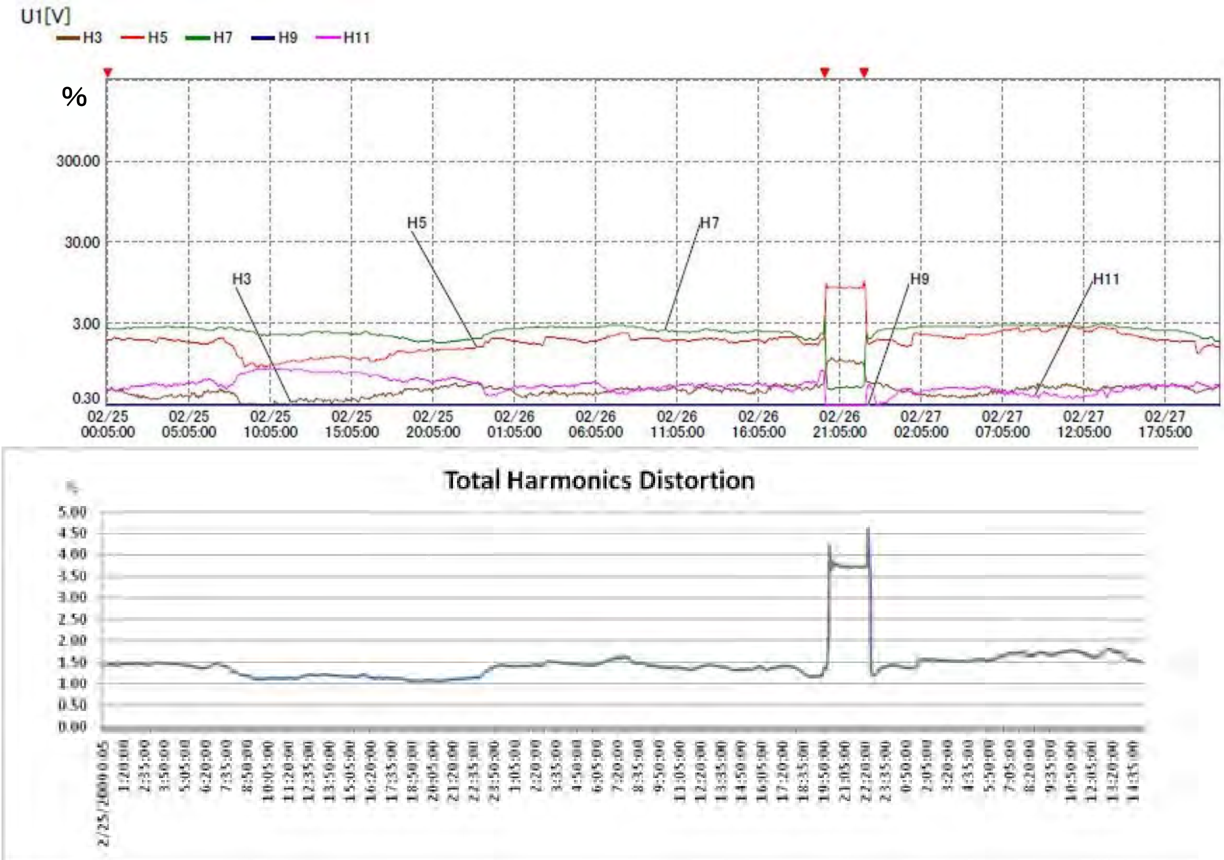
Source : Prepared by the Study Team

Figure 4.7-1 IEC Flicker Measurement Results (Pst, Plt)[Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

Concerning harmonics, according to the Japan Harmonics Control Measures Guidelines, voltage harmonics for each order ≦3% and total distortion ≦3% is required as the environmental target for Medium Voltage consumers. However, for the national stadium where measurement was conducted, fifth harmonics reached a maximum of 4.62% (effect mean value 10.55 V) and the total harmonics reached a maximum of 4.64% between 20:08~22:33 when the lights of the national stadium were turned on. These measured values exceed the regulation by Japan Harmonics Control Measures Guidelines

High frequency control measures need to be taken on the load side (use of a high frequency filter, multi-laying of inverter, switching of high frequency), however, the Study revealed that the Maldives currently has no clear power quality standards and, since there is a possibility of interference occurring in capacitors and other power instruments, it will be necessary to examine standards and regulations in future.

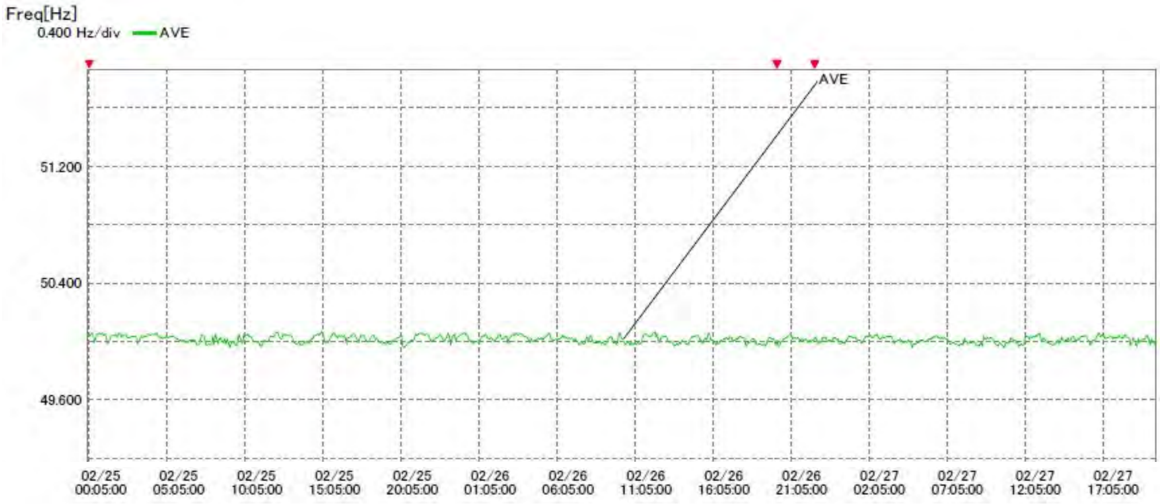
Accordingly, the grid interconnection converter will need to have specifications that conform to Japanese high frequency control guidelines.



Source： Prepared by the Study Team

Figure 4.7-2 Results of High Frequency Voltage Distortion Measurement [Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

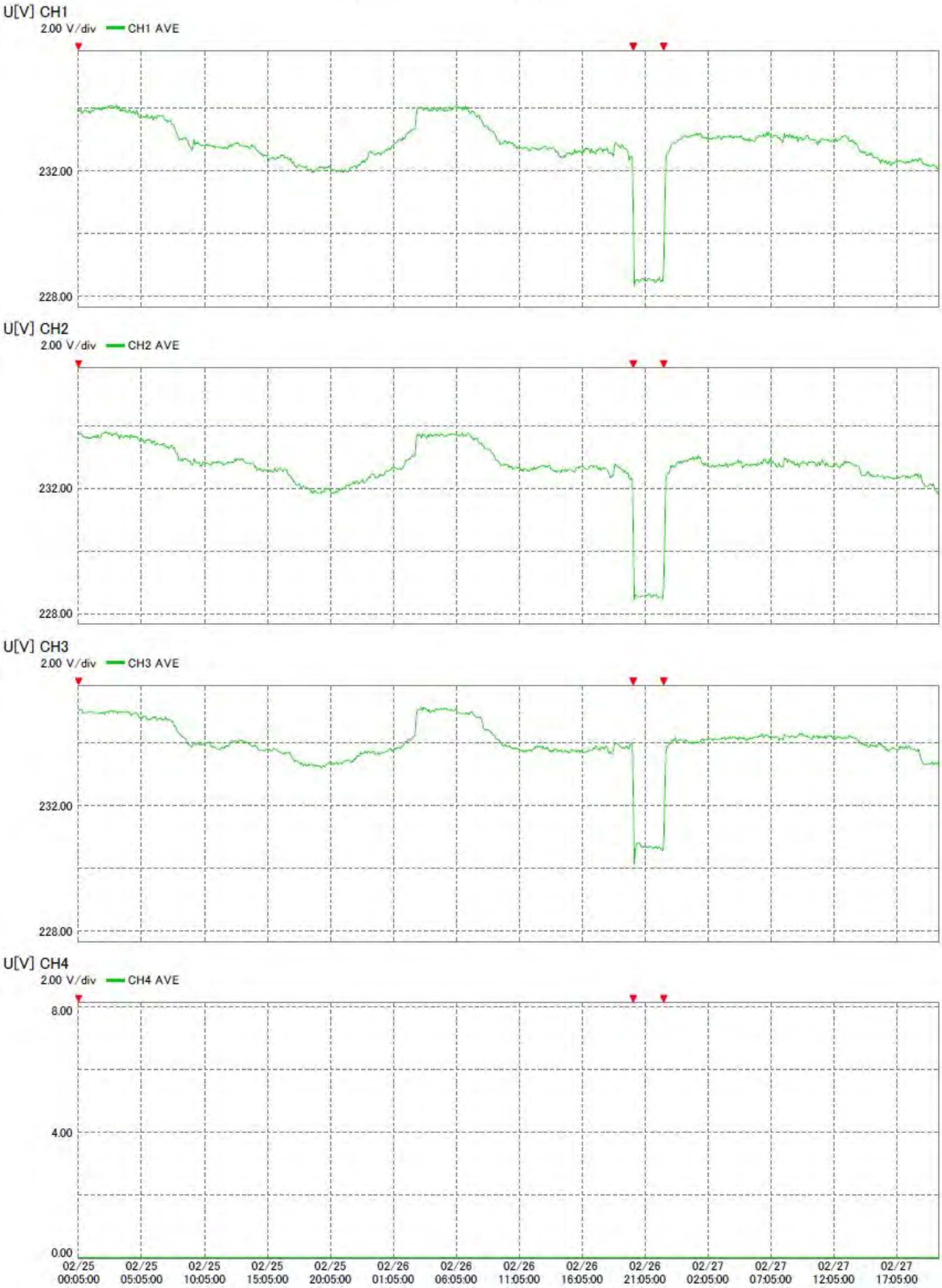
Concerning the frequency fluctuation, this is held to an extremely precise range of 49.96～50.06Hz and 50Hz±0.1%, and there is a low possibility of stoppages being caused by the detection of frequency fluctuations in the PV interconnection inverter.



Source： Prepared by the Study Team

Figure 4.7-3 Results of Frequency Fluctuation Measurement
[Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

Concerning voltage fluctuation, there is some voltage drop when the stadium lights are turned on, however, the fluctuation scope is 228.3~234.1V, which falls within the nominal voltage range of 230±2% (the STELCO standard is±2.5％ of nominal voltage). Therefore, there is no problem regarding PV interconnection in this respect too.



Source： Prepared by the Study Team

Figure 4.7-4 Voltage Fluctuation Measurement Results

[Measurement Point: National Stadium on the Distribution Tr Low Voltage Side]

Also, it was surveyed whether or not PV operation information (DC voltage and current, AC voltage, current and frequency, active power, reactive power, solar irradiation intensity, etc.) can be incorporated into the SCADA system with a view to monitoring the operating status and assessing stability of the grid-connected PV system.

The SCADA system currently enables 40 out of 98 substations and seven diesel power plants on Male' Island to be remotely monitored and controlled by wireless, and the PLC (Programmable Logic Controller) has almost reached full capacity. Since it will be difficult to install a new monitoring station, it is desirable to install data loggers, etc. that can monitor and record the operating condition of the PV systems at all times.

4.8 Technique for Determining the Introduced Capacity of Grid-Connected PV Systems

As the technique for determining the grid-connected PV system capacity that can be technically introduced in the Maldives, it is necessary to examine and decide the possible capacity by means of the following two steps: Step 1: examination of constraints from the viewpoint of power system operation, and Step 2: examination of constraints from the viewpoint of distribution line operation. The results of examination in each step are as shown below.

[Step 1] Examination of constraints from the viewpoint of power system operation

Based on the results of assessing load responsiveness of diesel generators as described in 4.5, the available fluctuation of diesel generators with governor-free operation is as follows by utilizing 2009 case on Male' Island .

41.96MW ＊ (1.0% / 4.0%) = approximately 16.78MW

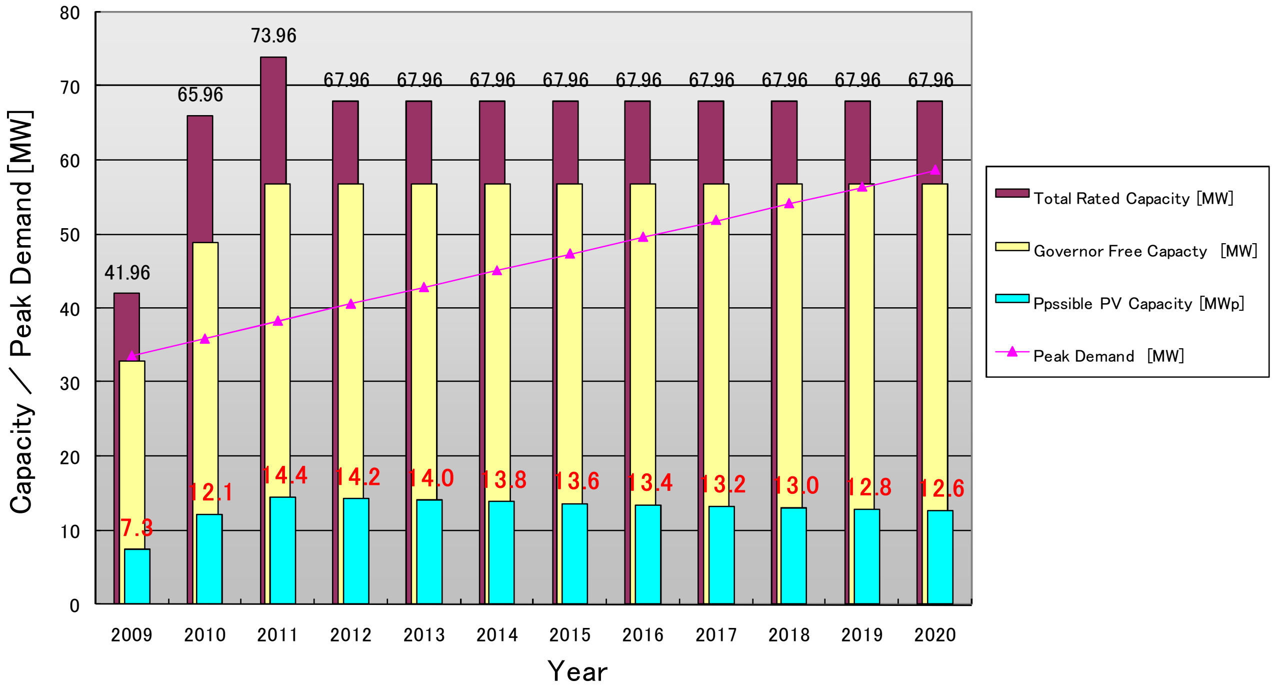
Here, the frequency control standard of STELCO is 50Hz±1.0% and, since the governor speed adjustment rate is 4%.

PV output fluctuation (kW) + Demand fluctuation (kW) ≤ available fluctuation of diesel generators with governor-free operation (kW)

From the above expression, assuming the demand fluctuation is around 7% of peak load based on STELCO operating performance, the available PV output fluctuation is as follows..

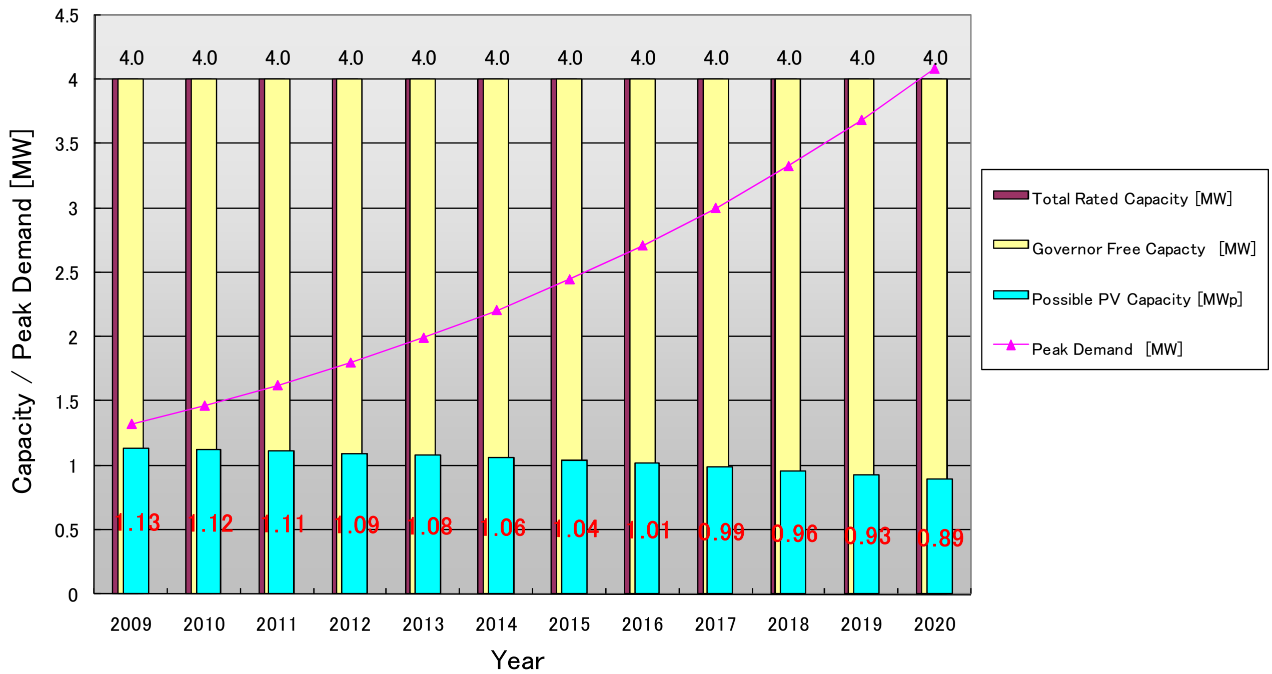
The available PV output fluctuation ≤ 16.78MW － 10.94MW = 5.84MW

Here, assuming that the fluctuation range of PV output is between 10~90% of rated output based on past cases, the potential grid-connected PV introduction capacity on Male' Island in 2009 is approximately 7.3MW. And in the same way, the potential grid-connected PV introduction capacity on Male' Island and Hulhumale' Island up to 2020 can be calculated as shown in the following figure.



Source： Prepared by the Study Team

Figure 4.8-1　Possible PV Capacity on Male' Island

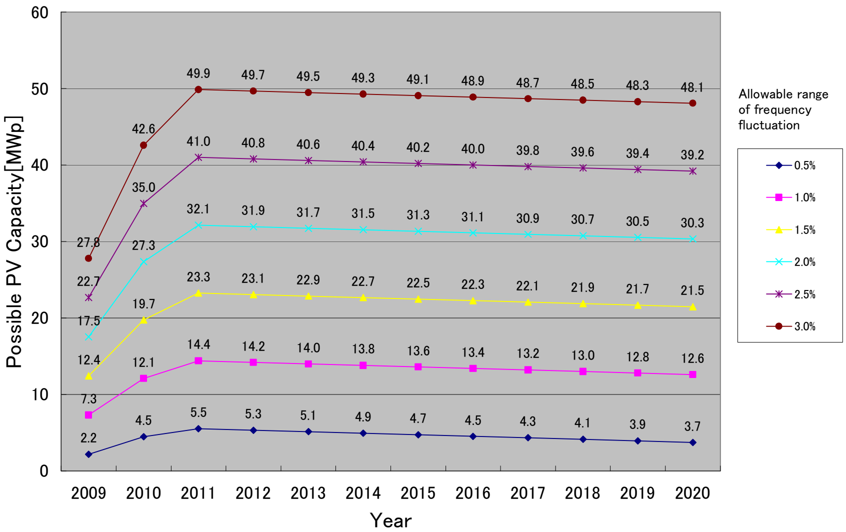


Source： Prepared by the Study Team

Figure 4.8-2　Possible PV Capacity on Hulhumale' Island

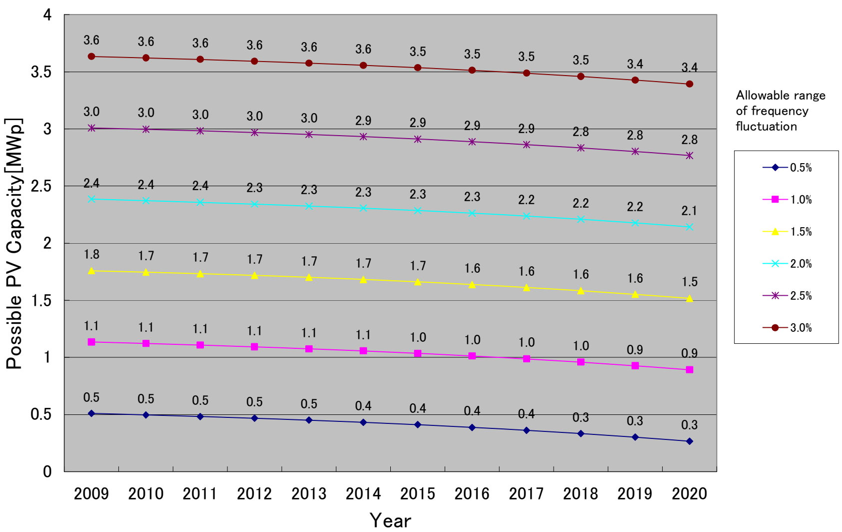
Moreover, in the actual operating stage, the governor-free capacity is limited in some cases due to the engine heating and periodic inspections, etc. described in 4.5. Accordingly, it will be necessary to carefully analyze PV output fluctuations from the actual operating data following PV introduction and, where the need exists, examine the implementation of steps to limit PV output in advance.

This examination is based on the frequency fluctuation control standard of STELCO. And the possible PV capacity is also changed in accordance with the standard. Therefore the sensibility analysis was executed using allowable frequency fluctuation as a parameter. The results are shown in below. However over 2% of range is not allowed at present condition due to the load sharing setting (1st step: 49Hz + 3 sec, 2nd step: 48.5Hz + 3 sec) of SCADA for power system stability and under frequency protection relay setting (47Hz + instant) for generators.



Source: Prepared by the Study Team

Figure 4.8-3 Relationship between Allowable Frequency Fluctuation and Possible PV Capacity on Male' Island



Source: Prepared by the Study Team

Figure 4.8-4 Relationship between Allowable Frequency Fluctuation and Possible PV Capacity on Hulhumale' Island

[Step 2] Examination of constraints from the viewpoint of distribution line operation

In the simulated calculation of voltage flow used in the examination described in 4.6, the PV interconnection capacity reaching the upper limit of the distribution line voltage control value was calculated under the harshest conditions of decoupling all load from each distribution line. As a result of the simulation, it was found that the rise in distribution line voltage was within the control standard even when PV energy was connected to the upper capacity limit of each distribution line. This can be explained by the fact that distribution lines are short in length (because of the small size of the island) and they have mostly been converted to heavy lines. From the results of examination, the limitations on distribution line operation are found to be as follows: on Male' Island, 5,330 kW on each distribution line and 42,640 kW over the entire distribution line network; and on Hulhumale' Island, 3,040 kW on each distribution line and 6,080 kW over the entire network.

Table 4.8-1 Examination Results regarding PV Connection Capacity to Distribution Lines (Male' Island)

Feeder No.	PV Connection Capacity [kW]	Peak Voltage [V]	Voltage Rise [V]	Fluctuation Rate [%]
FD2	5,330	11,083	83	0.75
FD3	5,330	11,070	70	0.64
FD4	5,330	11,028	28	0.25
FD5	5,330	11,096	96	0.87
FD6	5,330	11,225	225	2.05
FD7	5,330	11,118	118	1.07
FD8	5,330	11,109	109	0.99
FD9	5,330	11,089	89	0.81
Total	42,640	-	-	-

Source： Prepared by the Study Team

Table 4.8-2 Examination Results regarding PV Connection Capacity to Distribution Lines (Hulhumale' Island)

Feeder No.	PV Connection Capacity [kW]	Peak Voltage [V]	Voltage Rise [V]	Fluctuation Rate [%]
FD1	3,040	11,139	139	1.26
FD2	3,040	11,104	104	0.95
Total	6,080	-	-	-

Source： Prepared by the Study Team

From the above examination, it was concluded that values limited from the viewpoint of power system operation should be applied as the potential grid-connected PV capacity on Male' Island and Hulhumale' Island.

Moreover, regarding constraints in terms of the possible installation space, when the above examination results are converted into installation area, the possible installation capacity by 2020 on Male' Island (12.6 MW) requires space of approximately 90,000 m^2, while the possible capacity on Hulhumale' Island (0.89 MW) requires approximately 6,000 m^2. Since these areas account for 6.0% of total island area excluding streets, parks and cemeteries on Male' Island (1.5 km^2), there should be no problem whatsoever.

As for Hulhumale' Island, developing standard housings has approximately 750 m^2 of roof top areas. Therefore roof top areas of eight housing are almost equal to required areas for PV installation on Holhumale' Island.

Based on the results of this examination and the economic and financial feasibility study (refer to Chapter 5), the target grid-connected PV installation capacity by 2020 is set as follows.

Table 4.8-3 Target Grid-Connected PV Installation Capacity on Male' Island and Hulhumale' Island

(kW)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Male' Island	280	560	840	1,120	1,400	1,680	1,960	2,240	2,520	2,800
Hulhumale' Island	20	40	60	80	100	120	140	160	180	200

Source： Prepared by the Study Team

4.9 Standard Design Specifications of the Grid-Connected PV System

Taking into consideration the technical requirements examined in the Study and meteorological conditions and building strengths in the Maldives, the design standard specifications required of the grid-connected PV system are as indicated in the following table.

Table 4.9-1 Standard Design Specifications of the Grid-Connected PV System

Equipment	Item	Required Specifications
PV module	(1) Applicable standard	IEC and equivalent standard
	(2) Environment of use	Area prone to salt damage
	(3) Ambient temperature	Up to +40℃
	(4) Installation method	Sloping roof type or flat roof type
	(5) Type	Crystal silicon
	(6) Module efficiency	No less than 12%
	(7) Module capacity	No less than 100W/sheet
PV module installation stand	(1) Support mode	Sloping roof type: attached to main buildings Flat roof type: S stand
	(2) Environment of use	Area prone to salt damage
	(3) Material	SS400 hot-dip zinc finish or equivalent quality
	(4) Design standard wind velocity	15m above ground, wind velocity 60m/s
Connection box	(1) Structure	Indoor/Outdoor, wall-hanging type or vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	Up to +40℃, no less than 70%
	(4) Peak input voltage	No less than the string unit nominal open voltage (V_{OC})

Equipment	Item	Required Specifications
	(5) Number of input circuits	No less than the sub-array unit number of lines
	(6) Input current	No less than the module nominal shorting current (I_{SC}) per circuit
	(7) Number of output circuits	1 circuit
	(8) Output current	No less than the sub-array nominal shorting current (I_{SC})
	(9) In-built instruments	- Distribution line circuit breaker: Number of circuits - Backflow prevention diode: Each string - Induction lightning protector: All input/output circuits, between lines, between ground
Collecting box * This may be omitted if there is one connection box or the number of power conditioners input circuits exceeds the number of connection boxes.	(1) Structure	Indoor/Outdoor, wall-hanging type or vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	Up to +40℃, no less than 70%
	(4) Peak input voltage	No less than the string unit nominal open voltage (V_{OC})
	(5) Number of input circuits	No less than the number of integrated connection boxes
	(6) Input current	No less than the connection box output current
	(7) Number of output circuits	1 circuit
	(8) Output current	No less than the sub-array nominal shorting current x number of input circuits
	(9) In-built instruments	- Distribution line circuit breaker: Number of circuits - Induction lightning protector: All input/output circuits, between lines, between ground
Power conditioners	(1) Structure	Indoor/Outdoor, vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	Up to +40℃, no less than 70%
	(4) Main circuit type	Self-exciting voltage type
	(5) Switching method	High frequency PWM
	(6) Insulation method	Commercial frequency insulated transformer type Non-insulation (no transformer) only allowed in cases of small capacity
	(7) Cooling method	Forced air cooling
	(8) Rated input voltage	Around the string peak output voltage (Vpmax)
	(9) Input operating voltage range	The string peak output voltage (Vpmax) and nominal open voltage (Voc) must be in the range.
	(10) Number of input circuits	No less than the number of collection boxes
	(11) Output electricity mode	3φ3W
	(12) Rated output voltage	AC202V
	(13) Rated frequency	50Hz
	(14) AC output current distortion factor	No more than 5% of total current and 3% of each harmonic
	(15) Power control method	Peak output follow-up control
	(16) Rated power conversion	No less than 90%

Equipment	Item	Required Specifications
	efficiency	
	(17) Control function	- Automatic start/stop, soft start - Automatic voltage adjustment - Condensive reactive power control or output control function (only when there is risk of voltage deviations with reverse flow)
	(18) Grid connection protective function	- Over-voltage (OVR) - Under-voltage (UVR) - Frequency rise (OFR) - Frequency drop (UFR) - Over-voltage ground (OVGR) (can be omitted in case of low voltage interconnection) - Automatic reclose in case of recover from blackout (with a condition of receiving voltage confirmation) All settings and times shall be adjustable.
	(19) Isolated operation detection function	- Active type (1 or more of the following methods): ① Frequency shift type ② Active power fluctuation type ③ Reactive power fluctuation type ④ Load fluctuation type - Passive type (1 or more of the following methods) ① Power phase jump detection type ② 3rd harmonic voltage rise detection type ③ Frequency change rate detection type
Interconnection transformer	(1) Structure	Indoor/Outdoor, vertical self-supporting type
	(2) Environment of use	Area prone to salt damage (excluding indoor types)
	(3) Ambient temperature and humidity	+ Up to +40℃, no less than 70%
	(4) Primary voltage	3φ4W AC400V
	(5) Secondary voltage	3φ3W AC200V
	(6) Frequency	50Hz
	(7) Insulation class	Type B
	(8) Wire connection method	Y-Δ(Yd1)

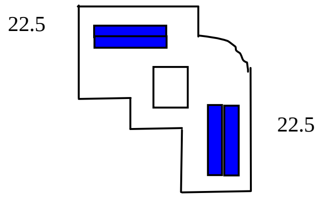
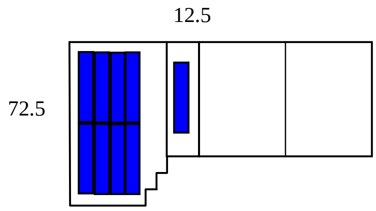
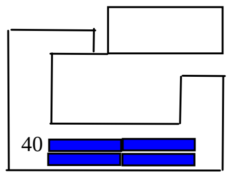
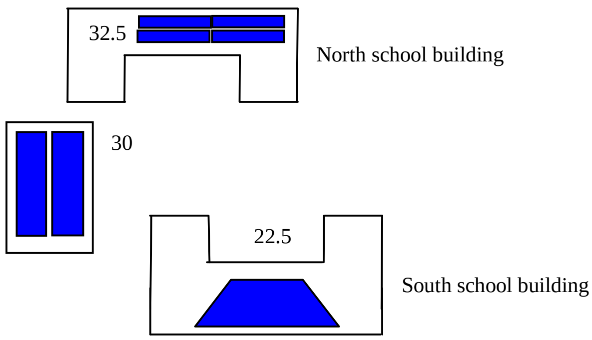
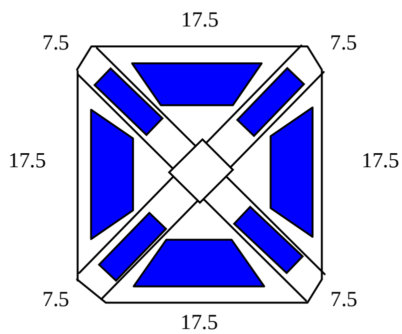
Source： Prepared by the Study Team

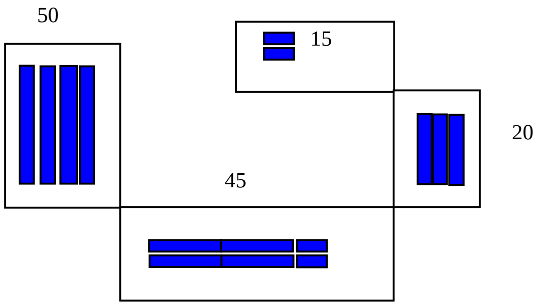
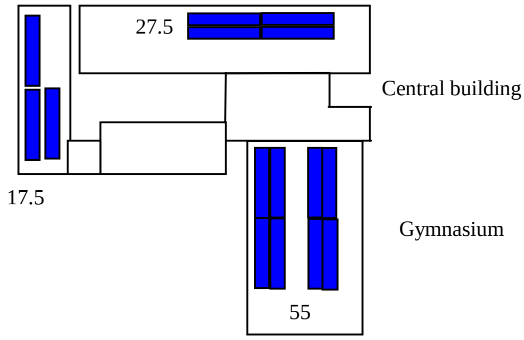
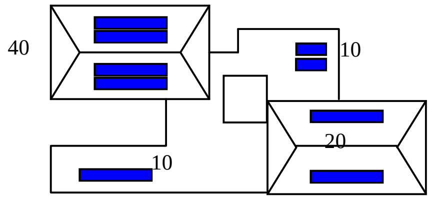
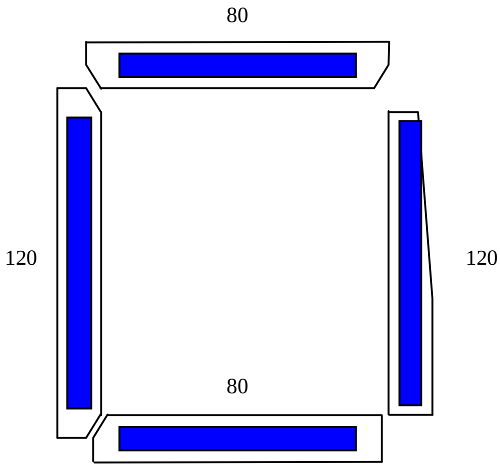
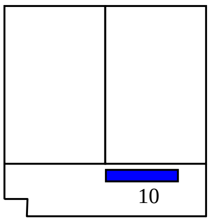
4.10 Potential Sites for Grid-Connected PV System Installation, and PV Installation Capacity

Concerning the potential sites selected in 4.4, field surveys were implemented on such items as the possible PV installation area, existing power receiving facilities and surrounding environment, etc. Concerning the PV installation capacity, the ideal array method was calculated upon considering the possible installation area and impact of obstructions to solar irradiation discussed in 4.3.

Tables 4.10-1 and 4.10-2 show the results of examining the PV array method, while the results of examination on PV installed capacity are as indicated in the comparison sheet of potential sites for PV installation as the start of this report.

Table 4.10-1 Results of PV Array Examination at Potential Sites on Male' Island

No.	Site	PV Installation Site
1	STELCO Building	
3	Dharubaaruge	
5	Giyaasudheen School	
6	Kalaafaanu School	
7	Maldives Center for Social Education	

No.	Site	PV Installation Site
8	Thaajuddeen School	
9	New Secondary School for Girls	
11	Faculty of Engineering	
12	National Stadium	
17	Faculty of Education	

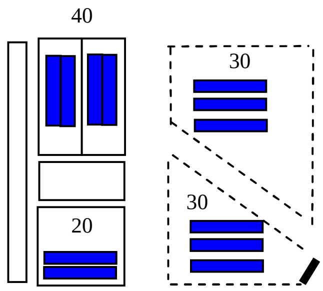
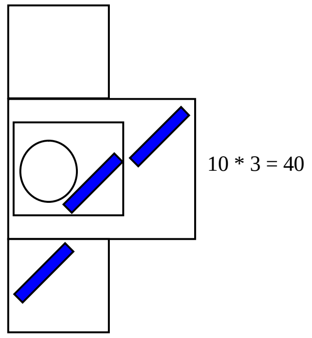
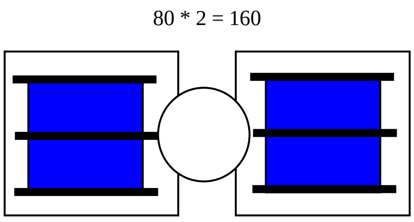
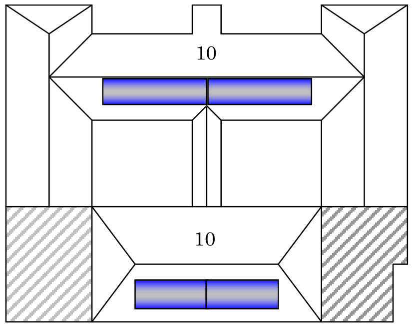
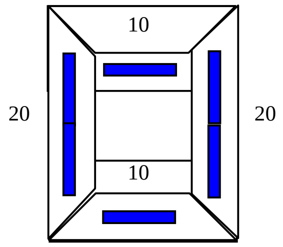
No.	Site	PV Installation Site
19	Male' South West Harbour Parking	
20	Grand Friday Mosque	
21	Jumhooree Maidhaan	
22	President's Office	

Table 4.10-2 Results of PV Array Examination at Potential Sites on Hulhumale' Island

No.	Site	PV Installation Site
2	Hospital	

4.11 Beneficial Effects of Grid-Connected PV System Introduction

4.11.1 Estimated Power Generation

The estimated amount of power generation at each potential site was calculated using the following expression:

$$Ep = \Sigma H_A / Gs * K * P$$

(Σ indicates the integrated value of estimated power generation calculated for each month).

Where, Ep = Estimated annual power generation (kWh/year)

H_A = Monthly average solar irradiation on the installation surface (kWh/m^2/day)

Gs = Solar irradiation intensity in standard conditions (kW/m^2) = 1 (kW/m^2)

K = Loss coefficient = Kd * Kt * η_{INV}*ηTR

* DC correction coefficient Kd: Correction for loss caused by dirt on solar cells and fluctuations in solar irradiation intensity. This was set at 0.8 here, also taking the correction for solar cell characteristic disparity into account.

* Temperature correction coefficient Kt : Correction coefficient taking into account temperature increases and fluctuations in the conversion efficiency of solar cells due to solar irradiation.

$$Kt = 1 + \alpha (Tm - 25) / 100$$

Where,

α: Peak output temperature coefficient (%・℃$^{-1}$) = - 0.5 (%-℃$^{-1}$) [Crystal]

Tm: Module temperature (℃) = Tav + ΔT

Tav: Monthly average temperature (℃)

ΔT: Module temperature increase (℃)

Open rear type	18.4
Roof installed type	21.5

* Inverter efficiency ηINV : Inverter AC-DC conversion efficiency: set at 0.95 here

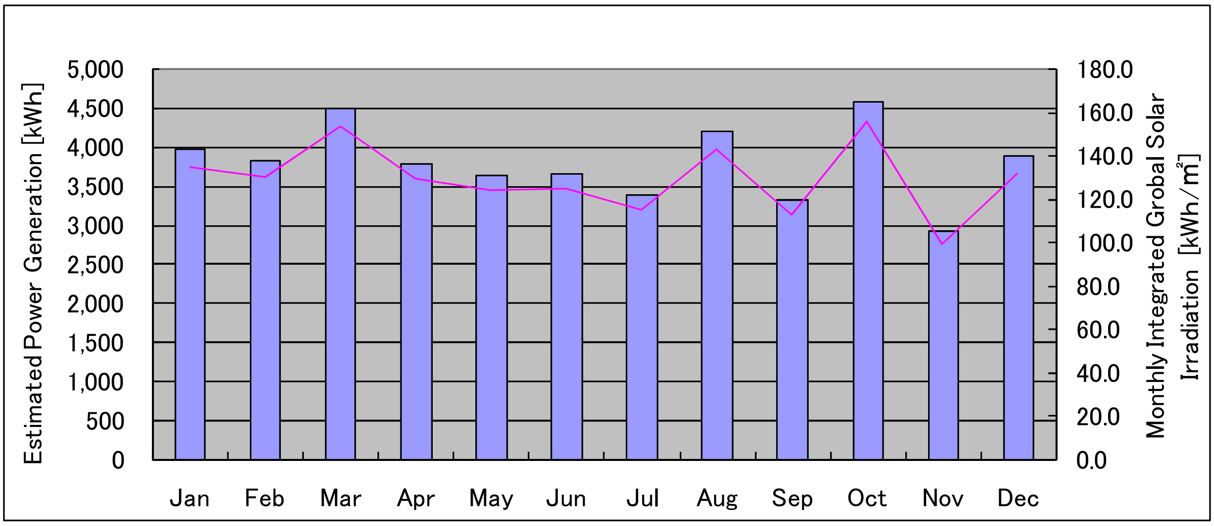
* Transformer efficiency ηTR : Transformer efficiency: set at 0.98 here considering that on-load and off-load loss are constant

For simplification, the horizontal surface amount of solar irradiation was adopted when calculating the monthly average amount of solar irradiation on the installed surface, and the impacts of obstructions discussed in 4.3 were taken into account. Concerning the impact of shade, this is conventionally examined upon considering the direct connection of PV modules, however, for the sake of simplification, in cases where roofs contain partial solar irradiation obstructions, conservative values were calculated assuming the whole roof to be affected.

Table 4.11.1-1 Estimated Annual Power Generation at Each Potential Site

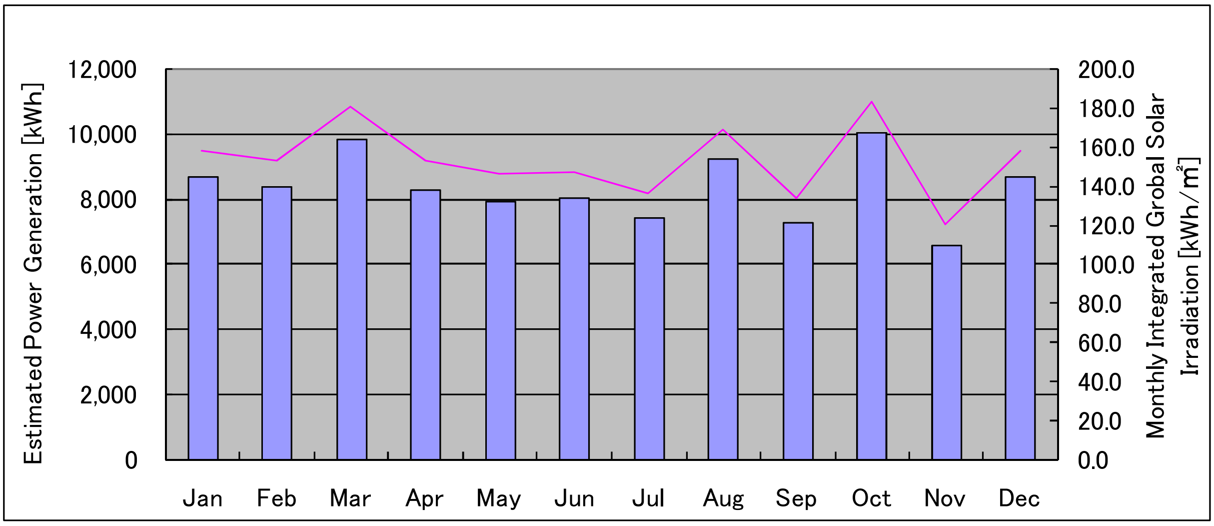
Island	Site Name	PV Capacity [kWp]	Annual Power Generation [kWh/year]
Male'	STELCO Building	45	45,739
	Dharubaaruge	85	100,382
	Giyaasudheen School	40	48,378
	Kalaafaanu School	85	117,069
	Maldives Center for Education	100	120,945
	Thaajuddeen School	130	157,228
	New Secondary School for Girls	100	90,778
	Faculty of Engineering	80	96,756
	National Stadium	400	483,780
	Faculty of Education	10	12,094
	Grand Friday Mosque	30	36,283
	Jumhooree Maidhaan	160	196,986
	President's Office	20	24,189
Hulhumale'	Hospital	60	72,567

Source： Prepared by the Study Team



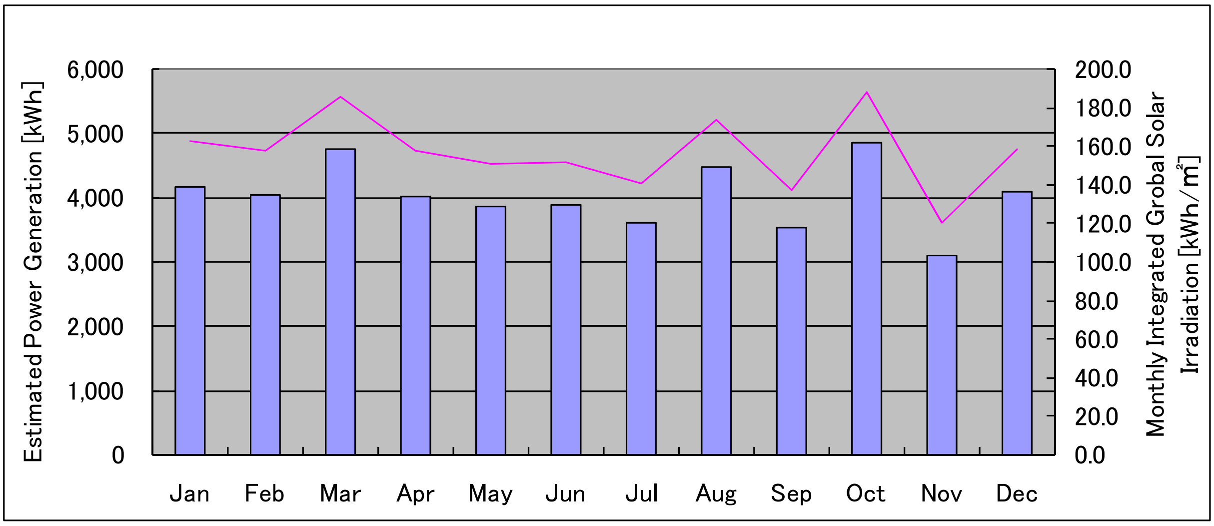
Source： Prepared by the Study Team

Figure 4.11.1-1 Monthly Power Generation Estimation (STELCO Building)



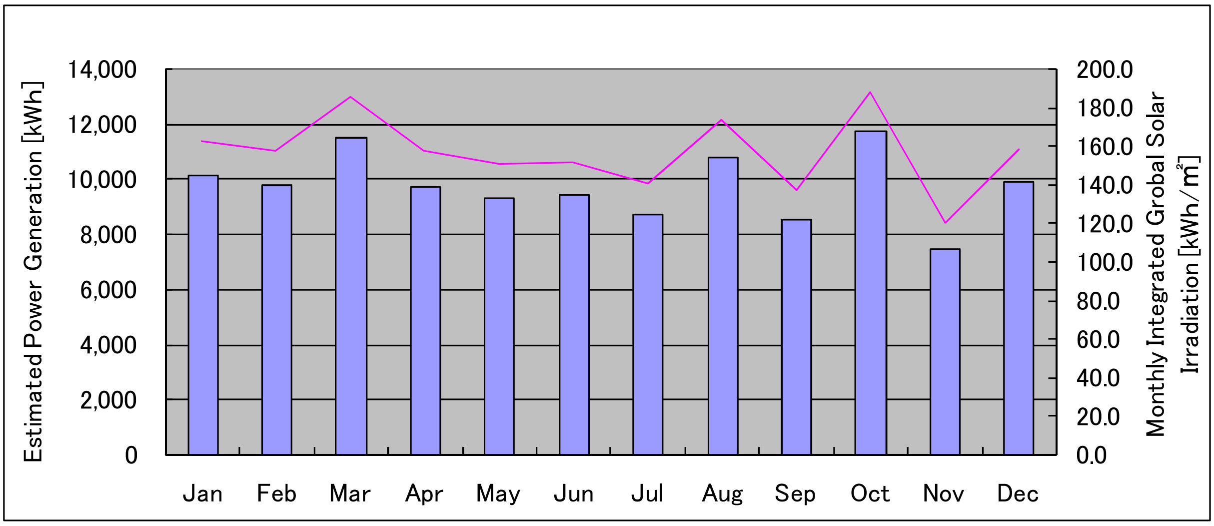
Source： Prepared by the Study Team

Figure 4.11.1-2 Monthly Power Generation Estimation (Dharubaaruge)



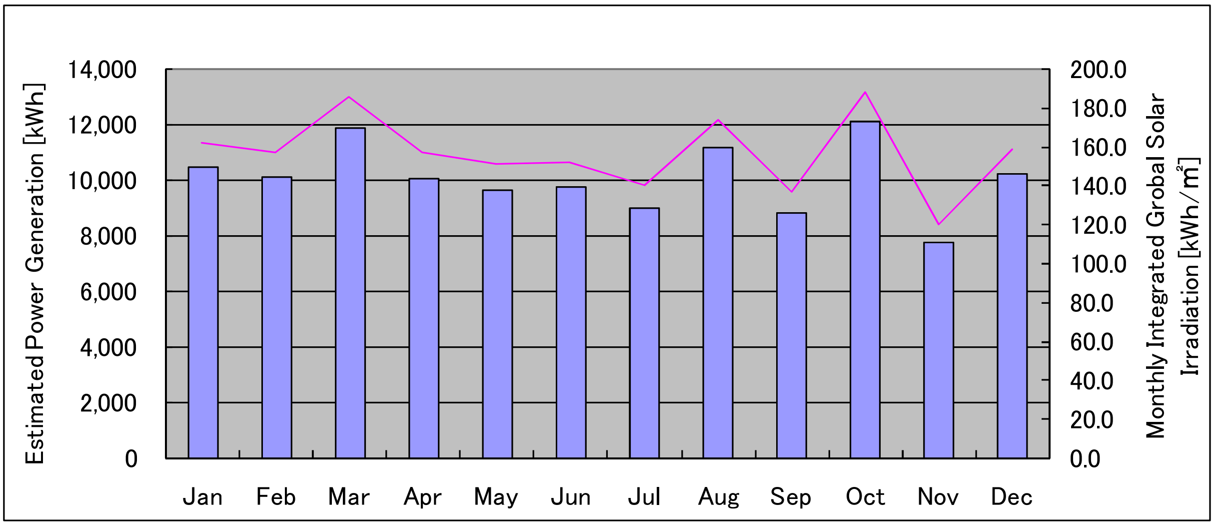
Source： Prepared by the Study Team

Figure 4.11.1-3 Monthly Power Generation Estimation (Giyaasudheen School)



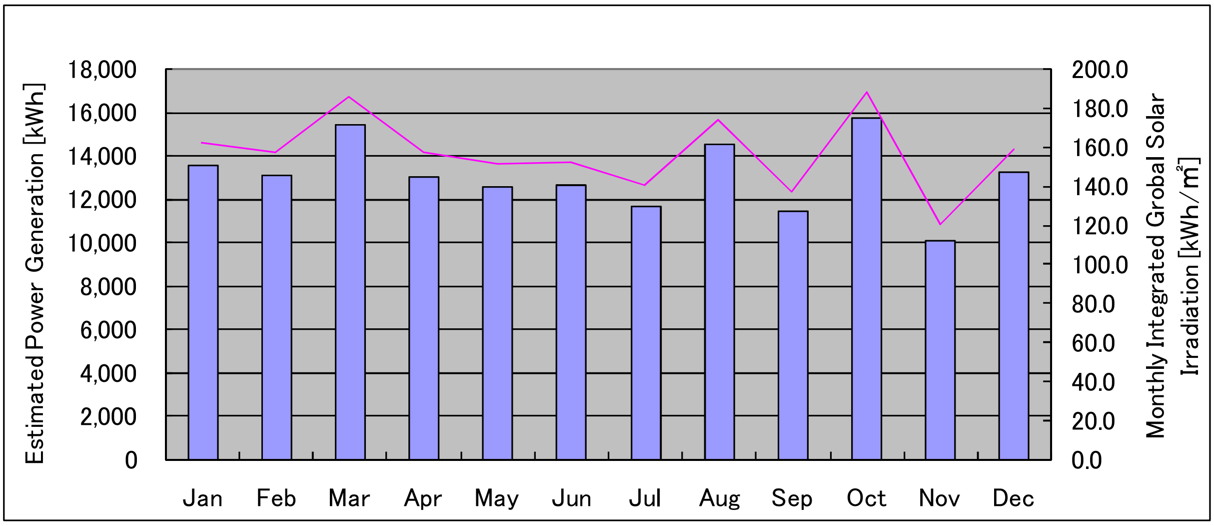
Source： Prepared by the Study Team

Figure 4.11.1-4 Monthly Power Generation Estimation (Kalaafaanu School)



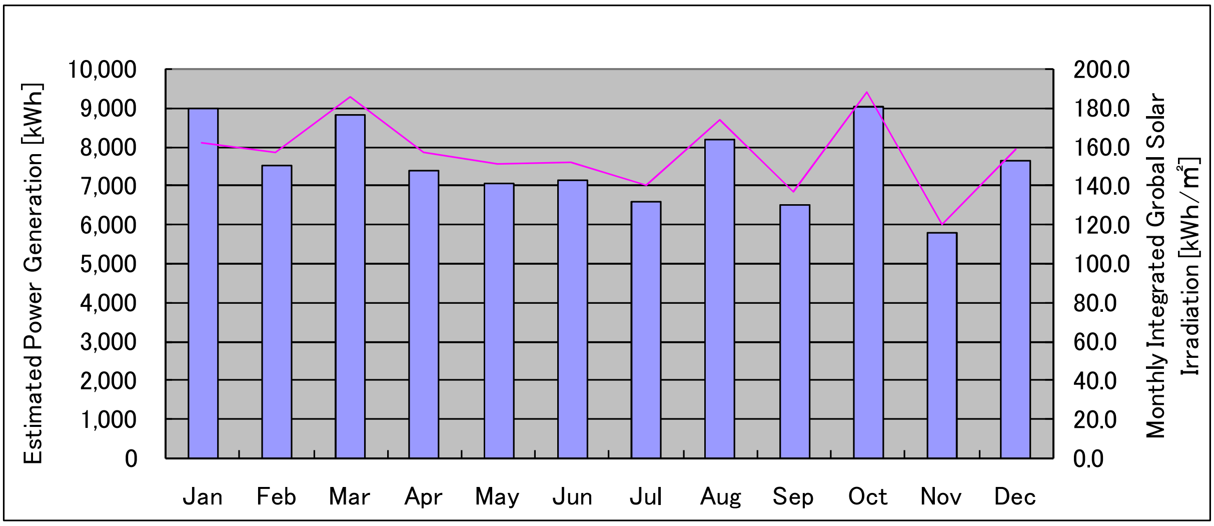
Source： Prepared by the Study Team

Figure 4.11.1-5 Monthly Power Generation Estimation (Maldives Center for Social Education)



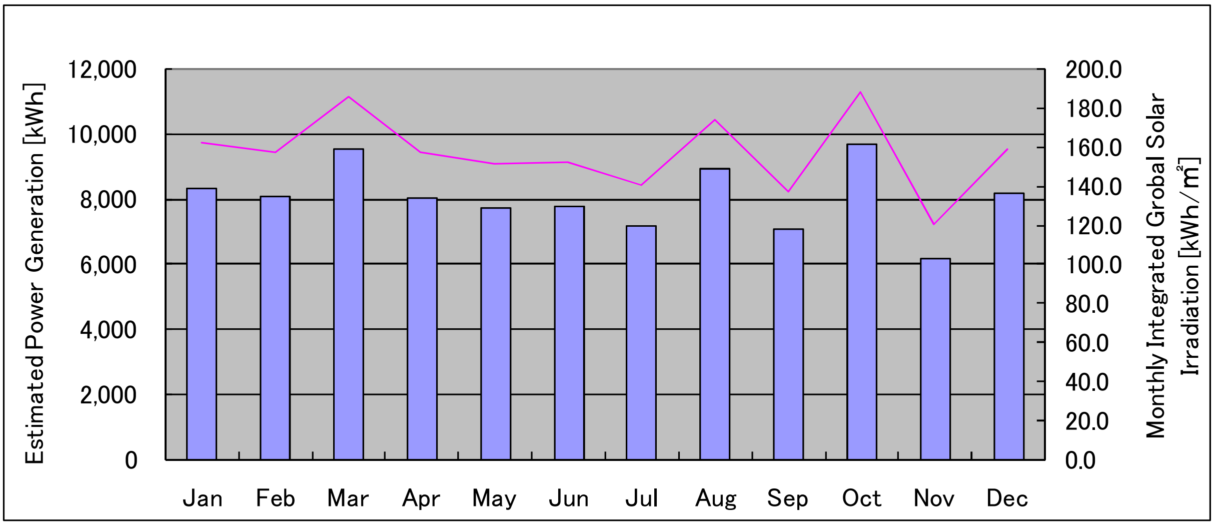
Source： Prepared by the Study Team

Figure 4.11.1-6 Monthly Power Generation Estimation (Thaajuddeen School)



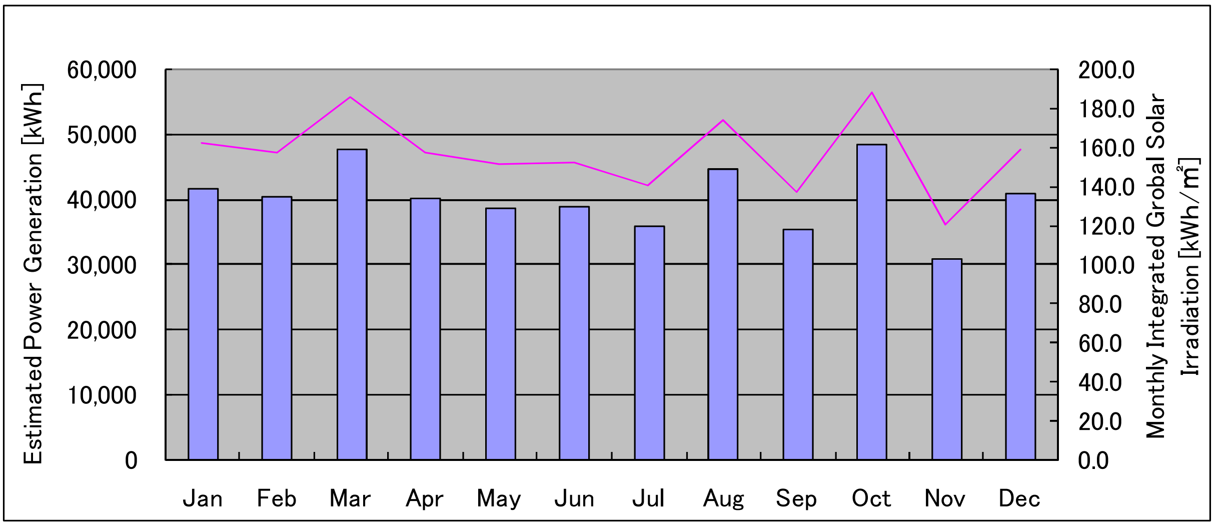
Source： Prepared by the Study Team

Figure 4.11.1-7 Monthly Power Generation Estimation (New Secondary School for Girls)



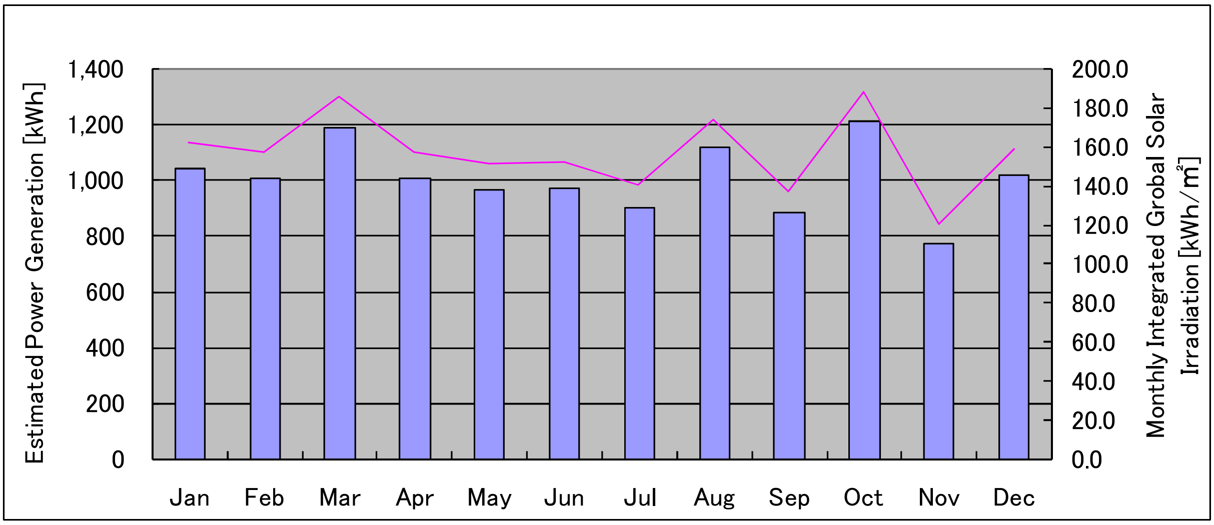
Source： Prepared by the Study Team

Figure 4.11.1-8 Monthly Power Generation Estimation (Faculty of Engineering)



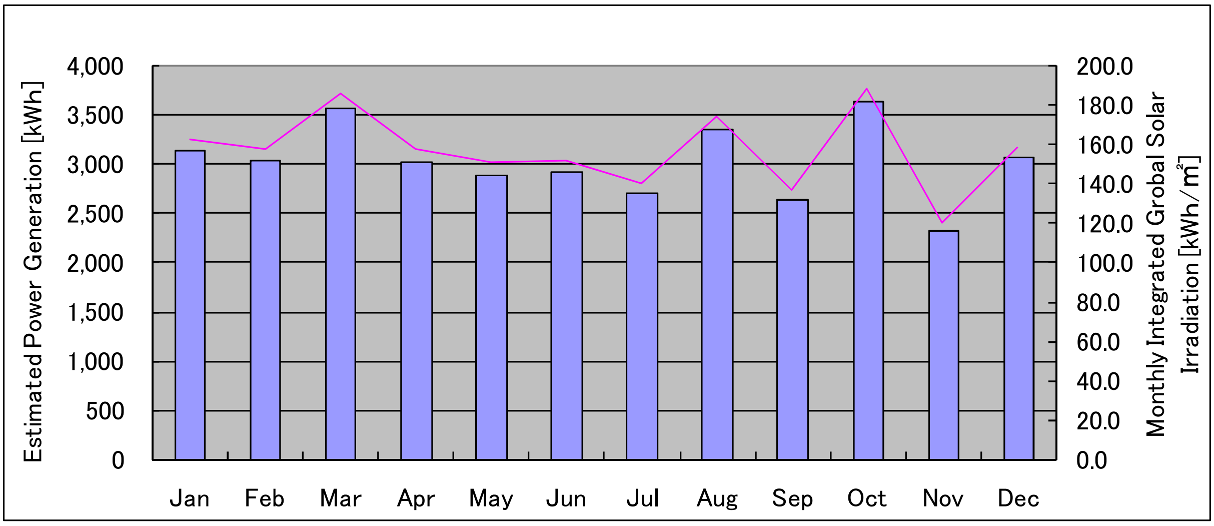
Source： Prepared by the Study Team

Figure 4.11.1-9 Monthly Power Generation Estimation (National Stadium)



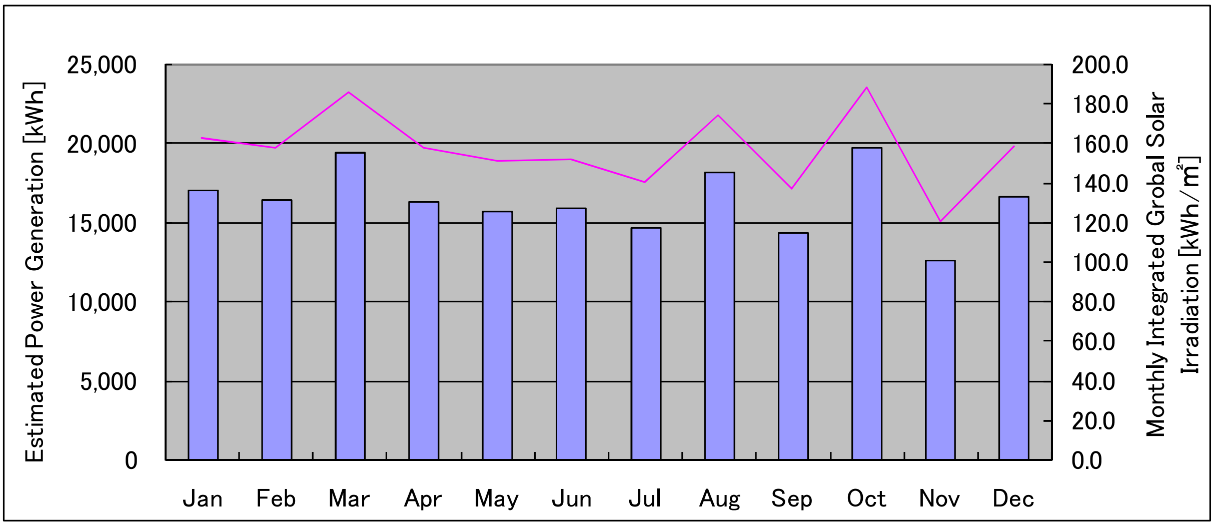
Source： Prepared by the Study Team

Figure 4.11.1-10 Monthly Power Generation Estimation (Faculty of Education)



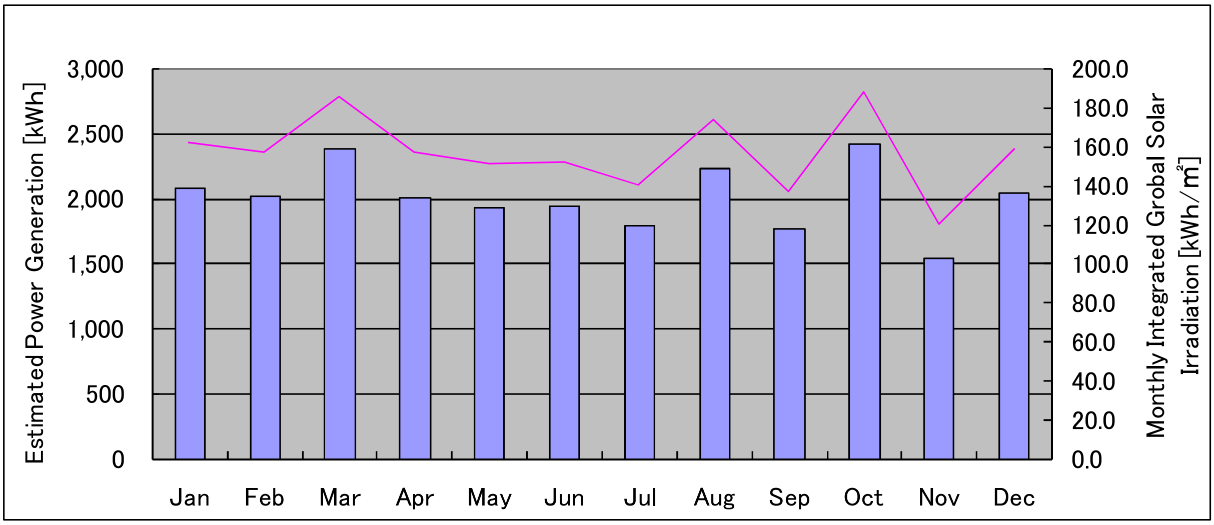
Source： Prepared by the Study Team

Figure 4.11.1-11　Monthly Power Generation Estimation (Grand Friday Mosque)



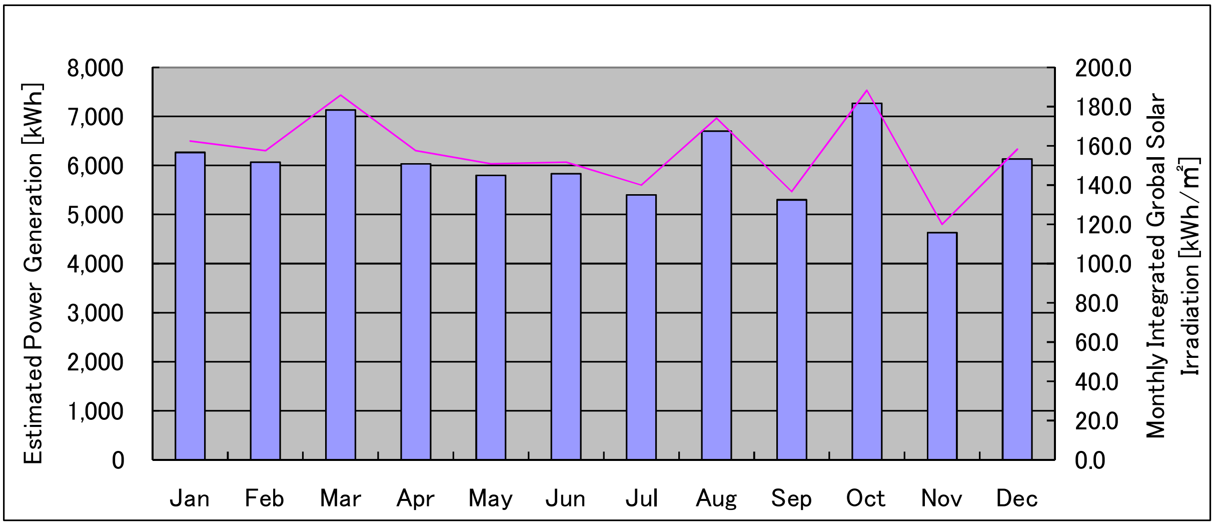
Source： Prepared by the Study Team

Figure 4.11.1-12　Monthly Power Generation Estimation (Jumhooree Maidhaan)



Source： Prepared by the Study Team

Figure 4.11.1-13　Monthly Power Generation Estimation (President’s Office)



Source： Prepared by the Study Team

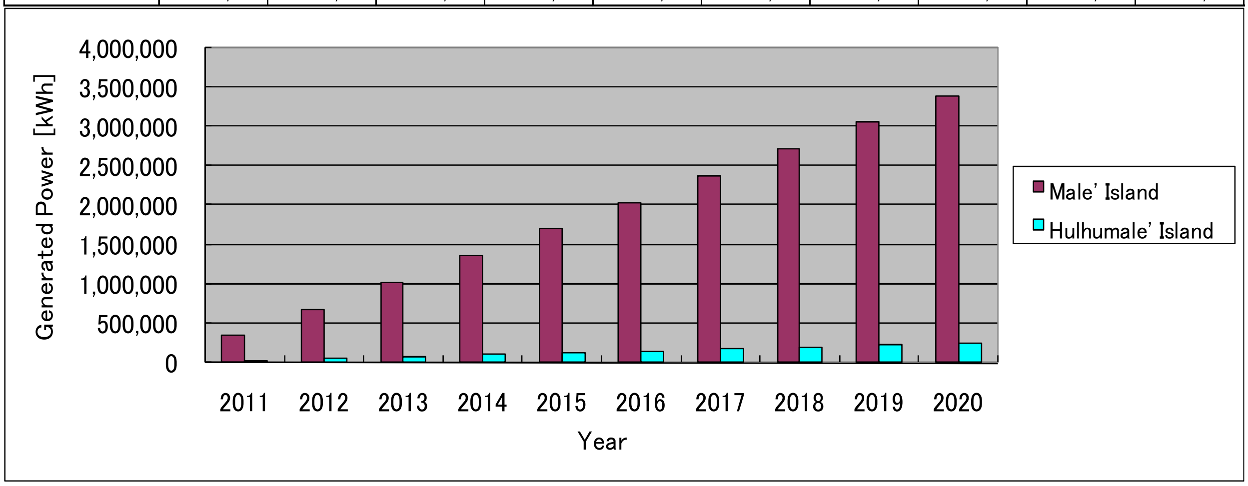
Figure 4.11.1-14 Monthly Power Generation Estimation (Hulhumale' Hospital)

Next, movements in the annual amount of power generation were estimated for the years from 2010 to 2020 based on the introduction target discussed in 4.8

In conducting the examination, considering installation at the pilot project site on Male' Island in 2011, it was assumed that all other systems are installed on roofs where there is no impact of shade. The results of calculation are indicated below.

(kWh)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Male' Island	338,646	677,292	1,015,938	1,354,584	1,693,230	2,031,876	2,370,522	2,709,168	3,047,814	3,386,460
Hulhumale' Island	24,189	48,378	72,567	96,756	120,945	145,134	169,323	193,512	217,701	241,890



Source： Prepared by the Study Team

Figure 4.11.1-15 Movements in Power Generation by Year

4.11.2 Diesel Fuel Consumption Saving

Based on operating performance figures obtained from STELCO for diesel power plants on Male' Island and Hulhumale' Island for the past three years, fuel consumption per unit power generation (kWh) was calculated as follows.

Table 4.11.2-1 Fuel Consumption at Diesel Power Plants on Male' Island and Hulhumale' Island

Island	Item	2006	2007	2008	3-month Mean
Male'	Power generation [kWh]	156,107,764	177,052,316	195,105,695	-
	Fuel consumption [liter]	40,151,086	45,482,134	50,460,116	-
	Fuel consumption per kWh [liter/kWh]	0.26	0.26	0.26	0.26
Hulhumale'	Power generation [kWh]	4,106,410	5,810,041	7,324,293	-
	Fuel consumption [liter]	1,196,425	1,614,299	2,061,552	-
	Fuel consumption per kWh [liter/kWh]	0.29	0.28	0.28	0.28

Source： Prepared by the Study Team using data obtained from STELCO

Using the above results, the amount of fuel savings calculated based on the grid-connected PV power generation each year as estimated in 4.11.1 was calculated in the manner shown in Table 4.11.2-2.

Table 4.11.2-2 Yearly Diesel Fuel Saving

(liter)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Male' Island	88,048	176,096	264,144	352,192	440,240	528,288	616,336	704,384	792,432	880,480	4,842,638
Hulhumale' Island	6,773	13,546	20,319	27,092	33,865	40,638	47,410	54,183	60,956	67,729	372,511

Source： Prepared by the Study Team

4.11.3 CO_2 Emission Reductions

Based on the diesel fuel savings calculated in 4.11.2, the following coefficient was used to calculate the amount of CO_2 emission reductions.

CO_2 reduction [kg] = Light oil CO_2 emission coefficient* x Diesel fuel saving
= 2.62 [kg-CO_2/liter] x Diesel fuel saving [liter]

* Concerning the emission coefficient, the Total Emissions Calculation Method Guidelines of the Ministry of Environment were quoted.

As a result, the amount of CO_2 emission reductions in each year was calculated as follows. In the case where the PV introduction target is achieved according to plan, the amount of CO_2 emission reductions over 10 years from 2010 to 2020 is 12,688 tons on Male' Island and 976 tons on Hulhumale' Island, resulting in a total reduction of 13,664 tons.

Table 4.11.3-1 Yearly CO_2 Reductions

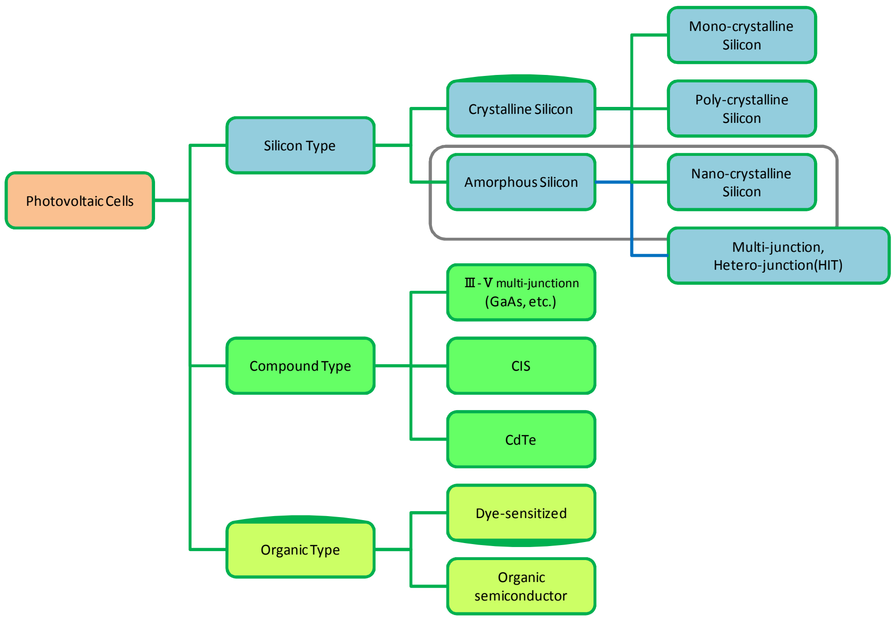
(kg)

Year	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Male' Island	230,686	461,371	692,057	922,743	1,153,428	1,384,114	1,614,800	1,845,485	2,076,171	2,306,856	12,687,710
Hulhumale' Island	17,745	35,490	53,235	70,980	88,725	106,470	124,215	141,960	159,705	177,450	975,978

Source: Prepared by the Study Team

4.12 Examination of Sola Cells and Assessment of Output

PV cells are categorized into silicon type, compound type and organic type by material. Based on the product record in 2008, approx. 99% of products are silicon type of PV and remaining is compound type and organic type. Compound type and organic type of PV cells are still in a research and development stage even though CIS PV cell, one of compound type is started to disseminate.



Source: AIST

Figure 4.12-1 Category of PV Cells by material

Silicon type of PV cell is categorized into crystalline silicon (mono-crystalline and poly-crystalline) and amorphous silicon (thin film silicon). As for the crystalline PV cell, mono-crystalline type was developed at Bell research institute, USA in 1954. Therefore the history after mass production is long and it is considered that the durability and reliability are high. In case of crystalline silicon type of PV cell, the life span is expected around 20 – 30 years. On the other hand, amorphous (thin film) silicon PV cell is the one which form thin film silicon on the glass or metallic plate. Although its conversion efficiency is less than crystalline, the flexibility of size and shape is merit. Amorphous silicon PV cell has characteristics of reaction to short wavelength light and approx. 10% output decrease under the condition of long period direct irradiation. Therefore it was used mainly for the calculators and watches using week light at indoor. Recently, it became to have practical durability even outside. Therefore it is sold for the outdoor purpose but its reliability has still not been verified yet because it just started the production.

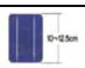
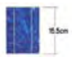
Moreover the cell efficiency of thin film type is less (approx. 10%) than crystalline type (approx. 15%). This means the thin film type cell needs 1.5 times of area comparing with crystalline type. Therefore the crystalline is effective under the condition of small land like Maldives

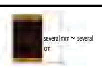
In addition, crystalline PV cell occupies 90% of market in Asia as shown in Table 4.12-2. The sales agents are selling mainly the crystalline PV cells. Therefore the crystalline silicon type has an advantage taking consideration into the marketability and ease to respond for trouble.

Reflecting with this, it is recommendable to apply crystalline silicon type of PV cells taking durability and reliability into consideration.

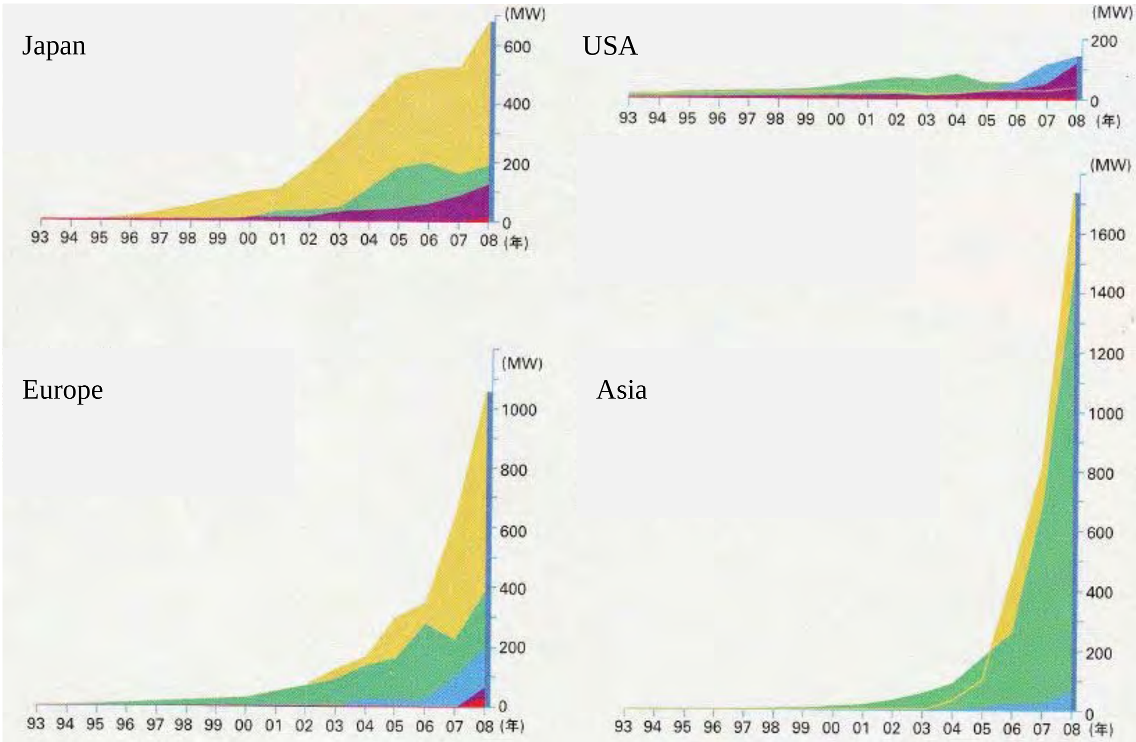
Table 4.12-1 Type of PV Cells and Characteristics

	Silicon				Compound		Organic	
	Crystalline silicon		Thin film silicon		CIS	Ⅲ-Ⅴ crystalline	Dye-sensitized	Oraganic thin film
	Mono-crystalline	Poly-crystalline	Amorphous	Multi-junction				
Characteristic	/ Utilize 200 μm～300 μm of thin mono-crystalline silicon plate / Most historic PV cell / Expensive but performance and reliability is high	/ Poly-crystalline plate with aggregate of small crystal / Cheaper than mono-crystalline and easy to produce / Most popular at present / Efficiency is lower than mono-crystalline type	/ 1 μm of thin film coating on a plate by amorphous silicon / Large area product is available / Mass-production / Performance has some issues comparing with crystalline silicon	/ Amorphous and small crystalline of laminated PV / Large area product is available / Mass-production / Perform under wide range of wavelength condition / less amount of silicon (approx. 1/100 of crystaline type) / Efficiency is higher than amorphous type	/ One of compound semiconductor / Thin film PV utilizing Cu (Cupper), In (Indium) and Se (Selenium) / Production process is simple / Expectation for high performance / R&D is on-going	/ Particular compound semiconductor plate utilizing Ga (gallium), As (Arsenic) etc. / High performance (30 - 40 % of efficiency) / High cost / Particular purpose such as space development / Reseach for cost reduction by concentrated PV system	/ Dye on titanium oxide (semiconductor) absorbs light and releases electron / Easy production / Expectation for low cost / Issues on efficiency and endurance	/ P-N junction of organic semiconductor / Expectation for low cost / Issues on efficiency and endurance
Module Efficiency ( ) means research stage	～19%	～15%	～6%	～12%	～11%	～31% (in case of concentrate)	(11%)	(5%)
Practicability	Practical application stage	Practical application stage	Practical application stage	Practical application stage	Practical application stage	Practical application stage	R&D stage	R&D stage
Manufacturer	Sharp, Sanyo (HIT Type)	Sharp, Kyocera, Mitsubishi	MHI, Kaneka	MHI, Kaneka, Fuji Electric, Sharp	Showa Shell, Honda	Sharp	Sharp, Fujikura, Sony, AISIN	Panasonic, ENEOS, Mitsubishi Chemical, Sumitomo Chemical


Source: Edited by the Study Team in reference to the materials by METI and NEDO in Japan



■ : Mono-crystalline、■ : Poly- crystalline、■ : Amorphous、■ : CdTe、■ : CIS

Source：Newton September 2009

Figure 4.12-2　Trend of PV introduction capacity in the world

4.13　Expected Model of Grid-Connected PV System Introduction

Since the total amount of installed capacity of the grid-connected PV systems on Male’ Island and Hulhumale’ Island will be limited to 13.49 MW, a scenario that entails disseminating the technology by 13.49 MW over 10 years until 2020 is considered. Regarding the parties responsible for introducing the technology, it is assumed that STELCO will take charge from 2011 to 2014 and that STELCO and the private sector will be jointly responsible from 2015 to 2020. Accordingly, the expected model of grid-connected PV system introduction shall be divided into two stages, i.e. the pilot project and the period up to 2014, and the period from 2015 to 2020.

In the pilot project and period up to 2014, since STELCO will be the agency responsible for introduction, two models of introduction can be considered: the model where STELCO introduces the grid-connected PV system as its own equipment into its own company buildings, and the model where STELCO introduces it as its own equipment into other companies’ buildings. As for the period from 2015 to 2020, since the private sector will join STELCO on the implementing side and consideration is given to establishing an excess power purchasing system when introducing to the private sector, another model, i.e. the model where building owners introduce equipment as private generator systems and sell excess power to STELCO, can be considered in addition to the above two.

Table 4.13-1 Expected Model of Grid-Connected PV System Introduction in the Pilot Project and Period until 2014

No.	Model of Introduction	Installation Site	PV System Owner	Features, Issues, Requirements, etc.
①	STELCO installs PV systems in its own building as company property.	STELCO's own facilities	STELCO	- Since STELCO owns the PV systems, planning and design for the PV systems is easier. - Installation sites can be selected by STELCO.
②	STELCO borrows rooftops owned by other entities and installs its PV systems.	Properties owned by third parties	STELCO	- Related regulations and constraints, rental fees for property shall be considered. - Agreement concerning system operation and security are required. - Since STELCO owns the PV facilities, there is no need to consider tariff for reverse power.

Source : Prepared by the Study Team

Table 4.13-2 Expected Model of Grid-Connected PV System Introduction in the Period from 2015 to 2020

No.	Model of Introduction	Installation Site	PV System Owner	Features, Issues, Requirements, etc.
①	STELCO installs PV systems in its own building as company property.	STELCO's own facilities	STELCO	- Since STELCO owns the PV systems, planning and design for the PV systems is easier. - Installation sites can be selected by STELCO.
②	STELCO borrows rooftops owned by other entities and installs its PV systems.	Properties owned by third parties	STELCO	- Related regulations and constraints, and rental fees for property shall be considered. - Agreement concerning system operation and security is required. - Since STELCO owns the PV facilities, there is no need to consider tariff for reverse power.
③	Building owners install PV systems as their own generators and sell excess power to STELCO.	Properties owned by third parties	Property owners	- Since PV systems are usually operated as in-house generators, reverse power is relatively little and the impact on distribution lines is small. - It is necessary to determine the interconnection guidelines and other transparent standards regarding protective equipment and so on.

Source : Prepared by the Study Team

The metering of PV power generation will be treated as follows. STELCO will install standalone meter for PV system in case that STELCO own the PV system. A meter without protection for reverse rotation is installed at interconnection point in order to measure stand-by consumption during nighttime.

On the other hand, as mentioned above, excess power purchasing system will be applied for private sectors after 2015. In case that private sectors own the system, the Team concluded that it is better to install a new meter (with protection for reverse rotation) to measure selling electricity beside of an existing buying meter (with protection for reverse rotation). It is the reason why the power purchasing price is uncertain because it must be decided taking financial condition after privatization of STELCO into consideration.

Table 4.13- 3 Metering method for grid-connected PV system

PV System owner	Fig. No.	interconnection category	Procurement & installation of meter	Type of meter	Installation point for meter	Boundary of properties and responsibility	Metering method
STELCO	①	LV	STELCO	Without protection for reverse rotation (MEA accredited products)	LV side	All STELCO's properties	Standalone meter for PV power generation
	②	MV			MV side of interconnection transformer		
Except for STELCO	③	LV 1Φ(～40A)	STELCO (PV System owner must shoulder the cost)	With protection for reverse rotation (MEA accredited products)	LV side (between existing meter and distribution board)	Primary side of meter or incoming cable terminal of MDB is boundary. The distribution lines side's cables belong to STELCO. The meters belong to the customer but installation, removal and replacement without approval from STELCO are prohibited	An additional meter (with protection for reverse rotation) to measure selling electricity must be install beside an existing meter (with protection for reverse rotation)
		LV 3Φ (～63A)					
	④	LV 3Φ (100～300A)	PV System owner (need STELCO's calibration) or can order to STELCO				
	⑤	MV (300A～)			MV side of receiving transformer		

Source: Prepared by the Study Team

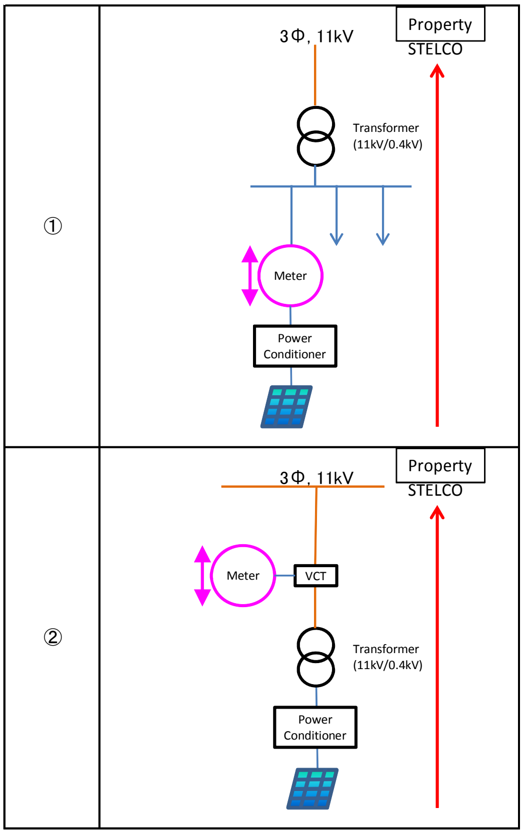


Figure 4.13- 1 Image for metering of grid-connected PV system（STELCO's installation）

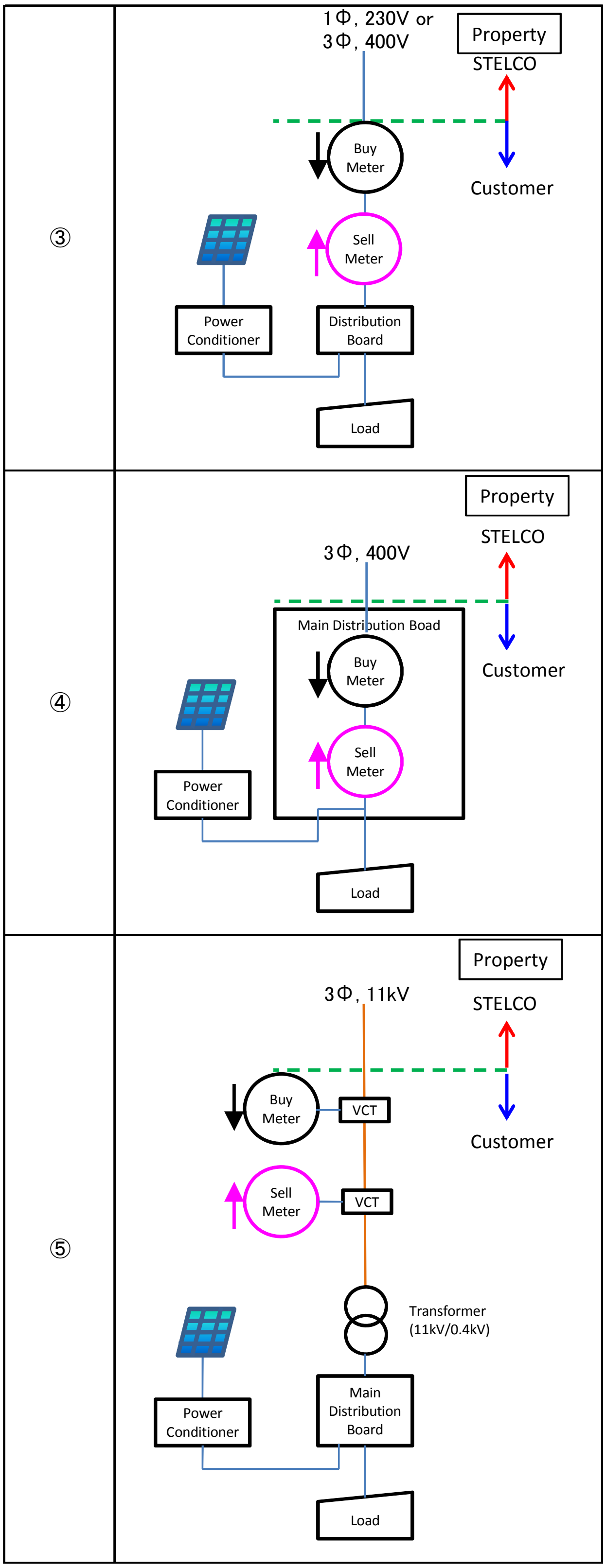


Figure 4.13- 2 Image for metering of grid-connected PV system（except for STELCO's installation）

4.14 Legal Systems (Building Law, etc.) concerning Existing Buildings

It is planned to install the PV panels on the square roof or roofs of existing buildings. On Male' Island, where buildings are densely packed, and Hulhumale' Island, which is undergoing large-scale development plans, this is deemed to be the optimum method upon taking the impact of shade, cost and ease of maintenance, etc into consideration. Roofing specifications in the Maldives generally consist of sheets metal roofing on sloped roofs on both RC buildings (reinforced concrete structures) and S buildings (steel structures). In cases where rooftops are used as open spaces, water-proofing specifications are applied to RC slab. The National Building Code of the Maldives was established in August 2008, this provides broad performance stipulations. Maldives National Building Act first draft was announced in June. 2009. They invited a public comment and they are adjusting it toward the enactment. When new building or rebuilding works are implemented, the responsible engineering section of the MHTE individually reviews and gives planning permission for each applied building. New Zealand and British standards are used to provide the basis for conducting review. Provided that the calculations used to prove the safety of structures can be explained in engineering terms, it doesn't matter which country's standard are used. The loads that are assumed when designing PV panels and supporting members generally comprise permanent dead load and natural external forces such as wind load, seismic load and snow loads, etc.; however, since the Maldives has never experienced earthquake disasters (excluding tsunami damage) in the past, it was confirmed with the MHTE Engineering Section that seismic load doesn't need to be considered.

Table 4.14-1 Assumed Loads when Installing PV Panels

No.	Load type	Contents
1	Dead load	Combined weight of the PV modules and supports, etc.
2	Wind load	Vectorial sum of the wind load (also taking monsoon strong winds into account) acting on the PV modules and the load acting on frame and other supporting structures
3	Snow load	Vertical snow load on PV module surfaces (not considered in this study)
4	Seismic load	Horizontal seismic force acting on structures (on steel structure frame, this seismic force is generally smaller than wind load and is not considered in the Study).

Source： Prepared by the Study Team

4.15 Structural Analysis of Buildings and Conceptual Design of Building Reinforcements

With respect to the potential sites proposed by each concerned government agency, field surveys and surveys of existing design documents were conducted; and the panel support methods and installation methods were classified and examined according to the facilities and buildings recommended upon taking obstructed solar radiation, generating capacity, ease of reinforcement and rehabilitation and public relations effect, etc. into account. Basically, in cases of sheets metal roofing, panels shall be supported on the purlin, while in cases of installation on square roof and on the ground, supporting frame shall be constructed out of steel frames and supported with RC foundations. Structural analysis of buildings is intended to quantitatively determine the impact that PV panels (decided according to the generating capacity, etc.) have on existing buildings when the panel load is installed on the planned roofs. First, existing design documents will be used to gauge the roof materials, the method used to support roof materials and cross-sectional performance of support members, etc. Next, a structural model will be constructed according to the roof support method; stress analysis taking the weight of panels into account will be implemented, and judgment will be made concerning whether or not the stress level exceeds the permissible bearing force of the support members.

If stress is found to exceed the bearing force in the above examination, the shape and connections, etc. of structures will be reconfirmed in detail based on the existing design documents and field surveys and, upon compiling feasible reinforcement methods including iron sheet wrapping, special fiber sheet reinforcement, addition of buckling prevention materials and so on, the quantity, term and cost of reinforcement works will be identified.

Table 4.15-1 Contents and Results of Examination on PV Panel Supports

No	Site	Support Type (Installed floor)	Examination Contents	Examination Results
Male' Island				
1	STELCO Building	S frame (rooftop RC)	Examination of S frame and floor attachment method	S frame, rooftop floor, foundation works
2	STELCO Power House	purlin attachment (roof)	None (there is impact from waste heat)	-----
3	Dharubaaruge	purlin attachment (roof)	Examination of purlin and panel attachment	Existing design documents unknown (impossible)
4	Velaanaage (Govt. Office)	Unknown (work in progress)	None	-----
5	Giyaasudheen School	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
6	Kalaafaanu School	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
7	Maldives Center for Social Education	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
8	Thaajuddeen School	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
9	New Secondary School for Girls	purlin attachment (roof)	Examination of purlin and panel attachment	No reinforcement
10	Indhira Gandhi Memorial Hospital (IGMH)	purlin attachment (roof)S frame (rooftop RC)	None (rehabilitation plan exists)	-----
11	Faculty of Engineering	purlin attachment (roof)	Examination of purlin and panel attachment	Unusual attachment, existing design documents unknown (impossible)
12	National Stadium	purlin attachment (roof)	Examination of purlin and panel attachment and main members	Existing design documents unknown (impossible)
13	Majeedhiya School	purlin attachment (roof)	None (major shade obstruction)	-----
14	Dharumavantha School	purlin attachment (roof)	None (major shade obstruction)	-----

No	Site	Support Type (Installed floor)	Examination Contents	Examination Results
15	Fen Building	purlin attachment (roof)	None (viewing of design documents was refused)	-----
16	Water Tank (MWSC)	purlin attachment (roof)	None (rehabilitation plan exists)	-----
17	Faculty Education	purlin attachment (roof)	Examination of purlin and panel attachment	Existing design documents unknown (impossible)
18	Sports Grounds	S frame (rooftop RC)	None (difficulty with facility maintenance)	-----
19	Male' South West Harbour Parking	purlin attachment (roof)	None (semi private, semi public facility)	-----
20	Grand Friday Mosque	purlin attachment (roof)	None (major impact from tower and dome)	-----
21	Jumhooree Maidhan	S frame (RC foundation)	Examination of S frame, RC foundations and design	Consensus from related government agencies is difficult (impossible)
22	President's Office	purlin attachment (roof)	Examination of purlin and panel attachment	Roof repair works No reinforcement
Hulhumale' Island				
1	Lale International School	purlin attachment (roof) S frame (rooftop RC)	None (private sector facility)	-----
2	Hulhumale Hospital	purlin attachment (roof)	None (insufficient power supply)	-----
3	Ghaazee School	purlin attachment (roof)	None (weak roof)	-----
4	HDC	purlin attachment (roof)	None (unusual roof shape makes installation difficult)	-----
5	Housing Flats	purlin attachment (roof)	None (consensus of residents is difficult)	-----

Source： Prepared by the Study Team

4.16 Cost Estimation of Grid-Connected PV System Introduction

4.16.1 Estimation Conditions

The cost estimation is based on the average exchange rate of US$1 = 95.69 yen for the six month period from December 2008 to May 2009. The estimated conditions are shown in the Table 4.6.1-1.

Table 4.16.1-1 Rough Project Cost Estimation Conditions

Contents	Estimation Conditions
(1) Equipment procurement cost	Equipment and material, transport, installation works (Existing structures reinforcement works cost) and procurement management cost, etc.
(2) Engineering service	Procurement Agent Fee and Consulting Services Fee

4.16.2 Project Cost

The project cost concerning introduction of the grid-connected PV system is approximately 1.95 million yen per kW (US$20,380/kW).

Table 4.16.2- 1 Breakdown for Project cost(Japanese supply)

Contents	Yen(thousand)/kW	composition ratio
(1) Equipment and material	1,335	68.5%
(2) Transport	52	2.7%
(3) Installation work	426	21.8%
(4) Procurement management cost	33	1.7%
(5) Engineering service	104	5.3%
Total	1,950	100%

As a result of Economic and Financial Feasibility Study in Chapter 5, the target grid-connected PV installation capacity by 2020 is 3,000kW. (Refer to Chapter 4, table 4.8-3)

Table 4.16.2-2 shows the project cost in each year taking the PV system price based on the NEDO "PV Roadmap toward 2030 (PV2030+)" into consideration, Prospects regarding future price movements in grid-connected PV systems are indicated in NEDO's PV Roadmap toward 2030 (PV2030+). According to the roadmap, the cost of PV power generation will be 23 yen/kWh in 2010 and 14 yen/kWh in 2020.

and the project cost comes to approximately US$ 56.4 million in total.

Table 4.16.2-2 Grid-Connected PV System Installed Capacity and Project Cost

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capapcity (kW)			300	300	300	300	300	300	300	300	300	300	3,000
Project Cost (million US$)		6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2		56.4

Source : Prepared by the Study Team

4.17 Examination of Environmental and Social Consideration

4.17.1 Environmental and Social Consideration Systems in the Maldives

Concerning legal systems related to environmental and social consideration in the Maldives, the EIA Regulations 2007 were enacted under the former Ministry of Environment, Energy and Water (MEEW) according to Article 5 of the Environment Protection and Preservation Act (1993). These regulations require that environmental impact assessment (EIA) be implemented for the following projects:

(1) New, or large-scale additional, resort development projects

(2) Aquaculture and processing facilities, and artificial atoll development projects
(3) Agriculture, stockbreeding and large-scale forest felling projects
(4) Port construction, dredging, landfill and shore protection projects
(5) Trunk road construction projects
(6) Airport, heliport and hydroplane hub construction projects
(7) Large-scale housing development and factory construction projects
(8) Incinerator, waste disposal site and large-scale waste storage and separation facilities
(9) Bottling plant and water supply/sewage system projects
(10) Power plant and petroleum/gas, etc. fuel treatment and refining facility construction projects
(11) Seawater desalination facilities and hospital construction projects

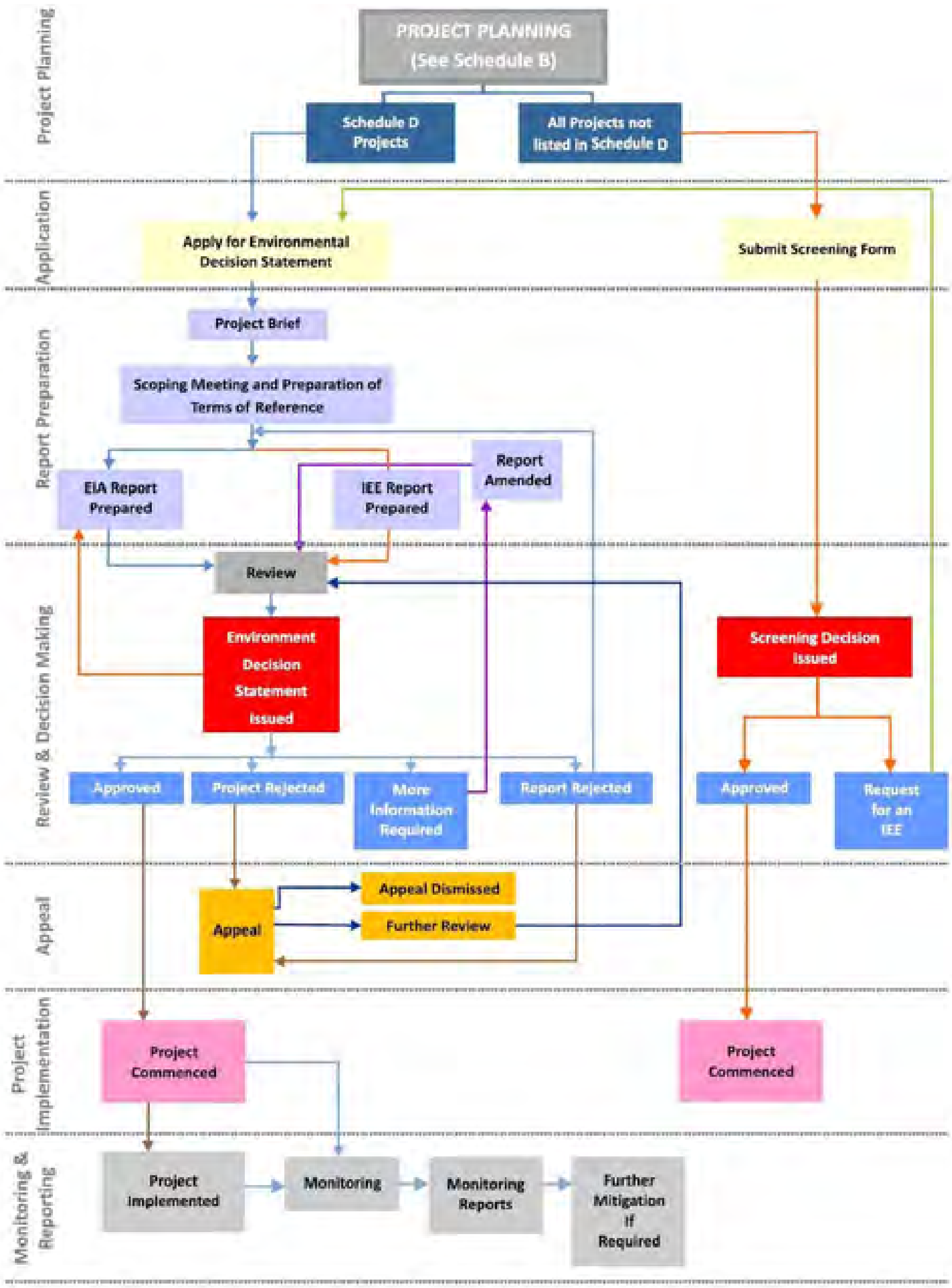
As is indicated above, EIA is required when constructing power plants. However, since this presumes the construction of diesel power plants, it will be necessary to submit a Development Proposal Screening Form to the Environmental Protection Agency (EPA) and undergo a screening review to determine whether or not grid-connected PV systems are subject to an EIA (or initial environmental examination: IEE). The result of screening will be notified to the project owner within 10 days from receipt of application, and in the case where an EIA or IEE is deemed necessary, the project owner will need to present an EIA/IEE Application Form (Form C2) and Project Brief to the EPA and commence the application procedure for an Environmental Decision Statement. On receiving the application form, the EPA will hold a scoping meeting together with representatives from related government agencies in order to discuss and confirm the expected environmental impacts of the proposed project. After the scoping meeting, the project owner will present the items (TOR) that need to be surveyed in the EIA or IEE to the EPA and, after receiving approval from the EPA, it will prepare the EIA or IEE report according to the TOR. The survey report will undergo review by the MHTE and external reviewers, and the result (one of the following) will be notified to the project owner by means of the Environmental Decision Statement. Figure 4.17.1-1 shows the work flow regarding EIA or IEE review to approval. All documents that need to be presented to the EPA will need to be prepared by a licensed EIA consultant in Maldives.

① Approval of the project application

② Request for renewed survey or provision of additional information concerning the contents of the submitted report

③ Refusal on the grounds of inadequate content of the EIA or IEE report

④ Refusal of the project application due to the possibility of project implementation exerting a massive impact on the environment



Source： “EIA Regulations 2007” MHTE

Figure 4.17.1-1 Environmental Impact Assessment
(or Initial Environmental Examination) Review Process

4.17.2 Agencies concerned with Environmental and Social Consideration

The Environmental Section of the MHTE is in charge of regulations, supervision and administration concerning environmental impact assessment, whereas the EPA implements review and approval work concerning the EIA or IEE for individual projects. The EPA has 78 employees as of June 2009 and it also implements research, education and enlightenment activities in the environmental field (biotechnology, biological diversity, water hygiene, marine hygiene, coastal area management, etc.).

4.17.3 Environmental and Social Consideration for Pilot Project Implementation

(1) Process and Results of Screening Review

According to the EIA Regulations 2007, in the screening stage, project owners are required to assess components that have the potential to impose environmental impact classified into three ranks, i.e. 1) No impact, 2) Impact exists, and 3) Adverse impact exists. Table 4.17.3-1 shows the screening results for the pilot project which were prepared by the Study Team in consultation with the MHTE.

Table 4.17.3-1 Pilot Project Screening

Environmental Components	No impact	Beneficial impact	Adverse impact
Seabed	○		
(Sea) water quality	○		
Fish stocks	○		
Coral reefs	○		
Sea grass beds	○		
Beaches	○		
Mangroves and wetlands	○		
Protected area	○		
Terrestrial vegetation	○		
Introduction of exotic species (density)	○		
Habitat change	○		
Air quality		○	
Groundwater quality	○		
Groundwater availability	○		
Noise levels		○	
Public wellbeing	○		
Public health		○	
Public safety	○		
Public transport	○		
Employment opportunities		○	
Economic Status		○	
Public views			○

Source : "EIA Regulations 2007" MHTE with additions made by the Study Team

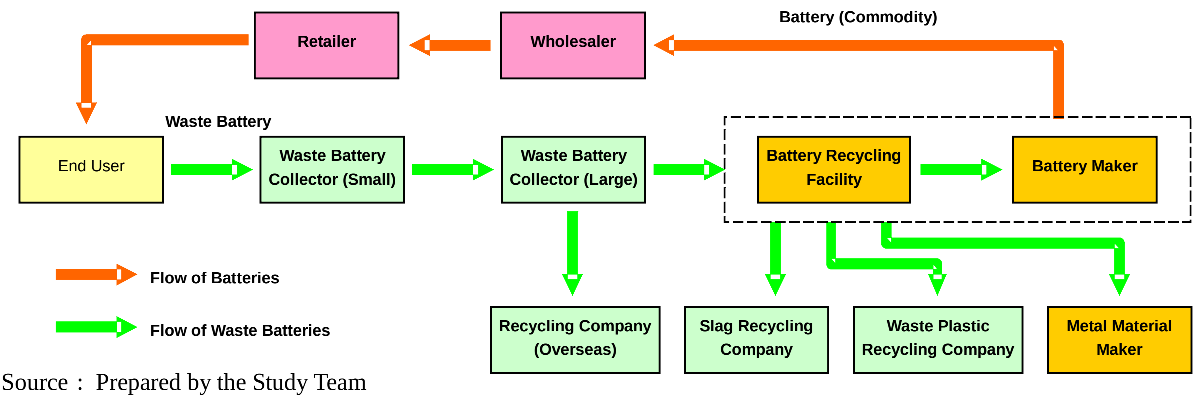
Implementation of the project will make it possible to reduce generated electric energy from DEG operation by power plants on Male' Island during the daytime peak period, thereby enabling emissions of atmospheric pollutants such as nitrogen oxides (NOx) and sulfur oxides (SOx), etc. and greenhouse gases (carbon dioxide: CO_2) from power plants to be reduced. Moreover, due to the proximity of power plants on Male' Island to residential areas and schools, noise from radiators and air suction/exhaust silencers and vibrations from the operation of generation equipment are exerting a serious environmental problem. Through reducing the operation of DEGs, it is anticipated that the project can also mitigate the environmental impacts caused by such noise and vibration. Other indirect benefits of project implementation will be economic ripple effects brought about by greater employment of local laborers, etc. and creation of new industries.

Envisaging implementation of the pilot project, the MHTE Energy Section, acting as the project owner, presented the designated screening form to the EPA. As a result of the EPA screening, a document was sent to the MHTE on June 1, 2009 notifying that the project will cause no major environmental impact and will not require an IEE.

(2) Treatment and Recycling of Waste Storage Batteries

Concerning the potential pilot project sites currently being forwarded, since the proposed plan does not include systems for isolated operation switchover requiring storage batteries, no environmental impact is considered necessary regarding the treatment and recycling of used batteries. However, if grid-connected PV systems with isolated operation switchover are introduced to facilities that require highly reliable power supply in the future, it will be necessary to pay ample attention to the waste battery treatment method. Since the Maldives does not have a commercial system for recycling even car batteries, it will be impossible to consign the treatment of PV sealed and valve-controlled lead storage batteries within that country. Accordingly, it may be necessary to appropriately store used storage batteries in materials warehouses next to power plants and, when a certain quantity has been reached, to transport them to recycling operators in nearby countries such as India and Sri Lanka, etc.

However, the export and import of used storage batteries for recycling or final disposal are regulated by the Basel Convention, which regulates the cross-border movement and disposal of hazardous waste products, and laws regulating the export and import of specific hazardous wastes, etc. In case of Maldives, which joined the Basel Convention in April 1992, permission for exporting waste batteries with the aim of recycling, cannot be granted unless it notifies the importing country, etc. of its intention to export the target objects and receives an agreement. Accordingly, the EPA is currently compiling a comprehensive Solid Waste Management Regulation and intends to examine the treatment method for waste batteries. In a past PV project, Japan transferred technology to Marshall Island counterparts concerning the recycling of lead from waste batteries for use as fishing plummets and neutralization of diluted sulfuric acid (electrolytic solution) with baking soda, and the Study Team explained this treatment method to Maldives side.



Source： Prepared by the Study Team

Figure 4.17.3-1 Expected Storage Battery Recycling System

(3) Visibility Obstructions

In the case where PV systems are installed on Hulhumale' Island near the approach of the airport, it is possible that the reflection of sunlight off PV panels will impede the visibility of aircraft pilots depending on the direction and tilt angle of the panels. In order to avoid such visibility obstructions, it is necessary to consider the following points, and air traffic control regulations in Maldives was confirmed.

- Angle of approach of aircraft to the airport runway
- Installation location, tilt angle and direction of PV panels
- Altitude of the sun at installation location in each season

On checking air control regulations in the Maldives with the Ministry of Civil Aviation and Communication, it was confirmed that the grid-connected PV systems proposed in the Study will not require any countermeasures (anti-dazzle PV modules, etc.) because their installation sites comply with the following scope and height regulations.

① Installation site

If panels are located within 2 degrees either side of the runway center line, the following height regulations will apply and detailed examination will be required to determine whether or not glare affects pilot operations.

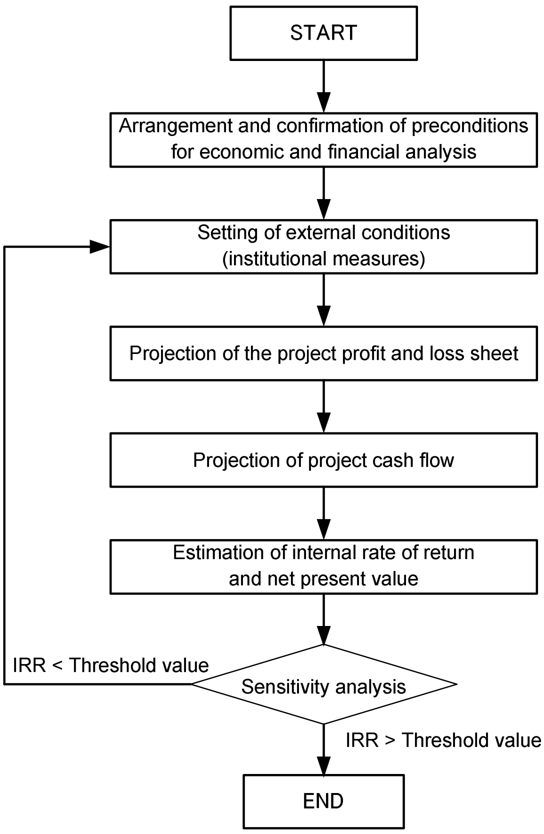
② Height

Concerning the scope of regulations described in ①, building height regulations are set according to the horizontal distance from the runway. Specifically, building height of approximately 1 m is allowed regarding a horizontal distance of 7 m from the runway.

CHAPTER 5 ECONOMIC AND FINANCIAL FEASIBILITY STUDY

5.1 Methodology of Economic and Financial Analysis on Introduction of the Grid-Connected PV System

Since one of the objectives of the Study is to confirm institutional measures necessary for disseminating grid-connected PV systems, conditions that are conducive to high economic and financial feasibility will be verified in the economic and financial analysis, and sensitivity analysis which examines some cases altering institutional conditions (surplus power purchasing system, subsidies, funds, etc.). Figure 5.1-1 shows the analysis flow: upon organizing and confirming the basic preconditions for the economic and financial analysis, conditions for implementing institutional measures for dissemination of the grid-connected PV system will be set and cash flow will be projected in each case. Based on the results of the cash flow projection, the internal rate of return and net present value of the project will be calculated, and sensitivity analysis based on altering some index values will be conducted. The final results will be fed back to examination of the appropriate institutional measures for disseminating the grid-connected PV system.



Source： Prepared by the Study Team

Figure 5.1-1 Flow of Economic and Financial Analysis

5.2 Setting of Preconditions

5.2.1 Conditions on PV System, Operation and Maintenance

The preconditions on PV system, operation and maintenance are as follows. These conditions are common to each type. Prices are those in effect as of May 2009.

PV system

PV system cost	:	US$ 20,380/kW including cost for construction works, installation works, design and supervision
Import duties	:	25% on equipment and materials price

Operation and maintenance

Diesel fuel price	:	US$ 0.63/ℓ (STO price MRf 8.1/ℓ)
Lubricant price	:	US$ 2.28/ℓ
Diesel fuel required to generate 1kWh	:	Male' 0.26ℓ/kWh, Hulhumale' 0.28ℓ/kWh
Lubricant required to generate 1kWh	:	0.001ℓ/kWh (same on Male' and Hulhumale')
DEG maintenance cost	:	US$ 0.034/kWh (same on Male' and Hulhumale')
PV system maintenance cost	:	US$ 0.004/kWh (same on Male' and Hulhumale')
Lifetime of main system components	:	PV panels: 30 years, Other parts: 15 years

Power consumption

Consumption amount to total power generation	:	94%
Ratio of power consumption on Male' Island and Hulhumale' Island	:	75%

Breakdown of power consumption by consumer category on Male' Island and Hulhumale' Island:

Domestic: 45% Businesses: 35% Government and schools: 20%

Administration cost : US$ 0.039/kWh

Exchange rate : US$ 1.00 ＝ ¥95.69 ＝ MRf 12.8 (end of May 2009)

Concerning measures for disseminating the grid-connected PV system in the Maldives, since STELCO is due to be privatized and government subsidies for STELCO to make up a deficit will no longer be available, supporting measures to reduce the financial burden on the initial investment will be needed. Besides, as introduction of the PV system can be also extended to the private sector, cases for introduction by solely STELCO and introduction by STELCO and the private sector will be examined.

Possible capacity 13.49MW is the figure derived from the results of technical feasibility study as the maximum capacity. Initial investment cost for the capacity 13.49MW will be US$ 253.7 million (MRf 3,247 million). This amount is equivalent to one-third of the central government expenditure in 2008 and exceeds the total amount of the national development expenditure. Since STELCO recorded deficit in the current account for the last three years and the central government also faces financial difficulties, it is necessary to calculate figures necessary for examination of institutional framework and examine viable installation capacity. Therefore, three cases, 13.49MW, 6MW and 3MW, are analyzed and the capacity suitable for the Maldives is examined.

Table 5.2.1-1 shows the power generation, consumption and fuel oil consumption, which is calculated on the basis of the preconditions above mentioned.

In the case of introduction by STELCO and the private sector, the system will be introduced by STELCO for the first five years from 2010 to 2014. It is assumed that introduction by the private sector will be carried out at one-third of the annual capacity from 2015. Introduction capacity and power generation for both cases is shown in Table 5.2.1-2.

Table 5.2.1-1 Power Generation, Consumption and Fuel Oil Consumption (2009-2020)

(1) Capacity 13.49MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
【Power Supply by Grid-connected PV System】												
PV System												
Capacity (kW)			1,340	2,690	4,040	5,390	6,740	8,090	9,440	10,790	12,140	13,490
Generation (kWh)			1,620,663	3,253,420	4,886,178	6,518,935	8,151,693	9,784,450	11,417,207	13,049,965	14,682,722	16,315,480
Power Generation with Introduction of PV System (kWh)	247,683,310	266,305,690	285,004,207	303,308,850	322,560,872	343,000,655	364,903,927	388,631,260	414,620,993	443,431,655	475,741,968	512,400,330
Fuel Consumption (ℓ)												
Diesel	64,606,791	69,499,373	74,421,975	79,257,482	84,358,114	89,791,319	95,634,301	101,988,020	108,975,352	116,752,403	125,509,357	135,483,764
Lub Oil	247,683	266,306	285,004	303,309	322,561	343,001	364,904	388,631	414,621	443,432	475,742	512,400
Fuel Reduction (ℓ)												
Diesel			423,307	850,001	1,276,695	1,703,389	2,130,083	2,556,777	2,983,471	3,410,165	3,836,859	4,263,553
Lub Oil			1,621	3,253	4,886	6,519	8,152	9,784	11,417	13,050	14,683	16,315

(2) Capacity 6MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
【Power Supply by Grid-connected PV System】												
PV System												
Capacity (kW)			599	1,198	1,797	2,396	2,995	3,596	4,197	4,798	5,399	6,000
Generation (kWh)			724,461	1,448,921	2,173,382	2,897,842	3,622,303	4,349,182	5,076,061	5,802,941	6,529,820	7,256,700
Power Generation with Introduction of PV System (kWh)	247,683,310	266,305,690	285,900,409	305,113,349	325,273,668	346,621,748	369,433,317	394,066,528	420,962,139	450,678,679	483,894,870	521,459,110
Fuel Consumption (ℓ)												
Diesel	64,606,791	69,499,373	74,655,907	79,728,732	85,066,682	90,737,206	96,817,506	103,407,890	110,631,887	118,645,604	127,639,222	137,850,295
Lub Oil	247,683	266,306	285,900	305,113	325,274	346,622	369,433	394,067	420,962	450,679	483,895	521,459
Fuel Reduction (ℓ)												
Diesel			189,376	378,751	568,127	757,503	946,878	1,136,907	1,326,936	1,516,965	1,706,993	1,897,022
Lub Oil			724	1,449	2,173	2,898	3,622	4,349	5,076	5,803	6,530	7,257

(3) Capacity 3MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
【Power Supply by Grid-connected PV System】												
PV System												
Capacity (kW)			300	600	900	1,200	1,500	1,800	2,100	2,400	2,700	3,000
Generation (kWh)			362,835	725,670	1,088,505	1,451,340	1,814,175	2,177,010	2,539,845	2,902,680	3,265,515	3,628,350
Power Generation with Introduction of PV System (kWh)	247,683,310	266,305,690	286,262,035	305,836,600	326,358,545	348,068,250	371,241,445	396,238,700	423,498,355	453,578,940	487,159,175	525,087,460
Fuel Consumption (ℓ)												
Diesel	64,606,791	69,499,373	74,750,462	79,917,842	85,350,347	91,115,425	97,290,280	103,975,872	111,295,077	119,404,001	128,492,828	138,799,108
Lub Oil	247,683	266,306	286,262	305,837	326,359	348,068	371,241	396,239	423,498	453,579	487,159	525,087
Fuel Reduction (ℓ)												
Diesel			94,821	189,642	284,463	379,284	474,104	568,925	663,746	758,567	853,388	948,209
Lub Oil			363	726	1,089	1,451	1,814	2,177	2,540	2,903	3,266	3,628

Source : Prepared by the Study Team

Table 5.2.1-2 Introduced Capacity and Generation by Implementing Body (2009 – 2020)

a. Introduction by solely STELCO

(1) Capacity 13.49MW

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Capacity (kW)	Yearly	1,340	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350
	Cumulative	1,340	2,690	4,040	5,390	6,740	8,090	9,440	10,790	12,140	13,490
Generation (kWh)		1,620,663	3,253,420	4,886,178	6,518,935	8,151,693	9,784,450	11,417,207	13,049,965	14,682,722	16,315,480

(2) Capacity of 6MW

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Capacity (kW)	Yearly	599	599	599	599	599	601	601	601	601	601
	Cumulative	599	1,198	1,797	2,396	2,995	3,596	4,197	4,798	5,399	6,000
Generation (kWh)		724,461	1,448,921	2,173,382	2,897,842	3,622,303	4,349,182	5,076,061	5,802,941	6,529,820	7,256,700

(3) Capacity of 3MW

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Capacity (kW)	Yearly	300	300	300	300	300	300	300	300	300	300
	Cumulative	300	600	900	1,200	1,500	1,800	2,100	2,400	2,700	3,000
Generation (kWh)		362,835	725,670	1,088,505	1,451,340	1,814,175	2,177,010	2,539,845	2,902,680	3,265,515	3,628,350

b. Introduction by STELCO and the Private Sector

(1) Capacity 13.49MW

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
(1) STELCO											
Capacity (kW)	Yearly	1,340	1,350	1,350	1,350	900	900	900	900	900	900
	Cumulative	1,340	2,690	4,040	5,390	6,290	7,190	8,090	8,990	9,890	10,790
Generation (kWh)		1,620,663	3,253,420	4,886,178	6,518,935	5,434,462	6,522,967	7,611,472	8,699,977	9,788,481	10,876,986
(2) Private Sector											
Capacity (kW)	Yearly	0	0	0	0	450	450	450	450	450	450
	Cumulative	0	0	0	0	450	900	1,350	1,800	2,250	2,700
Generation (kWh)		0	0	0	0	2,717,231	3,261,483	3,805,736	4,349,988	4,894,241	5,438,493

(2) Capacity of 6MW

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
(1) STELCO											
Capacity (kW)	Yearly	599	599	599	599	399	401	401	401	401	401
	Cumulative	599	1,198	1,797	2,396	2,795	3,196	3,597	3,997	4,398	4,799
Generation (kWh)		724,461	1,448,921	2,173,382	2,897,842	2,414,868	2,899,455	3,384,041	3,868,627	4,353,213	4,837,800
(2) Private Sector											
Capacity (kW)	Yearly	0	0	0	0	200	200	200	200	200	200
	Cumulative	0	0	0	0	200	400	600	801	1,001	1,201
Generation (kWh)		0	0	0	0	1,207,434	1,449,727	1,692,020	1,934,314	2,176,607	2,418,900

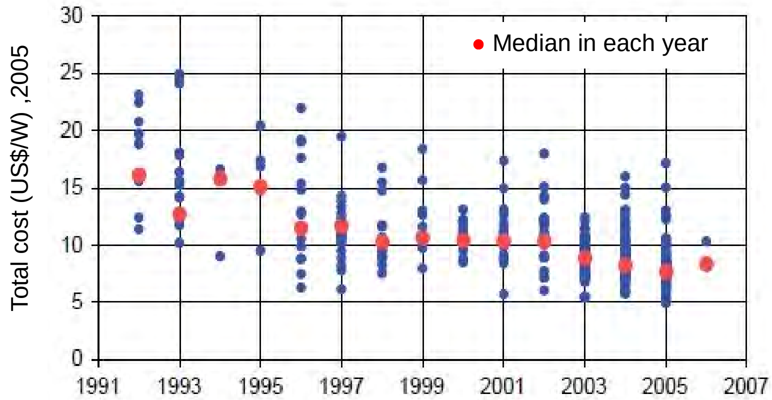
(3) Capacity of 3MW

		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
(1) STELCO											
Capacity (kW)	Yearly	300	300	300	300	200	200	200	200	200	200
	Cumulative	300	600	900	1,200	1,400	1,600	1,800	2,000	2,200	2,400
Generation (kWh)		362,835	725,670	1,088,505	1,451,340	1,209,450	1,451,340	1,693,230	1,935,120	2,177,010	2,418,900
(2) Private Sector											
Capacity (kW)	Yearly	0	0	0	0	100	100	100	100	100	100
	Cumulative	0	0	0	0	100	200	300	400	500	600
Generation (kWh)		0	0	0	0	604,725	725,670	846,615	967,560	1,088,505	1,209,450

Source : Prepared by the Study Team

5.2.2 Price Forecast of the Grid-Connected PV System

With regard to past price movements of grid-connected PV systems throughout the world, the International Energy Agency (IEA) has implemented a study, "the Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies" covering 11 countries including Japan, Europe and North America. According to the results of the study, the median value of the grid-connected PV system cost in each year does not always display a linear trend, however, since the cost was US$16/W in 1992 and US$8/W in 2006, an overall trend of cost reduction can be seen as shown in Figure 5.2.2-1.

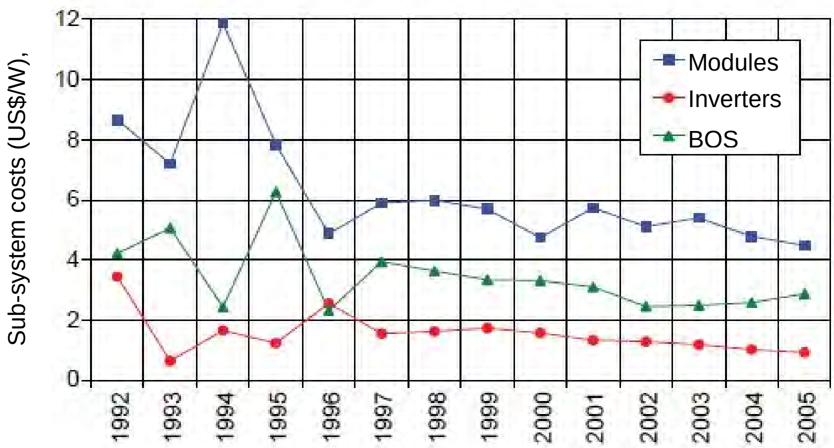


Note: Capacity of the sample facilities: 73% for less than 10kW, 24% for between 10 and 100 kW, and 4% for more than 100kW

Source : International Energy Agency, "Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies," 2007

Figure 5.2.2-1 Movements in Total Cost of Grid-Connected PV Systems

Figure 5.2.2-2 shows movements in the cost of sub-systems and indicates that prices have come down for all components including modules and inverters, etc.

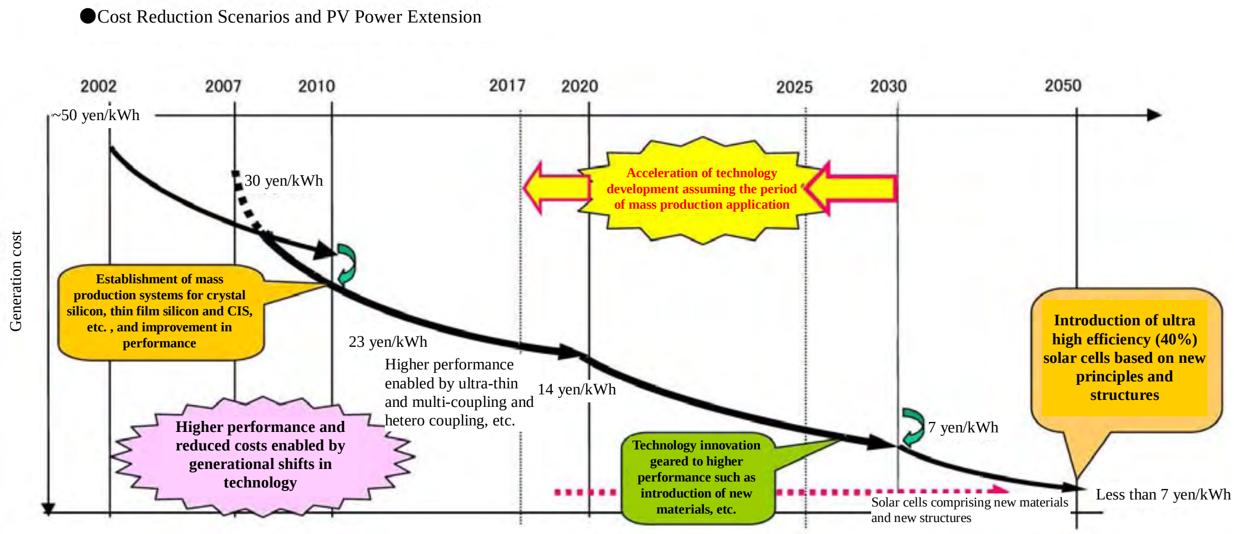


Source : International Energy Agency, "Cost and Performance Trends in Grid-Connected Photovoltaic Systems and Case Studies", 2007

Figure 5.2.2-2 Movements in Grid-Connected PV System Sub-System Costs

Accordingly, it is reported that the reduction in prices for the system components is the contributory factor to the price reduction of the grid-connected PV systems.

Prospects regarding future price movements in grid-connected PV systems are indicated in NEDO's PV Roadmap toward 2030 (PV2030+). According to the roadmap, the cost of PV power generation will be 23 yen/kWh in 2010 and 14 yen/kWh in 2020 (see Figure 5.2.2-3).



Time for realization (Development Completion)	2010 onwards	2020 (2017)	2030 (2025)	2050
Generation cost	Equivalent to the cost for domestic use (23 yen/kWh)	Equivalent to the cost for light and power (14 yen/kWh)	Equivalent to the cost for business use (7 yen/kWh)	Use in power source for all purposes (7 yen/kWh)
Module conversion efficiency	Practical module 16% (cells for research 20%)	Practical module 20% (cells for research 25%)	Practical module 25% (cells for research 30%)	Ultra high efficiency module 40%
Production for domestic market (GW/year)	0.5 - 1	2 - 3	6 - 12	25 - 35
Production for overseas markets (GW/year)	- 1	- 3	30 - 35	- 300
Main uses	Detached houses and public facilities	Houses (detached and collective), public facilities, offices, etc.	Houses (detached and collective), public facilities, private businesses, recharging of	Private sector uses, commercial uses, transport, agriculture, and isolated power sources

Source : "Photovoltaic Power Generation Roadmap for 2030 (PV2030+)," New Energy and Industrial Technology Development Organization (NEDO)

Figure 5.2.2-3 Scenario of PV System Economy Improvement in the Roadmap

The roadmap also sets the development target of PV module production cost at 100 yen/W for 2010, 75 yen/W for 2020, and less than 50 yen/W for 2030.

Based on the forecast scenario in this roadmap, the annual average cost will fall by approximately 3.9% per year for power generation and 2.5% per year for PV module production between 2010 and 2020. Therefore, it is assumed that the cost of the grid-connected PV system over the project period falls by 2.5% on average per year up to 2020. Table 5.2.2-1 shows the projected PV system price up to 2020 based on this assumption.

Table 5.2.2-1 PV System Price Projection

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Unit Price in the Road Map (USD/W)		1.05	→	→	→	→	→	→	→	→	→	0.78
PV System Unit Price (USD million/MW)		20.4	20.0	19.7	19.3	19.0	18.6	18.3	17.9	17.6	17.2	16.9

Source： Prepared by the Study Team based on the "Photovoltaic Power Generation Roadmap for 2030 (PV2030+)," New Energy and Industrial Technology Development Organization (NEDO)

Table 5.2.2-2 shows the introduction cost of the grid-connected PV system calculated on the basis of the unit cost of the PV system (US$ 20,380/kW) and the price projection. In order to commence full-scale operation from 2011, total project cost will arise for 10 years from 2010 to 2019 and will amount to approximately US$ 253.7 million for 13.49 MW, US$112.8 million for 6MW and US$ 56.4 million for 3MW under the case of installation by solely STELCO. The installation capacity will be 10.79MW, 4.8MW and 2.4MW for STELCO's portion under the case of installation by STELCO and private sector. The project cost will be 204.8 million US$, 91.1 million US$ and 45.6 million US$ respectively.

Table 5.2.2-2 Introduced Capacity and Project Cost

a. Introduction by solely STELCO

(1) Capacity 13.49MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capapcity (kW)			1,340	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	1,350	13,490
Project Cost (million US$)		27.3	27.0	26.6	26.1	25.6	25.2	24.7	24.2	23.7	23.3		253.7

(2) Capacity 6MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capapcity (kW)			599	599	599	599	599	601	601	601	601	601	6,000
Project Cost (million US$)		12.2	12.0	11.8	11.6	11.4	11.2	11.0	10.8	10.6	10.4		112.8

(3) Capacity 3MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capapcity (kW)			300	300	300	300	300	300	300	300	300	300	3,000
Project Cost (million US$)		6.1	6.0	5.9	5.8	5.7	5.6	5.5	5.4	5.3	5.2		56.4

b. Introduction by STELCO and Private Sector (STELCO's portion)

(1) 10.79 MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	合計
Capapcity (kW)			1,340	1,350	1,350	1,350	900	900	900	900	900	900	10,790
Project Cost (million US$)		27.3	27.0	26.6	26.1	17.1	16.8	16.5	16.1	15.8	15.5		204.8

(2) 4.8 MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	合計
Capapcity (kW)			599	599	599	599	399	401	401	401	401	401	4,799
Project Cost (million US$)		12.2	12.0	11.8	11.6	7.6	7.5	7.3	7.2	7.0	6.9		91.1

(3) 2.4 MW

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capapcity (kW)			300	300	300	300	200	200	200	200	200	200	2,400
Project Cost (million US$)		6.1	6.0	5.9	5.8	3.8	3.7	3.7	3.6	3.5	3.4		45.6

Source : Prepared by the Study Team

5.3 Financial Analysis

5.3.1 Preconditions

(1) Project Period

The project period is 25 years from 2010 to 2034.

(2) Cost

Financial cost consists of investment cost, replacement cost, operation and maintenance cost and import duties. The preconditions for calculating the costs are as indicated in Section 5.2, while the cost of introducing the grid-connected PV system is assumed to go down every year in line with the scenario of PV system cost reduction in the NEDO roadmap. Furthermore, the Maldives has no corporation tax system as of May 2009, however, such a tax is scheduled for introduction in 2010 and the maximum tax rate will be set at 15% of profits. However, since it is not clear whether the corporation tax will be applied to STELCO, financial analysis is conducted assuming that no corporation tax is levied. Under the case of installation by STELCO and private sector, power purchasing from the PV system installed by the private sector, it is assumed that the power purchasing from the private sector is only for excess power from the viewpoint of demand control (see Section 8.2.3, Chapter 8 for the detail institutional framework). It is assumed that rate of excess power purchasing is 20 percent and purchasing price is MRf 3/kWh which is average of the unit production cost for 2006 and 2007[1]. In this case, part of the power generated by the PV system will be consumed at source. STELCO do not need to supply power equivalent to the consumption at source. Therefore, the operation and maintenance cost for the volume of power generation is counted as negative cost.

[1] The purchasing price at the same as or less than the unit production cost is preferable for STELCO. The unit production cost depends on diesel price for the year. As the diesel price range in 2009 is similar to that in 2006 and 2007 so that average for two years is adopted.

(3) Revenue

The financial revenue from the grid-connected PV system is composed of electricity tariff from the consumers and saving of fuel costs that would be incurred in generating the same amount of power by diesel generator. Average electricity price was US$0.22 (MRf 2.87) for Male' Island and Hulhumale' Island under the tariff table applied from July 2005 to October 2009. After change of the tariff structure in November 2009, the price increased at 23%. Therefore it is assumed that the unit price per kWh is set at US$ 0.28 (MRf 3.53). In addition, with regard to unit price of the diesel fuel and lubricant reduced by introducing the grid-connected PV system, the STO price as of end of July 2009 and average price for the last three years are applied to diesel oil and lubricant oil respectively. Under the case of installation by STELCO and private sector, it is assumed that excess power from the PV system installed by the private sector is sold to STELCO. Therefore, the amount of excess power purchasing becomes negative revenue. Besides, consumption at source causes decline in STELCO's sales so that the amount of consumption at source is also negative revenue.

(4) Assessment of Feasibility

The financial internal rate of return (FIRR) is used to analyze feasibility of the project. Discount rate applied is 12%.

5.3.2 Results of Financial Analysis

Table 5.3.2-1 shows the cashflow under the condition with no supporting measures to installation of the grid-connected PV system. After completion of installation in 2019, the revenue will exceed the cost, however, net present value of the project for the project period is negative for all the cases, 13.49MW, 6MW and 3MW because investment cost is too huge against the revenue generated from the PV system during the installation period. In order to attain 12% of FIRR under the condition that the current electricity tariff does not change, supporting measures from the government, such as import duties exemption and financial assistance, should be applied during the initial investment period from 2010 up to 2019. Therefore, possible installation capacity is examined from the financial view point since STELCO is being privatized and cannot receive subsidies for making up deficit after completion of privatization, and financial capacity of the government is limited.

<Examination of installation capacity from the financial aspect>

Expenditure of the government is composed of current expenditure and capital expenditure, and the subsidies for state-owned enterprises like STELCO are included in the current expenditure. STELCO will not be able to receive the subsidies to make up deficit after completion of the privatization. National development expenditure, which is included in capital expenditure, is utilized for construction of infrastructure and investment in facilities. The development expenditure can be assumed as a source of financial assistance for the cost reduction of initial investment in PV system which will be installed by STELCO.

Table 5.3.2-1 Cashflow of Introduction the Grid-connected PV System

a. Installation by solely STELCO

(1) Capacity 13.49MW (Unit: US$)

	Cost					Benefit			Balance
	Grid-connected PV System			Import Duties	Total	Electricity Fee	Fuel Reduction	Total	
	Investment	Replace	O&M						
2010	27,308,677			4,674,977	31,983,654			0	-31,983,654
2011	27,041,486		6,457	4,592,119	31,640,062	453,786	271,565	725,351	-30,914,711
2012	26,570,500		12,963	4,474,372	31,057,834	910,958	545,301	1,456,259	-29,601,576
2013	26,099,513		19,468	4,356,625	30,475,607	1,368,130	819,036	2,187,166	-28,288,441
2014	25,628,527		25,974	4,238,879	29,893,379	1,825,302	1,092,772	2,918,074	-26,975,305
2015	25,157,540		32,479	4,121,132	29,311,152	2,282,474	1,366,507	3,648,981	-25,662,170
2016	24,686,554		38,985	4,003,385	28,728,924	2,739,646	1,640,243	4,379,889	-24,349,035
2017	24,215,567		45,490	3,885,639	28,146,696	3,196,818	1,913,979	5,110,797	-23,035,900
2018	23,744,580		51,996	3,767,892	27,564,469	3,653,990	2,187,714	5,841,704	-21,722,764
2019	23,273,594		58,501	4,003,385	27,335,481	4,111,162	2,461,450	6,572,612	-20,762,869
2020			65,007		65,007	4,568,334	2,735,186	7,303,520	7,238,513
2021			65,007		65,007	4,568,334	2,735,186	7,303,520	7,238,513
2022			65,007		65,007	4,568,334	2,735,186	7,303,520	7,238,513
2023			65,007		65,007	4,568,334	2,735,186	7,303,520	7,238,513
2024			65,007		65,007	4,568,334	2,735,186	7,303,520	7,238,513
2025		4,092,472	65,007	1,022,651	5,180,131	4,568,334	2,735,186	7,303,520	2,123,389
2026		3,958,154	65,007	989,072	5,012,233	4,568,334	2,735,186	7,303,520	2,291,287
2027		3,793,309	65,007	947,860	4,806,176	4,568,334	2,735,186	7,303,520	2,497,344
2028		3,628,464	65,007	906,649	4,600,120	4,568,334	2,735,186	7,303,520	2,703,400
2029		3,463,618	65,007	865,438	4,394,063	4,568,334	2,735,186	7,303,520	2,909,457
2030		3,298,773	65,007	824,227	4,188,006	4,568,334	2,735,186	7,303,520	3,115,513
2031		3,298,773	65,007	824,227	4,188,006	4,568,334	2,735,186	7,303,520	3,115,513
2032		3,298,773	65,007	824,227	4,188,006	4,568,334	2,735,186	7,303,520	3,115,513
2033		3,298,773	65,007	824,227	4,188,006	4,568,334	2,735,186	7,303,520	3,115,513
2034		3,298,773	65,007	824,227	4,188,006	4,568,334	2,735,186	7,303,520	3,115,513
Total	253,726,537	35,429,882	1,267,419	50,971,208	341,395,047	89,067,276	53,326,351	142,393,627	-199,001,420
							NPV		-161,512,916

(2) Capacity 6MW (Unit: US$)

	Cost					Benefit			Balance
	Grid-connected PV System			Import Duties	Total	Electricity Fee	Fuel Reduction	Total	
	Investment	Replace	O&M						
2010	12,207,386			2,089,785	14,297,171			0	-14,297,171
2011	11,998,408		2,887	2,037,540	14,038,834	202,849	121,489	324,338	-13,714,496
2012	11,789,429		5,773	1,985,295	13,780,498	405,698	242,978	648,676	-13,131,821
2013	11,580,451		8,660	1,933,051	13,522,161	608,547	364,467	973,014	-12,549,147
2014	11,371,472		11,546	1,880,806	13,263,824	811,396	485,957	1,297,353	-11,966,472
2015	11,199,764		14,433	1,834,667	13,048,864	1,014,245	607,446	1,621,691	-11,427,173
2016	10,990,088		17,329	1,782,248	12,789,665	1,217,771	729,354	1,947,125	-10,842,540
2017	10,780,412		20,225	1,729,829	12,530,465	1,421,297	851,262	2,272,559	-10,257,907
2018	10,570,735		23,121	1,677,410	12,271,266	1,624,823	973,170	2,597,993	-9,673,274
2019	10,361,059		26,017	1,782,248	12,169,324	1,828,350	1,095,077	2,923,427	-9,245,897
2020			28,913		28,913	2,031,876	1,216,985	3,248,861	3,219,948
2021			28,913		28,913	2,031,876	1,216,985	3,248,861	3,219,948
2022			28,913		28,913	2,031,876	1,216,985	3,248,861	3,219,948
2023			28,913		28,913	2,031,876	1,216,985	3,248,861	3,219,948
2024			28,913		28,913	2,031,876	1,216,985	3,248,861	3,219,948
2025		1,830,429	28,913	457,141	2,316,483	2,031,876	1,216,985	3,248,861	932,379
2026		1,757,286	28,913	438,855	2,225,055	2,031,876	1,216,985	3,248,861	1,023,807
2027		1,684,144	28,913	420,569	2,133,627	2,031,876	1,216,985	3,248,861	1,115,235
2028		1,611,001	28,913	402,284	2,042,198	2,031,876	1,216,985	3,248,861	1,206,663
2029		1,537,859	28,913	383,998	1,950,770	2,031,876	1,216,985	3,248,861	1,298,091
2030		1,469,601	28,913	366,934	1,865,448	2,031,876	1,216,985	3,248,861	1,383,414
2031		1,469,601	28,913	366,934	1,865,448	2,031,876	1,216,985	3,248,861	1,383,414
2032		1,469,601	28,913	366,934	1,865,448	2,031,876	1,216,985	3,248,861	1,383,414
2033		1,469,601	28,913	366,934	1,865,448	2,031,876	1,216,985	3,248,861	1,383,414
2034		1,469,601	28,913	366,934	1,865,448	2,031,876	1,216,985	3,248,861	1,383,414
Total	112,849,204	15,768,724	563,691	22,670,392	151,852,011	39,613,116	23,725,980	63,339,096	-88,512,915
							NPV		-71,834,365

(3) Capacity 3MW (Unit: US$)

	Cost					Benefit			Balance
	Grid-connected PV System			Import Duties	Total	Electricity Fee	Fuel Reduction	Total	
	Investment	Replace	O&M						
2010	6, 113, 883			1, 046, 637	7, 160, 520			0	-7, 160, 520
2011	6, 009, 219		1, 446	1, 020, 471	7, 031, 136	101, 594	60, 830	162, 424	-6, 868, 711
2012	5, 904, 555		2, 891	994, 305	6, 901, 752	203, 188	121, 660	324, 848	-6, 576, 903
2013	5, 799, 892		4, 337	968, 139	6, 772, 368	304, 781	182, 490	487, 271	-6, 285, 096
2014	5, 695, 228		5, 783	941, 973	6, 642, 984	406, 375	243, 321	649, 696	-5, 993, 288
2015	5, 590, 564		7, 228	915, 807	6, 513, 600	507, 969	304, 151	812, 120	-5, 701, 480
2016	5, 485, 901		8, 674	889, 641	6, 384, 216	609, 563	364, 981	974, 544	-5, 409, 672
2017	5, 381, 237		10, 120	863, 475	6, 254, 832	711, 157	425, 811	1, 136, 968	-5, 117, 864
2018	5, 276, 573		11, 565	837, 309	6, 125, 448	812, 750	486, 641	1, 299, 391	-4, 826, 057
2019	5, 171, 910		13, 011	889, 641	6, 074, 562	914, 344	547, 471	1, 461, 815	-4, 612, 747
2020			14, 457		14, 457	1, 015, 938	608, 301	1, 624, 239	1, 609, 783
2021			14, 457		14, 457	1, 015, 938	608, 301	1, 624, 239	1, 609, 783
2022			14, 457		14, 457	1, 015, 938	608, 301	1, 624, 239	1, 609, 783
2023			14, 457		14, 457	1, 015, 938	608, 301	1, 624, 239	1, 609, 783
2024			14, 457		14, 457	1, 015, 938	608, 301	1, 624, 239	1, 609, 783
2025		917, 674	14, 457	228, 952	1, 161, 083	1, 015, 938	608, 301	1, 624, 239	463, 157
2026		881, 042	14, 457	219, 794	1, 115, 293	1, 015, 938	608, 301	1, 624, 239	508, 947
2027		844, 410	14, 457	210, 636	1, 069, 502	1, 015, 938	608, 301	1, 624, 239	554, 737
2028		807, 778	14, 457	201, 478	1, 023, 712	1, 015, 938	608, 301	1, 624, 239	600, 528
2029		771, 145	14, 457	192, 320	977, 921	1, 015, 938	608, 301	1, 624, 239	646, 318
2030		734, 513	14, 457	183, 162	932, 131	1, 015, 938	608, 301	1, 624, 239	692, 108
2031		734, 513	14, 457	183, 162	932, 131	1, 015, 938	608, 301	1, 624, 239	692, 108
2032		734, 513	14, 457	183, 162	932, 131	1, 015, 938	608, 301	1, 624, 239	692, 108
2033		734, 513	14, 457	183, 162	932, 131	1, 015, 938	608, 301	1, 624, 239	692, 108
2034		734, 513	14, 457	183, 162	932, 131	1, 015, 938	608, 301	1, 624, 239	692, 108
Total	56, 428, 963	7, 894, 614	281, 906	11, 336, 384	75, 941, 867	19, 810, 791	11, 861, 876	31, 672, 667	-44, 269, 200
								NPV	-35, 938, 499

b. Installation by STELCO and Private Sector (STELCO's portion)

(1) Capacity 10.79MW (Unit: US$)

	Cost						Benefit					Balance
	Grid-connected PV System			Import Duties	Gen-set O&M	Total	Electricity Fee	Purchase of excess power	Fee for reduced demand	Fuel Reduction	Total	
	Investment	Replace	O&M									
2010	27, 308, 677			4, 674, 977		31, 983, 654					0	-31, 983, 654
2011	27, 041, 486		6, 457	4, 592, 119		31, 640, 062	453, 786			271, 565	725, 351	-30, 914, 711
2012	26, 570, 500		12, 963	4, 474, 372		31, 057, 834	910, 958			545, 301	1, 456, 259	-29, 601, 576
2013	26, 099, 513		19, 468	4, 356, 625		30, 475, 607	1, 368, 130			819, 036	2, 187, 166	-28, 288, 441
2014	17, 085, 684		25, 974	2, 825, 919		19, 937, 577	1, 825, 302			1, 092, 772	2, 918, 074	-17, 019, 504
2015	16, 771, 693		21, 653	2, 747, 421	-73, 026	19, 540, 768	1, 673, 814	-124, 993	-608, 660	1, 366, 507	2, 306, 669	-17, 234, 099
2016	16, 457, 702		25, 990	2, 668, 924	-87, 652	19, 152, 616	2, 009, 074	-150, 028	-730, 572	1, 640, 243	2, 768, 717	-16, 383, 899
2017	16, 143, 711		30, 327	2, 590, 426	-102, 279	18, 764, 464	2, 344, 333	-175, 064	-852, 485	1, 913, 979	3, 230, 763	-15, 533, 701
2018	15, 829, 720		34, 664	2, 511, 928	-116, 906	18, 376, 312	2, 679, 593	-200, 099	-974, 397	2, 187, 714	3, 692, 810	-14, 683, 502
2019	15, 515, 729		39, 001	2, 668, 924	-131, 533	18, 223, 654	3, 014, 852	-225, 135	-1, 096, 310	2, 461, 450	4, 154, 857	-14, 068, 797
2020			43, 338		-146, 160	43, 338	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	4, 573, 566
2021			43, 338		-146, 160	43, 338	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	4, 573, 566
2022			43, 338		-146, 160	43, 338	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	4, 573, 566
2023			43, 338		-146, 160	43, 338	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	4, 573, 566
2024			43, 338		-146, 160	43, 338	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	4, 573, 566
2025		4, 092, 472	43, 338	1, 022, 651	-146, 160	5, 158, 462	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	-541, 557
2026		3, 958, 154	43, 338	989, 072	-146, 160	4, 990, 564	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	-373, 659
2027		3, 793, 309	43, 338	947, 860	-146, 160	4, 784, 507	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	-167, 603
2028		3, 628, 464	43, 338	906, 649	-146, 160	4, 578, 451	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	38, 454
2029		2, 309, 701	43, 338	576, 958	-146, 160	2, 929, 998	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	1, 686, 907
2030		2, 199, 804	43, 338	549, 484	-146, 160	2, 792, 627	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	1, 824, 278
2031		2, 199, 804	43, 338	549, 484	-146, 160	2, 792, 627	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	1, 824, 278
2032		2, 199, 804	43, 338	549, 484	-146, 160	2, 792, 627	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	1, 824, 278
2033		2, 199, 804	43, 338	549, 484	-146, 160	2, 792, 627	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	1, 824, 278
2034		2, 199, 804	43, 338	549, 484	-146, 160	2, 792, 627	3, 350, 112	-250, 171	-1, 218, 222	2, 735, 186	4, 616, 904	1, 824, 278
Total	204, 824, 417	28, 781, 122	866, 567	41, 302, 247	-2, 703, 788	275, 774, 353	66, 531, 522	-4, 627, 880	-22, 535, 761	53, 326, 351	92, 694, 232	-183, 080, 121
											NPV	-143, 520, 382

(2) Capacity 4.8MW (Unit: US$)

	Cost						Benefit					Balance
	Grid-connected PV System			Import Duties	Gen-set O&M	Total	Electricity Fee	Purchase of surplus power	Fee for reduced demand	Fuel Reduction	Total	
	Investment	Replace	O&M									
2010	12,207,386			2,089,785		14,297,171					0	-14,297,171
2011	11,998,408		2,887	2,037,540		14,038,834	202,849			121,489	324,338	-13,714,496
2012	11,789,429		5,773	1,985,295		13,780,498	405,698			242,978	648,676	-13,131,821
2013	11,580,451		8,660	1,933,051		13,522,161	608,547			364,467	973,014	-12,549,147
2014	7,580,981		11,546	1,253,871		8,846,398	811,396			485,957	1,297,353	-7,549,046
2015	7,466,509		9,622	1,223,111	-32,450	8,699,242	743,779	-55,542	-270,465	607,446	1,025,217	-7,674,025
2016	7,326,725		11,553	1,188,165	-38,961	8,526,443	893,032	-66,687	-324,739	729,354	1,230,959	-7,295,484
2017	7,186,941		13,483	1,153,219	-45,473	8,353,644	1,042,285	-77,833	-379,013	851,262	1,436,701	-6,916,943
2018	7,047,157		15,414	1,118,273	-51,985	8,180,844	1,191,537	-88,978	-433,286	973,170	1,642,442	-6,538,402
2019	6,907,373		17,345	1,188,165	-58,496	8,112,883	1,340,790	-100,124	-487,560	1,095,077	1,848,184	-6,264,699
2020			19,276		-65,008	19,276	1,490,042	-111,269	-541,834	1,216,985	2,053,924	2,034,649
2021			19,276		-65,008	19,276	1,490,042	-111,269	-541,834	1,216,985	2,053,924	2,034,649
2022			19,276		-65,008	19,276	1,490,042	-111,269	-541,834	1,216,985	2,053,924	2,034,649
2023			19,276		-65,008	19,276	1,490,042	-111,269	-541,834	1,216,985	2,053,924	2,034,649
2024			19,276		-65,008	19,276	1,490,042	-111,269	-541,834	1,216,985	2,053,924	2,034,649
2025		1,830,429	19,276	457,140	-65,008	2,306,845	1,490,042	-111,269	-541,834	1,216,985	2,053,924	-252,920
2026		1,757,286	19,276	438,855	-65,008	2,215,417	1,490,042	-111,269	-541,834	1,216,985	2,053,924	-161,492
2027		1,684,144	19,276	420,569	-65,008	2,123,989	1,490,042	-111,269	-541,834	1,216,985	2,053,924	-70,064
2028		1,611,001	19,276	402,284	-65,008	2,032,561	1,490,042	-111,269	-541,834	1,216,985	2,053,924	21,364
2029		1,025,862	19,276	255,999	-65,008	1,301,136	1,490,042	-111,269	-541,834	1,216,985	2,053,924	752,788
2030		980,356	19,276	244,622	-65,008	1,244,254	1,490,042	-111,269	-541,834	1,216,985	2,053,924	809,670
2031		980,356	19,276	244,622	-65,008	1,244,254	1,490,042	-111,269	-541,834	1,216,985	2,053,924	809,670
2032		980,356	19,276	244,622	-65,008	1,244,254	1,490,042	-111,269	-541,834	1,216,985	2,053,924	809,670
2033		980,356	19,276	244,622	-65,008	1,244,254	1,490,042	-111,269	-541,834	1,216,985	2,053,924	809,670
2034		980,356	19,276	244,622	-65,008	1,244,254	1,490,042	-111,269	-541,834	1,216,985	2,053,924	809,670
Total	91,091,360	12,810,504	385,416	18,368,434	-1,202,484	122,655,714	29,590,543	-2,058,206	-10,022,566	23,725,980	41,235,751	-81,419,963
											NPV	-63,828,776

(3) Capacity 2.4MW (Unit: US$)

	Cost						Benefit					Balance
	Grid-connected PV System			Import Duties	Gen-set O&M	Total	Electricity Fee	Purchase of surplus power	Fee for reduced demand	Fuel Reduction	Total	
	Investment	Replace	O&M									
2010	6,113,883			1,046,637		7,160,520					0	-7,160,520
2011	6,009,219		1,446	1,020,471		7,031,136	101,594			60,830	162,424	-6,868,711
2012	5,904,555		2,891	994,305		6,901,752	203,188			121,660	324,848	-6,576,903
2013	5,799,892		4,337	968,139		6,772,368	304,781			182,490	487,271	-6,285,096
2014	3,796,819		5,783	627,982		4,430,583	406,375			243,321	649,696	-3,780,888
2015	3,727,043		4,819	610,538	-16,252	4,342,400	372,511	-27,817	-135,458	304,151	513,386	-3,829,014
2016	3,657,267		5,783	593,094	-19,502	4,256,144	447,013	-33,381	-162,550	364,981	616,063	-3,640,081
2017	3,587,491		6,746	575,650	-22,753	4,169,888	521,515	-38,944	-189,642	425,811	718,740	-3,451,148
2018	3,517,716		7,710	558,206	-26,003	4,083,632	596,017	-44,508	-216,733	486,641	821,417	-3,262,215
2019	3,447,940		8,674	593,094	-29,254	4,049,708	670,519	-50,071	-243,825	547,471	924,094	-3,125,614
2020			9,638		-32,504	9,638	745,021	-55,635	-270,917	608,301	1,026,771	1,017,133
2021			9,638		-32,504	9,638	745,021	-55,635	-270,917	608,301	1,026,771	1,017,133
2022			9,638		-32,504	9,638	745,021	-55,635	-270,917	608,301	1,026,771	1,017,133
2023			9,638		-32,504	9,638	745,021	-55,635	-270,917	608,301	1,026,771	1,017,133
2024			9,638		-32,504	9,638	745,021	-55,635	-270,917	608,301	1,026,771	1,017,133
2025		917,674	9,638	228,952	-32,504	1,156,264	745,021	-55,635	-270,917	608,301	1,026,771	-129,493
2026		881,042	9,638	219,794	-32,504	1,110,474	745,021	-55,635	-270,917	608,301	1,026,771	-83,703
2027		844,410	9,638	210,636	-32,504	1,064,683	745,021	-55,635	-270,917	608,301	1,026,771	-37,912
2028		807,778	9,638	201,478	-32,504	1,018,893	745,021	-55,635	-270,917	608,301	1,026,771	7,878
2029		514,719	9,638	128,213	-32,504	652,570	745,021	-55,635	-270,917	608,301	1,026,771	374,201
2030		490,298	9,638	122,108	-32,504	622,043	745,021	-55,635	-270,917	608,301	1,026,771	404,728
2031		490,298	9,638	122,108	-32,504	622,043	745,021	-55,635	-270,917	608,301	1,026,771	404,728
2032		490,298	9,638	122,108	-32,504	622,043	745,021	-55,635	-270,917	608,301	1,026,771	404,728
2033		490,298	9,638	122,108	-32,504	622,043	745,021	-55,635	-270,917	608,301	1,026,771	404,728
2034		490,298	9,638	122,108	-32,504	622,043	745,021	-55,635	-270,917	608,301	1,026,771	404,728
Total	45,561,825	6,417,112	192,756	9,187,726	-601,323	61,359,419	14,798,828	-1,029,242	-5,011,961	11,861,876	20,619,502	-40,739,917
											NPV	-31,942,242

Source : Prepared by the Study Team

Table 5.3.2-2 shows fiscal revenue and expenditure of the central government for the last three years. On average, MRf 2,057 million (US$ 160 million) was spent as development expenditure while fiscal balance was deficit during those periods.

Table 5.3.2-2 Fiscal Revenue and Expenditure of the Central Government

(Unit: million MRf)

	2006	2007	2008
Revenue and Grants	6, 154. 0	7, 852. 6	9, 757. 0
Expenditure and Lending	6, 948. 1	8, 914. 3	11, 321. 6
Development Expenditure	1, 458. 4	1, 952. 6	2, 760. 7
Balance	−794. 1	−1, 061. 7	−1, 564. 6

Source: MOFT

Financial assistance is applied to installation of the PV system all over the world and that is indispensable for the dissemination of the grid-connected PV system in the Maldives in order to reduce the financial burden of initial investment as mentioned above.

Table 5.3.2-3 shows the amount of financial assistance from the government and cost borne by STELCO. Supposed that import duties exemption is applied to the equipment of the PV system, the financial assistance from the government should be US$ 20.7 million for 13.49MW, US$ 9.2 million for 6MW, and US$ 4.6 million for 3MW under the case of installation by solely STELCO. The amount for STELCO's portion under the case of installation by STELCO and private sector should be US$ 17.5 million for 10.79MW, US$ 7.8 million for 4.8MW, and US$ 3.9 million for 2.4MW.

Table 5.3.2-3 Financial Assistance Necessary for the Initial Investment and STELCO's Cost

a. Installation by solely STELCO

		Capacity		
		13.49 MW	6 MW	3 MW
Initial investment	(MRf)	3,247,699,675	1,444,469,809	722,201,412
	(US$)	253,726,537	112,849,204	56,421,985
< Financial Assistance >				
Financial assistance to initial investment	(MRf)	2,651,422,015	1,179,265,152	589,678,148
	(US$)	207,142,345	92,130,090	46,068,605
Ration of financial assistance to initial investment (%)		81.64%	81.64%	81.64%
Average assistance per year	(MRf/year)	265,142,201	117,926,515	58,967,815
	(US$/year)	20,714,234	9,213,009	4,606,861
Ratio to development expenditure（%）		12.9%	5.7%	2.9%
< Cost borne by STELCO >				
Total cost	(MRf)	596,277,660	265,204,657	132,612,577
	(US$)	46,584,192	20,719,114	10,360,358
Yearly cost	(MRf/year)	59,627,766	26,520,466	13,261,258
	(US$/year)	4,658,419	2,071,911	1,036,036
Ratio of yearly cost to depreciation for 2008		105.6%	47.0%	23.5%

b. Installation by STELCO and Private Sector (STELCO's portion)

		Capacity		
		10.79 MW	4.8 MW	2.4 MW
Initial investment	(MRf)	2,621,752,532	1,165,969,412	583,102,047
	(US$)	204,824,417	91,091,360	45,554,847
< Financial Assistance >				
Financial assistance to initial investment	(MRf)	2,233,470,982	994,455,311	497,462,230
	(US$)	174,489,920	77,691,821	38,864,237
Ration of financial assistance to initial investment (%)		85.19%	85.29%	85.30%
Average assistance per year	(MRf/year)	223,347,098	99,445,531	49,746,223
	(US$/year)	17,448,992	7,769,182	3,886,424
Ratio to development expenditure（%）		10.9%	4.8%	2.4%
< Cost borne by STELCO >				
Total cost borne by STELCO	(MRf)	388,281,550	171,514,101	85,729,130
	(US$)	30,334,496	13,399,539	6,697,588
Yearly cost borne by STELCO	(MRf/year)	38,828,155	17,151,410	8,572,913
	(US$/year)	3,033,450	1,339,954	669,759
Ratio of yearly cost to depreciation for 2008		68.7%	30.4%	15.2%

Note: Import duties exemption is not included in the amount of financial assistance.

Source : Prepared by the Study Team

Annual average cost borne by STELCO is US$ 4.7 million for 13.49MW, US$ 2.1 million for 6MW, and US$ 1 million for 3MW. Those figures for STELCO's portion under the case of installation by STELCO and private sector are US$ 3 million for 10.79MW, US$ 1.4 million for 4.8MW, and US$ 0.7 million for 2.4MW. Installation of the PV system with capacity of 13.49MW and 6MW is the large-scale investment for STELCO considering the ratio of the cost to the depreciation in 2008.

As a measure to reduce diesel consumption, making the transition from the conventional diesel power generation to renewable energy is consistent with the carbon neutral policy announced by the Government of Maldives. Therefore, development expenditure can be regarded as one of the financial sources for introduction of the grid-connected PV system. However, implementation method of the public works is being reviewed through promotion of privatization and utilization of private finance, in order to improve the financial deficit. It is also assumed that review of measures for the poor formulated by the former government, budget allocation to alleviation of overconcentration in Male' and measures for the weak will be further enhanced. Thus, securing of financing from the conventional financial sources could be limited.

With regard to the other financial sources, green tax which the President of the Maldives revealed could be considered. It is planned that the tourists should pay US$ 3 per day from 2010. According to the announcement, it is foreseen that the number of tourists is annually 700 thousand, average length of stay is 3 days, and tax revenue will increase by US$ 6.3 million per year. In the meeting with Ministry of Finance and Treasury, it is confirmed that part of revenue from the green tax will be allocated for introduction of renewable energy. Power generation by the grid-connected PV system will contribute to reduction of CO_2 emission through decreasing fossil fuel consumption. Therefore, utilization of the tax revenue for introduction of the PV system seems to be consistent with the objective of the green tax.

For the capacity of 13.49MW and 6MW, the annual average amount of financial assistance to the initial investment cost exceeds the revenue of 6.3 million US$ from the green tax. For the capacity of 3MW, the annual average amount of financial assistance to the initial investment cost is US$ 4.6 million under the case of installation by solely STELCO, which is equivalent to about 73 percent of the annual revenue from the green tax. Installation of the PV system with the capacity of 3MW can be realized when the amount can be allocated for that every year. Under the case of installation by STELCO and private sector, STELCO’s portion is 2.4MW and the financial assistance for the initial investment from the government is US$ 3.9 million, which is equivalent to about 61 percent of the annual revenue from the green tax. As explained above, the maximum possible capacity is 13.49MW in Male’ and Hulhumale, however, the capacity over 10MW is very huge in the world. Considering the financial constraints of both the government and STELCO mentioned above, 3MW is the installation capacity which can be realized with utilization of green tax as a source of financial assistance from the government. Table 5.3.2-4 shows cashflow for introduction of the grid-connected PV system with capacity of 3MW under the condition that import duties exemption and financial assistance from the government is provided to the initial investment cost. Table 5.3.2-4 b. shows the results of analysis under the conditions that excess power from power generation by privately installed PV system is 20% and purchasing price is MRf 3/kWh which is equivalent to the unit production cost.

Table 5.3.2-4 Cashflow for Introduction of the Grid-Connected PV System with Capacity of 3MW

a. Installation by solely STELCO (Unit: US$)

	Cost					Benefit			Balance
	Grid-connected PV System			Import Duties	Total	Electricity Fee	Fuel Reduction	Total	
	Investment	Replace	O&M						
2010	1,122,509				1,122,509			0	-1,122,509
2011	1,103,293		1,446		1,104,738	101,594	60,830	162,424	-942,314
2012	1,084,076		2,891		1,086,968	203,188	121,660	324,848	-762,119
2013	1,064,860		4,337		1,069,197	304,781	182,490	487,271	-581,926
2014	1,045,644		5,783		1,051,427	406,375	243,321	649,696	-401,731
2015	1,026,428		7,228		1,033,656	507,969	304,151	812,120	-221,536
2016	1,007,211		8,674		1,015,885	609,563	364,981	974,544	-41,342
2017	987,995		10,120		998,115	711,157	425,811	1,136,968	138,853
2018	968,779		11,565		980,344	812,750	486,641	1,299,391	319,047
2019	949,563		13,011		962,574	914,344	547,471	1,461,815	499,242
2020			14,457		14,457	1,015,938	608,301	1,624,239	1,609,783
2021			14,457		14,457	1,015,938	608,301	1,624,239	1,609,783
2022			14,457		14,457	1,015,938	608,301	1,624,239	1,609,783
2023			14,457		14,457	1,015,938	608,301	1,624,239	1,609,783
2024			14,457		14,457	1,015,938	608,301	1,624,239	1,609,783
2025		917,674	14,457		932,131	1,015,938	608,301	1,624,239	692,108
2026		881,042	14,457		895,499	1,015,938	608,301	1,624,239	728,741
2027		844,410	14,457		858,867	1,015,938	608,301	1,624,239	765,373
2028		807,778	14,457		822,234	1,015,938	608,301	1,624,239	802,005
2029		771,145	14,457		785,602	1,015,938	608,301	1,624,239	838,637
2030		734,513	14,457		748,970	1,015,938	608,301	1,624,239	875,270
2031		734,513	14,457		748,970	1,015,938	608,301	1,624,239	875,270
2032		734,513	14,457		748,970	1,015,938	608,301	1,624,239	875,270
2033		734,513	14,457		748,970	1,015,938	608,301	1,624,239	875,270
2034		734,513	14,457		748,970	1,015,938	608,301	1,624,239	875,270
Total	10,360,358	7,894,614	281,906	0	18,536,877	19,810,791	11,861,876	31,672,667	13,135,790
								NPV	1,496
								FIRR	12.00%

b. Installation by STELCO and Private Sector (STELCO's portion 2.4MW) (Unit: US$)

	Cost						Benefit					Balance
	Grid-connected PV System			Gen-set O&M	Import Duties	Total	Electricity Fee	Purchase of surplus power	Fee for reduced demand	Fuel Reduction	Total	
	Investment	Replace	O&M									
2010	898,741					898,741					0	-898,741
2011	883,355		1,446			884,801	101,594			60,830	162,424	-722,377
2012	867,970		2,891			870,861	203,188			121,660	324,848	-546,013
2013	852,584		4,337			856,921	304,781			182,490	487,271	-369,650
2014	558,132		5,783			563,915	406,375			243,321	649,696	85,781
2015	547,875		4,819	-16,252		536,442	372,511	-27,817	-135,458	304,151	513,386	-23,056
2016	537,618		5,783	-19,502		523,899	447,013	-33,381	-162,550	364,981	616,063	92,164
2017	527,361		6,746	-22,753		511,355	521,515	-38,944	-189,642	425,811	718,740	207,385
2018	517,104		7,710	-26,003		498,811	596,017	-44,508	-216,733	486,641	821,417	322,606
2019	506,847		8,674	-29,254		486,268	670,519	-50,071	-243,825	547,471	924,094	437,826
2020			9,638	-32,504		-22,866	745,021	-55,635	-270,917	608,301	1,026,771	1,049,637
2021			9,638	-32,504		-22,866	745,021	-55,635	-270,917	608,301	1,026,771	1,049,637
2022			9,638	-32,504		-22,866	745,021	-55,635	-270,917	608,301	1,026,771	1,049,637
2023			9,638	-32,504		-22,866	745,021	-55,635	-270,917	608,301	1,026,771	1,049,637
2024			9,638	-32,504		-22,866	745,021	-55,635	-270,917	608,301	1,026,771	1,049,637
2025		917,674	9,638	-32,504		894,808	745,021	-55,635	-270,917	608,301	1,026,771	131,963
2026		881,042	9,638	-32,504		858,176	745,021	-55,635	-270,917	608,301	1,026,771	168,595
2027		844,410	9,638	-32,504		821,544	745,021	-55,635	-270,917	608,301	1,026,771	205,227
2028		807,778	9,638	-32,504		784,911	745,021	-55,635	-270,917	608,301	1,026,771	241,859
2029		514,719	9,638	-32,504		491,853	745,021	-55,635	-270,917	608,301	1,026,771	534,918
2030		490,298	9,638	-32,504		467,432	745,021	-55,635	-270,917	608,301	1,026,771	559,339
2031		490,298	9,638	-32,504		467,432	745,021	-55,635	-270,917	608,301	1,026,771	559,339
2032		490,298	9,638	-32,504		467,432	745,021	-55,635	-270,917	608,301	1,026,771	559,339
2033		490,298	9,638	-32,504		467,432	745,021	-55,635	-270,917	608,301	1,026,771	559,339
2034		490,298	9,638	-32,504		467,432	745,021	-55,635	-270,917	608,301	1,026,771	559,339
Total	6,697,588	6,417,112	192,756	-601,323	0	12,706,133	14,798,828	-1,029,242	-5,011,961	11,861,876	20,619,502	7,913,369
											NPV	1,616
											FIRR	12.01%

Source : Prepared by the Study Team

Next, cases of different contribution rates from the green tax for financial assistance are examined. As mentioned above, 3MW of the PV system can be installed under the case of installation by solely STELCO when 4.6 million US$ is provided, which is equivalent to 73 % of annual tax revenue from the green tax. However, if the percentage decreases to 50 or 30 %, shortfall should be covered by any other financial sources. As shown in Table 5.3.2-5, under the case of installation by solely STELCO, allowable amount and shortfall is 3.2 million US$ and 1.5 million US$ for contribution rate of 50%, and 1.9 million US$ and 2.7 million US$ for contribution rate of 30% respectively. In the same way, shortfall is 0.7 million US$ for 50% and 2 million US$ for 30% to the STELCO's portion under the case of installation by STELCO and private sector.

As discussed, the Government of Maldives is promoting the financial reform and provision of large-scale financial assistance from the national development expenditure to the initial investment would be difficult. However, part of the financial assistance, which could not be covered by the other financial sources, would be derived from the development expenditure. Ratio of the shortfall to the development expenditure is within the range between 0.5 percent and 1.7 percent for the case of contribution rates of 50% and 30% respectively. The percentage is less than the figures shown in Table 5.3.2-3 b., which is under the case of providing all the assistance from the development expenditure. Therefore, the national development expenditure also can be considered as a financial source for alleviation of financial burden on initial investment, combined with the other financial sources.

Table 5.3.2-5 Amount of Financial Assistance by Contribution Rate from the Green Tax

	Contribution Rate from the Green Tax			
	73%/61%	50%	30%	0%
a. Installation by solely STELCO (3MW)				
Necessary amount（US$）	4,606,861			
Allowable amount（US$）	4,606,861	3,150,000	1,890,000	0
Shortfall（US$）	0	1,456,861	2,716,861	4,606,861
Ratio of shortfall to the national development expenditure	-	0.9%	1.7%	2.9%
b. Installation by STELCO and private sector (STELCO's portion: 2.4MW)				
Necessary amount（US$）	3,886,424			
Allowable amount（US$）	3,886,424	3,150,000	1,890,000	0
Shortfall（US$）	0	736,424	1,996,424	3,886,424
Ratio of shortfall to the national development expenditure	-	0.5%	1.2%	2.4%

Source : Prepared by the Study Team

Besides, as another financial source, carbon tax on use of fossil fuel could be considered. Beneficiaries of diesel power generation indirectly consume fossil fuel through power consumption. Accordingly, part of revenue from the carbon tax can be utilized for transition to renewable energy (see Section 8.2.3, Chapter 8 for detail of institutional framework). In case that the shortfall of the financial assistance is provided from the carbon tax revenue, required amount is as shown in Table 5.3.2-5. When the shortfall is divided evenly to the customers, the amount per kWh for electricity consumption is as shown in Table 5.3.2-6, calculating on the basis of the power demand forecast for 10 years.

Table 5.3.2-6 Amount per kWh for the Case that the Shortfall is divided evenly to the Customers

	Contribution Rate from the Green Tax			
	73%/61%	50%	30%	0%
a. Installation by solely STELCO (3MW)				
Shortfall（US$）	0	1,456,861	2,716,861	4,606,861
Collection of shortfall from carbontax (MRf/kWh)	-	0.005	0.01	0.017
b. Installation by STELCO and private sector (STELCO's portion: 2.4MW)				
Shortfall（US$）	0	736,424	1,996,424	3,886,424
Collection of shortfall from carbontax (MRf/kWh)	-	0.003	0.007	0.014

Source : Prepared by the Study Team

5.3.3 Sensitivity Analysis

Sensitivity analysis is carried out on the following conditions.

- Rise in PV system price decreasing rate
- Decrease of PV system price
- Increase of O&M cost
- Increase of electricity tariff
- Increase/decrease of fuel price

Regarding the rise in decreasing rate of the PV system price, the case that increase of supply in Japan, Europe and U.S. and commencement of production in emerging countries like India and China expand the production in the world and the system price decrease faster than that described in the NEDO's PV Road Map is examined. As for the base case, PV system price decreasing rate is 2.5% per year in line with the PV Road Map. The cases of 3 percent and 3.5 percent up to 2020 are examined in the sensitivity analysis. Table 5.3.3-1 shows the results of the analysis.

Table 5.3.3-1 Results of the Cases of Rise in Decreasing Rate of the PV System Price

Decreasing Rate	Installation by solely STELCO (3MW)		Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)	
	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)
Base Case (2.5%)	12.00	81.64	12.01	85.30
3.0%	12.25	81.40	12.23	85.13
3.5%	12.50	81.15	12.46	84.96

Source : Prepared by the Study Team

Cases where the unit system cost is 5 percent and 10 percent less are examined. Decreasing rate of the unit price is 2.5 percent per year as set in the NEDO's PV Road Map. Table 5.3.3-2 shows the results of the analysis.

Table 5.3.3-2 Results of the Cases of Initial Unit Price Decrease in PV System

Decreasing Rate	Installation by solely STELCO (3MW)		Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)	
	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)
Base Case	12.00	81.64	12.01	85.30
5% less	12.77	80.88	12.86	84.66
10% less	13.56	80.06	13.75	83.97

Source : Prepared by the Study Team

Regarding the O&M cost, the cases of 10 percent and 20 percent more than the base case are examined. Table 5.3.3-3 shows the results of the analysis.

Table 5.3.3-3 Results of the Cases of Increase in O&M Cost

O&M Cost	Installation by solely STELCO (3MW)		Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)	
	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)
Base Case	12.00	81.64	12.01	85.30
10% up	11.99	81.66	11.99	83.32
20% up	11.97	81.68	11.96	85.33

Source : Prepared by the Study Team

Although the electricity tariff is currently being reviewed and the tariff table will not be reviewed again for certain time, the cases of 10 percent and 20 percent increase are examined. Table 5.3.3-4 shows the results of the analysis.

Table 5.3.3-4 Results of the Cases of Increase in Electricity Tariff

Electricity Tariff	Installation by solely STELCO (3MW)		Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)	
	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)
Base Case	12.00	81.64	12.01	85.30
10% up	12.95	80.70	12.82	84.69
20% up	14.31	79.28	14.37	83.79

Source : Prepared by the Study Team

With regard to the fuel price, the cases of 2 percent increase and 1 percent decrease per year are examined for the sensitivity analysis. Table 5.3.3-5 shows the results of the analysis.

Table 5.3.3-5 Results of the Cases of Increase/Decrease in Fuel Price

Fuel Price	Installation by solely STELCO (3MW)		Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)	
	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)	FIRR (%)	Ratio of Financial Assistance which meet FIRR12% (%)
Base Case	12.00	81.64	12.01	85.30
2% up	13.51	80.08	14.35	83.44
1% down	11.30	82.32	10.87	86.10

Source : Prepared by the Study Team

For the case of installation by STELCO and private sector, the volume of power purchasing and the price also have a major impact on the results of the analysis, therefore, the cases of double the average electricity price and less than unit production cost (90%) for the purchasing price, and 50 percent and 100 percent (purchasing all generated power) for the rate of excess power are examined, while those figures are 20 percent of excess power and MRf 3/kWh for the base case. As shown in Table 5.3.3-6, under the case of double the average electricity price, FIRR is less than 12 percent for each rate of excess power. For the cases of less than the unit production cost, FIRR exceeds 12 percent for each rate of excess power. For the base case, increase of the rate of excess power causes increase of the FIRR.

Table 5.3.3-6 Results of Analysis by Percentage of Excess Power and Purchasing Price

Purchasing Price	Percentage of Excess Power	FIRR (%)
MRf 7.04 (Double the average electricity price)	20	10.57
	50	10.40
	100	10.12
MRf 3 (Base case)	20	12.01
	50	13.79
	100	16.37
MRf 2.7 (90 percent of the unit production cost)	20	12.09
	50	13.98
	100	16.69

Source : Prepared by the Study Team

From the results abovementioned, factors which have a major affect on profitability of the project are system price, electricity tariff, fuel price, the volume of excess power and the purchasing price.

5.4 Economic Analysis

5.4.1 Preconditions

(1) Cost

Economic costs for dissemination of the grid-connected PV system are investment cost, replacement cost and operation and maintenance cost. The conversion factor 0.9 is applied to calculation of international price.

(2) Benefit

The economic benefits from introducing the grid-connected PV system are tariff revenue from the consumers, consumer surplus comparing the cost per kWh for introduction of private generator by the consumers to electricity price of STELCO and saving of fuel costs that would be incurred in generating the same amount of power by diesel facilities. The conversion factor 0.9 is applied to calculation of international price. Concerning fuel costs, the State Trading Organization (STO) centrally administers diesel fuel trading in the Maldives, and STELCO must purchase diesel for power generation from the STO. However, because the STO has a monopoly on oil and fuel products and its prices do not correctly reflect the market price, the economic benefit of fuel cost savings is calculated based on the diesel price in the Singapore market adopted as an indicator of the international price.

<Consumer Surplus>

According to results of interview survey on private power generation, it is said that operation and maintenance of a generator with capacity of 4.5kW costs MRf 500 per day. Based on the records of

STELCO on power generation and fee collection for the last three years, average power consumption per day per consumer in Male' and Hulhumale' is 19 kWh. When the average electricity price is MRf 3.52 which is the price after revision, electricity fee is MRf 66.88 per day (see Table 5.4.1-1). Difference of the daily cost is MRf433.12 and this means that daily cost of private power generation is MRf 22.8 per kWh more than that of power purchasing from STELCO. Cost of a generator is about US$ 389 (MRf 4,979) per kW so that the generator with capacity of 4.5W costs US$ 1,750.5 (MRf 22,406). Assumed that life time of the generator is 15 years and daily generation is 19 kWh on the basis of the STELCO's records, the cost of the generator is MRf 0.22 per kWh. Thus, Difference of the consumption cost per kWh between the private generator and power purchasing from STELCO is total MRf 23.02 (MRf 22.8 + MRf 0.22).

Table 5.4.1-1 Comparison of Cost between Private Power Generation and Power Purchasing from STELCO

	Power Purchasing from STELCO	Private Power Generation (4.5kW)
Generator	-	US$ 1,750.5 (MRf 22,406)
Daily cost	US$ 5.23 (MRf 66.88)	US$ 39 (MRf 500)
Cost per kWh	US$ 0.28 (MRf 3.52)	US$ 2.07 (MRf 26.54)

Source : Prepared by the Study Team

Supposed the current average electricity price is the lowest willingness to pay (P1) and the unit cost on introduction of private generator is the highest willingness to pay (P2), a figure corresponding to 25 percent of the difference between P1 and P2 is considered as the consumer surplus[2]. According to the figures shown in the above table, the consumer surplus per kWh is MRf 5.76, which corresponds to 25 percent of MRf 23.02, the difference of the cost per kWh between the private generation and power purchasing from STELCO. In order to utilize the figure in the economic analysis, it is converted to the international price by the official exchange rate and the standard conversion factor 0.9, and finally the consumer surplus of US$ 0.41/kWh is obtained.

< International Price of Diesel Fuel >

As for the fuel cost, management of domestic transaction of diesel fuel is unified to State Trading Organization (STO) in the Maldives. STELCO has to procure the diesel fuel from STO for the power generation. Transaction of oil products is monopolized by STO and the proper market price is not reflected in the domestic price. Therefore, Singapore market price is used as a benchmark for conversion of domestic diesel price to the international price.

[2] Regarding the methodology of calculation of consumer surplus on electricity development project, refer to "Example of Indicator for Economic Analysis by Willingness to Pay on Electricity Development Project in the Developing Countries based on the results of socio-economic survey in the rural area of Malawi", Toshiyuki HAYASHI, Senior Adviser of JICA

The trend of diesel fuel price is as shown in Figure 3.3.3-1 and fluctuation of the STO price and the Singapore market price shows almost the same trend. With regard to the difference between those prices from 2004 onward, the Singapore market price is 75 percent of the STO price on average, while the amount increased in a phase of downturn in Singapore market price. Therefore, coefficient of 0.75 is used for conversion of the diesel fuel price to the international price.

(3) Assessment of Feasibility

The economic internal rate of return (EIRR) is used to analyze feasibility of the project. 12 % of the discount rate is applied to the assessment.

5.4.2 Results of Economic Analysis

As shown in Table 5.4.2-1, supposed that the financial assistance which meets FIRR 12 percent is provided by the government to the initial investment cost of the capacity 3MW, EIRR is 23.50 percent for the case of installation by solely STELCO and 27.93 percent for the STELCO’s portion under the case of installation by STELCO and private sector. Both the installation patterns turned out to be economically feasible for the base case.

Table 5.4.2-1 Results of Economic Analysis for the Capacity of 3MW

a. Installation by solely STELCO (Unit: US$)

	Cost				Benefit				Balance
	Grid-connected PV System			Total	Electricity Fee	Consumer Surplus	Fuel Reduction	Total	
	Investment	Replace	O&M						
2010	1,118,731			1,118,731				0	-1,118,731
2011	1,099,514		1,117	1,100,632	77,898	140,217	43,901	262,016	-838,616
2012	1,080,298		2,219	1,082,517	154,712	278,482	87,255	520,449	-562,069
2013	1,061,082		3,346	1,064,428	233,295	419,932	131,596	784,823	-279,605
2014	1,041,866		4,474	1,046,339	311,879	561,382	175,937	1,049,198	2,859
2015	1,022,649		5,601	1,028,250	390,462	702,832	220,278	1,313,572	285,322
2016	1,003,433		6,728	1,010,161	469,046	844,282	264,619	1,577,947	567,786
2017	984,217		7,855	992,072	547,629	985,732	308,960	1,842,322	850,250
2018	965,001		8,982	973,983	626,212	1,127,182	353,301	2,106,696	1,132,713
2019	945,784		10,109	955,894	704,796	1,268,632	397,643	2,371,071	1,415,177
2020			11,237	11,237	783,379	1,410,083	441,984	2,635,445	2,624,209
2021			11,237	11,237	783,379	1,410,083	441,984	2,635,445	2,624,209
2022			11,237	11,237	783,379	1,410,083	441,984	2,635,445	2,624,209
2023			11,237	11,237	783,379	1,410,083	441,984	2,635,445	2,624,209
2024			11,237	11,237	783,379	1,410,083	441,984	2,635,445	2,624,209
2025		917,650	11,237	928,887	783,379	1,410,083	441,984	2,635,445	1,706,558
2026		881,018	11,237	892,255	783,379	1,410,083	441,984	2,635,445	1,743,190
2027		844,386	11,237	855,622	783,379	1,410,083	441,984	2,635,445	1,779,823
2028		807,754	11,237	818,990	783,379	1,410,083	441,984	2,635,445	1,816,455
2029		771,121	11,237	782,358	783,379	1,410,083	441,984	2,635,445	1,853,087
2030		734,489	11,237	745,726	783,379	1,410,083	441,984	2,635,445	1,889,720
2031		734,489	11,237	745,726	783,379	1,410,083	441,984	2,635,445	1,889,720
2032		734,489	11,237	745,726	783,379	1,410,083	441,984	2,635,445	1,889,720
2033		734,489	11,237	745,726	783,379	1,410,083	441,984	2,635,445	1,889,720
2034		734,489	11,237	745,726	783,379	1,410,083	441,984	2,635,445	1,889,720
Total	10,322,576	7,894,374	218,981	18,435,931	15,266,614	27,479,912	8,613,245	51,359,772	32,923,841
								NPV	4,798,105
								EIRR	23.50%

b. Installation by STELCO and Private Sector (STELCO's portion) (Unit: US$)

	Cost					Benefit						Balance
	Grid-connected PV System			Reduction of Gen-set O&M	Total	Electricity Fee	Consumer Surplus	Purchase of surplus power	Fee for reduced demand	Fuel Reduction	Total	
	Investment	Replace	O&M									
2010	895, 716				895, 716						0	-895, 716
2011	880, 330		1, 242		881, 572	77, 898	140, 217			43, 901	262, 016	-619, 556
2012	864, 945		2, 466		867, 410	154, 712	278, 482			87, 255	520, 449	-346, 962
2013	849, 559		3, 718		853, 277	233, 295	419, 932			131, 596	784, 823	-68, 454
2014	834, 174		4, 971		839, 144	311, 879	561, 382			175, 937	1, 049, 198	210, 054
2015	818, 788		6, 223	-13, 992	825, 011	416, 493	702, 832	-24, 295	-115, 693	220, 278	1, 199, 615	374, 604
2016	803, 402		7, 475	-16, 807	810, 878	500, 315	844, 282	-29, 185	-138, 976	264, 619	1, 441, 055	630, 177
2017	788, 017		8, 728	-19, 623	796, 745	584, 138	985, 732	-34, 075	-162, 260	308, 960	1, 682, 495	885, 751
2018	772, 631		9, 980	-22, 439	782, 612	667, 960	1, 127, 182	-38, 964	-185, 544	353, 301	1, 923, 935	1, 141, 324
2019	757, 246		11, 233	-25, 255	768, 478	751, 782	1, 268, 632	-43, 854	-208, 828	397, 643	2, 165, 375	1, 396, 896
2020			12, 485	-28, 071	12, 485	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	2, 394, 329
2021			12, 485	-28, 071	12, 485	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	2, 394, 329
2022			12, 485	-28, 071	12, 485	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	2, 394, 329
2023			12, 485	-28, 071	12, 485	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	2, 394, 329
2024			12, 485	-28, 071	12, 485	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	2, 394, 329
2025		917, 650	12, 485	-28, 071	930, 135	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 476, 679
2026		881, 018	12, 485	-28, 071	893, 503	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 513, 311
2027		844, 386	12, 485	-28, 071	856, 871	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 549, 943
2028		807, 754	12, 485	-28, 071	820, 239	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 586, 576
2029		771, 121	12, 485	-28, 071	783, 606	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 623, 208
2030		734, 489	12, 485	-28, 071	746, 974	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 659, 840
2031		734, 489	12, 485	-28, 071	746, 974	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 659, 840
2032		734, 489	12, 485	-28, 071	746, 974	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 659, 840
2033		734, 489	12, 485	-28, 071	746, 974	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 659, 840
2034		734, 489	12, 485	-28, 071	746, 974	835, 604	1, 410, 083	-48, 744	-232, 112	441, 984	2, 406, 814	1, 659, 840
Total	8, 264, 808	7, 894, 374	243, 312	-519, 183	16, 402, 493	16, 232, 532	27, 479, 912	-901, 527	-4, 292, 988	8, 613, 245	47, 131, 175	30, 728, 681
											NPV	5, 200, 776
											EIRR	27. 93%

Source : Prepared by the Study Team

5.4.3 Sensitivity Analysis

Sensitivity analysis is carried out on the following conditions in the same way of the financial analysis.

- Rise in PV system price decreasing rate
- Decrease of PV system price
- Increase of O&M cost
- Increase of electricity tariff
- Increase/decrease of fuel price

As for the base case of the rise in decreasing rate of the PV system price, PV system price decreasing rate is 2.5% per year in line with the PV Road Map. The cases of 3 percent and 3.5 percent up to 2020 are examined in the sensitivity analysis. Table 5.4.3-1 shows the results of the analysis.

Table 5.4.3-1 Results of the Cases of Rise in Decreasing Rate of the PV System Price

Decreasing Rate	EIRR (%)	
	Installation by solely STELCO (3MW)	Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)
Base Case (2.5%)	23.50	27.93
3.0%	23.77	28.22
3.5%	24.04	28.52

Source : Prepared by the Study Team

Cases where the unit system cost is 5 percent and 10 percent less are examined. Decreasing rate of the unit price is 2.5 percent per year as set in the NEDO's PV Road Map. Table 5.4.3-2 shows the results of the analysis.

Table 5.4.3-2 Results of the Cases of Initial Unit Price Decrease in PV System

Decreasing Rate	EIRR (%)	
	Installation by solely STELCO (3MW)	Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)
Base Case	23.50	27.93
5% less	24.44	29.03
10% less	25.43	30.20

Source : Prepared by the Study Team

Regarding the O&M cost, the cases of 10 percent and 20 percent more than the base case are examined. Table 5.4.3-3 shows the results of the analysis.

Table 5.4.3-3 Results of the Cases of Increase in O&M Cost

O&M Cost	EIRR (%)	
	Installation by solely STELCO (3MW)	Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)
Base Case	23.50	27.93
10% up	23.49	27.91
20% up	23.48	27.90

Source : Prepared by the Study Team

Although the electricity tariff is currently being reviewed and the tariff table will not be reviewed again for certain time, the cases of 10 percent and 20 percent increase are examined. Table 5.4.3-4 shows the results of the analysis.

Table 5.4.3-4 Results of the Cases of Increase in Electricity Tariff

Electricity Tariff	EIRR (%)	
	Installation by solely STELCO (3MW)	Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)
Base Case	23.50	27.93
10% up	23.89	28.29
20% up	24.63	29.04

Source : Prepared by the Study Team

With regard to the fuel price, the cases of 2 percent increase and 1 percent decrease per year are examined for the sensitivity analysis. Table 5.4.3-5 shows the results of the analysis.

Table 5.4.3-5 Results of the Cases of Increase/Decrease in Fuel Price

Fuel Price	EIRR (%)	
	Installation by solely STELCO (3MW)	Installation by STELCO and Private Sector (STELCO's Portion) (2.4MW)
Base Case	23.50	27.93
2% up	24.24	28.80
1% down	23.16	27.53

Source : Prepared by the Study Team

For the case of installation by STELCO and private sector, the volume of power purchasing and the price also have a major impact on the results of the analysis, therefore, the cases of double the average electricity price and less than unit production cost (90%) for the purchasing price, and 50 percent and 100 percent for the rate of excess power are examined, while those figures are 20 percent of excess power and MRf 3/kWh for the base case. As shown in Table 5.4.3.-6, under the case of double the average electricity price, FIRR is less than 12 percent for each rate of excess power exceeds 20 percent. For the cases of less than the unit production cost, FIRR always exceeds 12 percent for each rate of excess power. For the base case, increase of the rate of excess power causes increase of the FIRR.

Table 5.4.3-6 Results of Analysis by Percentage of Excess Power and Purchasing Price

Purchasing Price	Percentage of Excess Power	EIRR (%)
MRF 7.46 (Double the average electricity price)	20	27.35
	50	27.27
	100	27.15
MRF 3 (Base case)	20	27.93
	50	28.70
	100	29.94
MRF 2.7 (90 percent of the unit production cost)	20	27.97
	50	28.80
	100	30.12

Source : Prepared by the Study Team

5.4.4 Examination of Profitability on Private Investment in the PV System

With regard to dissemination of the grid-connected PV system in Male' and Hulhumale', investment profitability for the case of installation by private sector is examined. Assumptions for the analysis are as follows.

PV system cost: US$ 18,950/kW including construction and installation works, etc. (calculated on the basis of the cost estimate of the project), and 25% of import duties on the price of equipment

Operation and maintenance: US$ 0.004/kWh

Lifetime of major components: 30 years for PV panels and 15 years for the other components
Implementing body: Private business in Male' and Hulhumale'
Annual average power consumption: 11,000kWh/year
Ratio of excess power: 20% of power generation by the PV system
Capacity: 2kW
Discount rate: 6.5% (Interest rate of time deposit of commercial banks)

Under the conditions abovementioned, consumption volume at source is about 9,700kWh per year, which is equivalent to 90 percent of annual average power consumption. Supposed that the ratio of excess power is fixed at 20 percent, total benefit (loss) during the investment period is as shown in Table 5.4.4-1 for several cases of the excess power purchasing price and the investment period.

Table 5.4.4- 1 Results of Investment Profitability of Private Investment in the PV System

Ration of Excess Power	Purchasing Price	FIRR (%)	NPV (US$)	Total Benefit during the Investment Period (US$)
Investment Period 15 years				
20％	Double the average electricity tariff	6.25	-547	19,355
	Same as the unit production cost	2.62	-8,298	7,744
	90％ of the unit production cost	2.38	-8,783	7,018
Investment Period 10 years				
20％	Double the average electricity tariff	-0.33	-9,958	-602
	Same as the unit production cost	-4.79	-15,884	-8,343
	90％ of the unit production cost	-5.08	-16,254	-8,826

Source : Prepared by the Study Team

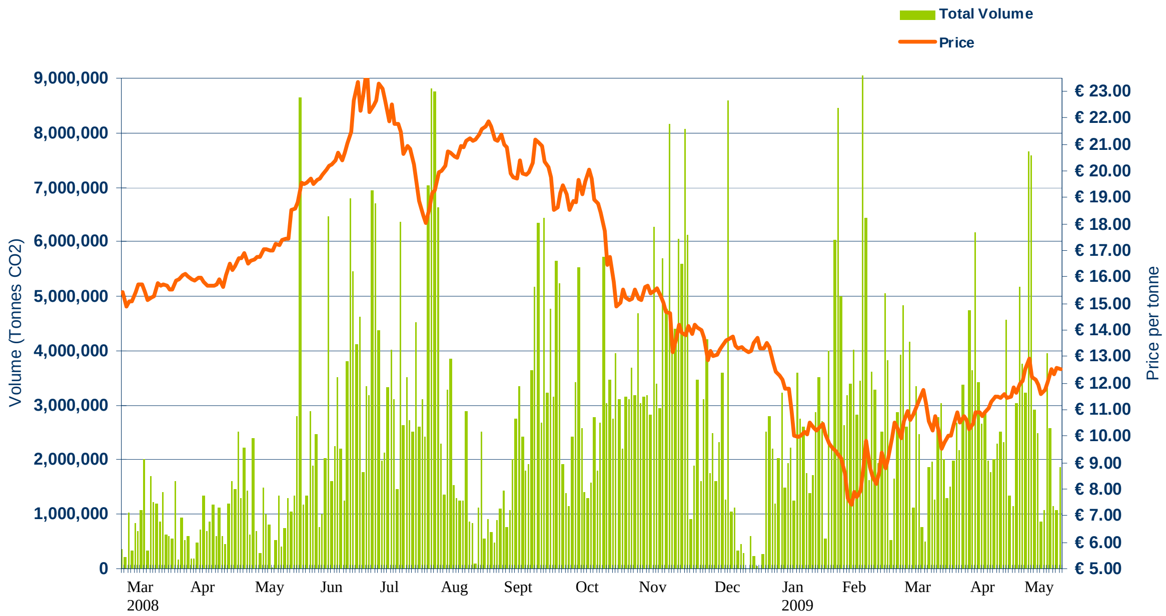
In the case of installation by STELCO and private sector, FIRR turns out to be 6.25 under the conditions that investment period is 15 years, excess power is 20 percent and purchasing price is double the average electricity tariff. The figure is slightly less than 6.5 of the discount rate. In order to improve the profitability of the investment, it is necessary to raise the purchasing price or to make the investment period long. There is not advantage for STELCO on increases in the purchasing price and long investment period is not preferable for the investors. However, as mentioned in Section 8.2.3, Chapter 8, those who are going to invest in renewable energy in the Maldives do not always emphasize the profitability, but also give importance to reduction of electricity bill and environmental protection. Therefore, when the priority is placed on not profitability but recovery of the investment cost, total revenue of US$ 7,018 can be obtained for the case of the investment period 15 years even though the purchasing price of the excess power is 90 percent of the unit production cost. If the period is set at 10 years, the total revenue during the investment period is negative for every condition.

5.5 Assessment of Impact on Investment Profitability of CDM Project Implementation

One method for improving the profitability of investment into the grid-connected PV system is to register the CO_2 emission reductions arising from the reduction in diesel power generation as a CDM project, and to sell the CERs that can be dealt through the project registration. However, in order to realize implementation as a CDM project, it is necessary to undergo a series of procedures ranging from project design document (PDD) preparation to validation, registration and verification. If the revenue from CER sales exceeds the costs of these procedures, the attempt to improve the investment profitability through implementation as a CDM project will be an effective measure. Therefore, in order to verify the improvement in investment profitability resulting from CDM project implementation, it is necessary to grasp CER trading price movements in markets and the cost of project registration.

5.5.1 Movements in the CER Trading Price

Figure 5.5.1-1 shows movements in CER futures trading quantities and prices on the European Climate Exchange (ECX), which is one of the European markets that have a great impact on emission credit prices. The price of CER futures trading showed a steady decline from July 2008 to February 2009, however, it started increasing again from March 2009. Concerning this price increase from March 2009, according to the Mitsui Sumitomo Bank newsletter, "Climate Change and Emission Credit Trading Vol. 15," since companies who had more emissions quotas than actual emissions at the end of April 2009 (the due date for the EU-ETS) had to purchase the necessary quantity of EUAs in the markets during that month, they were willing to purchase even at high prices. Since the price of CERs is linked to the price of EUAs, a similar trend can be seen in the price of CERs. Moreover, another factor behind the rise in CER prices has been the fact that increase in the price of crude oil has triggered major price hikes in natural gas, thereby leading to a stronger desire among power companies to purchase emission credits with a view to boosting coal-fired power generation.



Source : European Climate Exchange, Market Data
Note : Trading prices are delivery prices as of December 2009.

Figure 5.5.1-1 Quantities and Prices of CER Futures Trading on the ECX (March 2008-May 2009)

According to the "Variable Factors in Medium to Long-Term Emission Credit Prices" by Japan Research Institute, Limited, medium to long-term trends in the price of emission credits are determined by a number of factors including demand and supply on the macro level as well as political and technical factors. Table 5.5.1-1 shows the main factors that have an impact on the price of emission credits (source: Mitsui Sumitomo Bank newsletter, "Climate Change and Emission Credit Trading Vol. 6").

Table 5.5.1-1 Major Factors Affecting the Price of Emission Credits

Factors that could cause the price of emission credits to rise	- The case where the issued quantity of emission credits is reduced (the latest analysis by UN agencies shows that the total issued quantity of CERs may fall to approximately 1.6 billion t-CO_2). - The case where economic activities become more prosperous in Japan and EU countries, leading to an increase in energy consumption and higher emissions of greenhouse gases. - The case where major new demand for emission credits is created by introduction of an emission credits trading system in the United States, etc. - The case where the price of emission credits is politically induced due to, for example, reduction of EUA quotas geared to strengthening the superiority and competitiveness of low-carbon technologies in the EU - The case where power generation by sources that do not emit greenhouse gases (hydropower, nuclear power, etc.) is reduced, while thermal power generation is increased to offset that
Factors that could cause the price of emission credits to fall	- The case where surplus grant emission credits owned by Eastern Europe, Russia and Ukraine (maximum 9 billion t-CO_2) are put on sale, leading to an excess in supply of credits - The case where policies geared to forcefully disseminating renewable energy (fixed purchase price system, etc.) are implemented in developed countries, leading to a reduction in greenhouse gas emissions - The case where CCS (carbon dioxide recovery and storage) technology and other technologies capable of greatly reducing greenhouse gas emissions are made available for use at low cost

	- The case where the issued amount of emission credits increases due to simplification of the CDM project registration and emission credit issue processes - The case where the Kyoto Protcol is discontinued from 2012 and is superseded by a new framework in which emission credits cannot be used from 2013 onward

Source： Mitsui Sumitomo Bank newsletter, "Climate Change and Emission Credit Trading Vol. 6"

It is considered that the future price of CERS will revert to a downward trend once the rush to purchase emission credits in time for the EU-ETS cutoff has settled down. At the same time, since there is a possibility that the factors indicated in Table 5.5.1-1 could cause fluctuations, it is extremely difficult to project future price movements. Therefore, it is assumed that CER prices will move between the lowest price recorded in February 2009 and the highest price since then in May 2009, and the average price during this period of €11.25 (approximately US$15.75) is used as the CER price in this study. Since introduction of the grid-connected PV system will enable CO_2 emissions to be cut by 61,398 tons for 13.49MW, 27,315 tons for 6MW and 13,664 tons for 3MW for the period up to 2020, the cumulative amount of CER trading until 2020 will be about US$ one million (see Table 5.5.1-2).

Table 5.5.1-2 CO_2 Reductions and CER Sales

(1) Capacity 13.49MW

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
CO_2 Reduction (tonne)	1,109	2,227	3,345	4,463	5,581	6,699	7,817	8,935	10,053	11,171	61,398
CER Sales (US$)	17,468	35,075	52,683	70,290	87,898	105,505	123,113	140,720	158,328	175,936	967,016

(2) Capacity 6MW

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
CO_2 Reduction (tonne)	496	992	1,488	1,985	2,481	2,979	3,477	3,974	4,472	4,970	27,315
CER Sales (US$)	7,815	15,629	23,444	31,258	39,073	46,914	54,756	62,598	70,439	78,281	430,207

(3) Capacity 3MW

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
CO_2 Reduction (tonne)	248	497	745	994	1,242	1,491	1,739	1,987	2,236	2,484	13,664
CER Sales (US$)	3,913	7,826	11,738	15,651	19,564	23,477	27,389	31,302	35,215	39,128	215,203

Source: Prepared by the Study Team

5.5.2 Project Formulation Cost

CDM project formulation will require a process of project planning, preparation of project documents, validation and project registration, and this will be followed by implementation, monitoring, verification and certification. CERs can only be acquired in the event where issue of CERs is permitted. This series of procedures incurs costs and, according to the "Clean Development Mechanism: A User's Guide" by the UNDP, CDM project transaction costs can be divided into the costs incurred before implementation and those incurred during implementation. In developing countries, since experts are limited in number, cost estimate for the case where foreign consultants are recruited are given as shown in Table 5.5.2-1.

Table 5.5.2-1 Transaction Costs of CDM Project Formulation

Cost Item	Cost (US$)
1. Pre-operational stage	
(1) Feasibility assessment	5,000-20,000
(2) Preparation of project design document (PDD)	25,000-40,000
(3) Validation	10,000-15,000
(4) Registration	10,000* per year
(5) Legal work	20,000-25,000
2. Operational stage	
(1) Rewards for CER sales success	5-10% of CER value
(2) Risk mitigation	1-3% of CER value
(3) Monitoring and verification	3,000-15,000 per year

Source : UNDP, The Clean Development Mechanism: A User's Guide, Chapter 5
Note : Applied when the CO_2 reduction is 10,000~15,000 tons per year.

Since total introduction capacity of the grid-connected PV system under the project is less than 15 MW, it is expected that the project will be implemented as a small-scale CDM project. Therefore, the minimum level in the range of cost estimate shown in the UNDP guide is adopted as the pre-operational costs, while the lowest rates is adopted for CER sales rewards and risk management in the operational stage. However, concerning the monitoring and verification, since an annual cost of US$3,000 for foreign consultants is unrealistic, a cost of US$10,000 is assumed in this study. Table 5.5.2-2 shows the transaction costs in the pre-operational and operational stages.

Table 5.5.2-2 Transaction Costs in Small-Scale CDM Project Formulation

Cost Item	Rough Cost (US$)
1. Pre-operational stage	
(1) Feasibility assessment	5,000
(2) Preparation of Project design document (PDD)	25,000
(3) Validation	10,000
(4) Registration	10,000 per year
(5) Legal work	20,000
2. Operational stage	
(1) Rewards for CER sales success	5% of CER value
(2) Risk mitigation	1% of CER value
(3) Monitoring and verification	10,000 per year

Source : Prepared by the Study Team based on The Clean Development Mechanism: A User's Guide, Chapter 5, UNDP

Accordingly, the cost of CDM project formulation will be US$70,000 in the pre-operational stage and the cost during the operational stage (until 2020) will be as shown in Table 5.5.2-3.

Table 5.5.2-3 Costs in the Operational Stage (until 2020)

a. Installation by solely STELCO

(1) Capacity 13.49MW (Unit: US$)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Success Fee	873	1,754	2,634	3,515	4,395	5,275	6,156	7,036	7,916	8,797	48,351
Risk Management	175	351	527	703	879	1055	1231	1407	1583	1759	9,670
Monitoring & Verification	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000

(2) Capacity 6MW (Unit: US$)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Success Fee	391	781	1,172	1,563	1,954	2,346	2,738	3,130	3,522	3,914	21,511
Risk Management	78	156	234	313	391	469	548	626	704	783	4,302
Monitoring & Verification	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000

(3) Capacity 3MW (Unit: US$)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Success Fee	196	391	587	783	978	1,174	1,369	1,565	1,761	1,956	10,760
Risk Management	39	78	117	157	196	235	274	313	352	391	2,152
Monitoring & Verification	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000

b. Installation by STELCO and Private Sector (STELCO's Portion)

(1) Capacity 10.79MW (Unit: US$)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Success Fee	873	1,754	2,634	3,515	2,930	3,517	4,104	4,691	5,278	5,865	35,161
Risk Management	175	351	527	703	586	703	821	938	1056	1,173	7,033
Monitoring & Verification	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000

(2) Capacity 4.8 MW (Unit: US$)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Success Fee	391	781	1,172	1,563	1,302	1,564	1,825	2,087	2,348	2,609	15,642
Risk Management	78	156	234	313	260	313	365	417	470	522	3,128
Monitoring & Verification	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000

(3) Capacity 2.4MW (Unit: US$)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Success Fee	196	391	587	783	652	783	913	1,043	1,174	1,304	7,826
Risk Management	39	78	117	157	130	157	183	209	235	261	1,566
Monitoring & Verification	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000

Source: Prepared by the Study Team

5.5.3 Profit from CDM Project Formulation

Table 5.5.3-1 shows profits in the case where the PV system is installed by solely STELCO and the project is implemented as a CDM project. The cost for the process of project formulation and registration will incur at the first year, and the cost for registration, monitoring, verification and others like rewards for CERs sales success and risk mitigation will incur from the second year. CER trading will be conducted from the second year when power generation by the installed PV system will be commenced. Considering the balance for the capacity 13.49MW, the annual revenue will exceed the annual cost from the third year under the both cases of installation by solely STELCO and installation by STELCO and private sector, while the cumulative balance up to 2020 is US$ 638,995 and US$ 390,989 respectively.

Table 5.5.3-1 Profit from CDM Project Formulation

a. Installation by solely STELCO

(1) Capacity 13.49MW (Unit: US$)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Revenue												
CER sales (US$)		17,468	35,075	52,683	70,290	87,898	105,505	123,113	140,720	158,328	175,936	967,016
Cost												
Project formulation	60,000											60,000
Registration	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	110,000
Monitroing & Verification		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000
Other		1,048	2,105	3,161	4,218	5,274	6,330	7,387	8,443	9,499	10,556	58,021
Sub-Total	70,000	21,048	22,105	23,161	24,218	25,274	26,330	27,387	28,443	29,499	30,556	328,021
Profit (Loss)	-70,000	-3,580	12,970	29,522	46,072	62,624	79,175	95,726	112,277	128,829	145,380	638,995

(2) Capacity 6MW (Unit: US$)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Revenue												
CER sales (US$)		7,815	15,629	23,444	31,258	39,073	46,914	54,756	62,598	70,439	78,281	430,207
Cost												
Project formulation	60,000											60,000
Registration	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	110,000
Monitroing & Verification		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000
Other		469	937	1,406	1,876	2,345	2,815	3,286	3,756	4,226	4,697	25,813
Sub-Total	70,000	20,469	20,937	21,406	21,876	22,345	22,815	23,286	23,756	24,226	24,697	295,813
Profit (Loss)	-70,000	-12,654	-5,308	2,038	9,382	16,728	24,099	31,470	38,842	46,213	53,584	134,394

(3) Capacity 3MW (Unit: US$)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Revenue												
CER sales (US$)		3,913	7,826	11,738	15,651	19,564	23,477	27,389	31,302	35,215	39,128	215,203
Cost												
Project formulation	60,000											60,000
Registration	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	110,000
Monitroing & Verification		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000
Other		235	469	704	940	1,174	1,409	1,643	1,878	2,113	2,347	12,912
Sub-Total	70,000	20,235	20,469	20,704	20,940	21,174	21,409	21,643	21,878	22,113	22,347	282,912
Profit (Loss)	-70,000	-16,322	-12,643	-8,966	-5,289	-1,610	2,068	5,746	9,424	13,102	16,781	-67,709

b. Installation by STELCO and Private Sector (STELCO's portion)

(1) Capacity 10.79MW (Unit: US$)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Revenue												
CER sales (US$)		17,468	35,075	52,683	70,290	58,599	70,337	82,075	93,814	105,552	117,290	703,183
Cost												
Project formulation	60,000											60,000
Registration	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	110,000
Monitroing & Verification		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000
Other		1,048	2,105	3,161	4,218	3,516	4,220	4,925	5,629	6,334	7,038	42,194
Sub-Total	70,000	21,048	22,105	23,161	24,218	23,516	24,220	24,925	25,629	26,334	27,038	312,194
Profit (Loss)	-70,000	-3,580	12,970	29,522	46,072	35,083	46,117	57,150	68,185	79,218	90,252	390,989

(2) Capacity 4.8MW (Unit: US$)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Revenue												
CER sales (US$)		7,815	15,629	23,444	31,258	26,049	31,276	36,504	41,732	46,959	52,187	312,853
Cost												
Project formulation	60,000											60,000
Registration	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	110,000
Monitroing & Verification		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000
Other		469	937	1,406	1,876	1,562	1,877	2,190	2,504	2,818	3,131	18,770
Sub-Total	70,000	20,469	20,937	21,406	21,876	21,562	21,877	22,190	22,504	22,818	23,131	288,770
Profit (Loss)	-70,000	-12,654	-5,308	2,038	9,382	4,487	9,399	14,314	19,228	24,141	29,056	24,083

(3) Capacity 2.4MW (Unit: US$)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Revenue												
CER sales (US$)		3,913	7,826	11,738	15,651	13,043	15,651	18,260	20,868	23,477	26,085	156,512
Cost												
Project formulation	60,000											60,000
Registration	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	110,000
Monitroing & Verification		10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	100,000
Other		235	469	704	940	782	940	1,096	1,252	1,409	1,565	9,392
Sub-Total	70,000	20,235	20,469	20,704	20,940	20,782	20,940	21,096	21,252	21,409	21,565	279,392
Profit (Loss)	-70,000	-16,322	-12,643	-8,966	-5,289	-7,739	-5,289	-2,836	-384	2,068	4,520	-122,880

Source : Prepared by the Study Team

As for the balance for the capacity 6MW, the annual revenue will exceed the annual cost from the forth year under the both cases of installation by solely STELCO and installation by STELCO and private sector, while the cumulative balance up to 2020 is US$ 134,394 and US$ 24,083 respectively. Regarding the capacity of 3MW, the annual revenue will exceed the annual cost in 2016 under the cases of installation by solely STELCO. The cumulative cost up to 2020 exceeds the cumulative revenue by US$ 67,709. The annual revenue will exceed the annual cost in 2019 under the cases of installation by STELCO and private sector and the revenue is US$ 4,520. However, the cumulative balance up to 2034 is - 59,600 US$ even though 25 years pass from the installation of the PV system. Therefore, CDM project formulation would not be profitable under the case of 3MW.

5.6 Investment Financing Plan

As stated earlier, since privatization of STELCO is being proceeded, STELCO will not be able to receive the subsidies for making up a deficit from the government, it is not realistic for STELCO to raise funds from the financial markets under the condition where there is no supporting measures to reduce financial burden on initial investment in the grid-connected PV system. Therefore, it is necessary to provide the financial assistance by utilizing the green tax which is going to be newly introduced in 2010 as a financial source to reduce initial investment burden. Table 5.6-1 shows an investment financing plan for the Government of Maldives and STELCO on the initial investment of installation of the grid-connected PV system with the capacity of 3MW.

Table 5.6-1 Investment Financing Plan for Installation of PV System with Capacity of 3MW

a. Installation by solely STELCO

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capacity (kW)		300	300	300	300	300	300	300	300	300	300	3,000
Financial Assistance (million US$)	4.99	4.91	4.82	4.74	4.65	4.56	4.48	4.39	4.31	4.22		46.07
STELCO (million US$)	1.12	1.10	1.08	1.06	1.05	1.03	1.01	0.99	0.97	0.95		10.36
Total	6.11	6.01	5.90	5.80	5.70	5.59	5.49	5.38	5.28	5.17		56.43

b. Installation by STELCO and Private Sector (STELCO's portion)

	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total
Capacity (kW)		300	300	300	300	200	200	200	200	200	200	2,400
Financial Assistance (million US$)	5.22	5.13	5.04	4.95	3.24	3.18	3.12	3.06	3.00	2.94		38.86
STELCO (million US$)	0.90	0.88	0.87	0.85	0.56	0.55	0.54	0.53	0.52	0.51		6.70
Total	6.11	6.01	5.90	5.80	3.80	3.73	3.66	3.59	3.52	3.45		45.56

Source : Prepared by the Study Team

A partner of privatization of STELCO is expected not only to manage the existing electricity power generation and distribution system and improvement of operational efficiency but also to develop power generation facilities using renewable energy sources. In the meeting with the authorities concerned, it is identified that they expect the partner to invest in STELCO's portion of the PV system installation. Therefore, the financial contribution from the partner is assumed as financial source for the STELCO's portion in this study.

Table 5.6-2 shows the financial projection of STELCO up to 2020 for the case of installation of the grid-connected PV system with capacity of 3MW by STELCO and private sector. The deficit is large due to huge construction cost of the 4^{th} power development project in 2009 and 2010. However, the balance will become positive finally after 2012 even though the business profit tax is imposed on the profit at the maximum tax rate of 15%.

Table 5.6-2 Financial Projection of STELCO

(Unit: Million MRf)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
1. Revenue												
(1) Turnover	702	934	1,005	1,075	1,148	1,225	1,306	1,395	1,491	1,598	1,716	1,850
Total Revenue	702	934	1,005	1,075	1,148	1,225	1,306	1,395	1,491	1,598	1,716	1,850
2. Expenses												
(1) Investment	304	336	77	76	74	49	48	47	46	45	44	0
Generator	304	258	0	0	0	0	0	0	0	0	0	0
PV System	0	78	77	76	74	49	48	47	46	45	44	0
(2) Fuel	531	582	628	674	725	780	841	909	985	1,072	1,171	1,287
Diesel	523	574	619	665	714	769	829	895	971	1,056	1,154	1,268
Lube Oil	7	8	9	9	10	11	12	13	14	16	17	19
(3) Operation & Maintenance	80	86	92	99	106	113	120	129	137	147	158	171
Generator	80	86	92	99	106	113	120	128	137	147	158	171
PV System	0.0	0.0	0.0	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
(4) Replacement	0	0	0	0	0	0	0	0	0	0	0	0
(5) Administration	93	100	107	115	122	130	139	149	159	170	183	197
(6) Other Expenses	18	18	18	18	18	18	18	18	18	18	18	18
(7) Credit Cost	20	20	20	20	20	20	20	20	20	20	20	20
(8) Excess Power Purchasing	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.4	0.5	0.6	0.7	0.7
(9) Depreciation	28	47	52	57	62	65	68	71	74	77	80	80
Total Enpenses	1,072	1,189	994	1,058	1,127	1,175	1,255	1,342	1,440	1,550	1,675	1,773
Profit/Loss	-371	-255	11	17	22	51	51	53	51	47	41	77
Business profit tax (from 2010)		0	2	2	3	8	8	8	8	7	6	12
Revenue/loss after tax	-371	-255	9	14	18	43	44	45	43	40	35	65

Source : Prepared by the Study Team

Notes 1: Investment cost of Gen-set for 2009 is based on the contract amount of the 4th Power Development Project. Investment cost of Gen-set for 2010 is estimated on the basis of data of the 4th Power Development Project.

2: Replacement cost for the new investment doe not occur during this period.

3: Administration cost, other expenses and credit cost is the average figure for the last five years.

4: Depreciation is based on the STELCO's straight line method (6.67% per year).

5.7 Budget to be prepared for Execution of Each Measure

Budget necessary for execution of each measure is as follows

(1) Import Duties Exemption

Total amount of import duties to be exempted in case of the capacity 3MW : US$ 11,336,384

Import duties for 2.4MW of the STELCO's portion for Measure D : US$ 9,187,726

(2) Financial Assistance (Green Tax and Development Expenditure) and Carbon Tax

For the case of installation by STELCO and provate sector (Measure D), the financial assistance for the STELCO'S portion is as follows (see Table 5.7-1.).

Total amount of financial assistance to initial investment : US$ 38,864,237

Annual average amount (Total amount is divided by 10) : US$ 3,886,424

Annual amount from green tax : 61% of green tax revenue

Annual amount from development expenditure : 2.4% of development expenditure

<Contribution Ratio of Green Tax and Shortfall>

61% from green tax = US$ 3,886,424 ➔ No shortfall

50% from green tax = US$ 3,150,000 ➔ Shortfall US$ 736,424

30% from green tax = US$ 1,890,000 ➔ Shortfall US$ 1,996,424

0% from green tax = US$ 0 ➔ Shortfall US$ 3,886,424

<Contribution from Green Tax for Shortfall>

61% from green tax ➔ No shortfall

50% from green tax ➔ Necessary amount US$ 736,424

30% from green tax ➔ Necessary amount US$ 1,996,424

0% from green tax ➔ Necessary amount US$ 3,886,424

<Contribution from Carbon Tax for Shortfall and the Amount/kWh >

61% from green tax ➔ No shortfall

50% from green tax ➔ Necessary amount US$ 736,424 = MRf 0.003/kWh

30% from green tax ➔ Necessary amount US$ 1,996,424 = MRf 0.007/kWh

0% from green tax ➔ Necessary amount US$ 3,886,424 = MRf 0.014/kWh

Table 5.7- 1 Contribution Ratio from Green Tax and Shortfall

STELCO's portion (2.4MW) for the case of installation by STELCO and private sector	Contribution Ratio from Green Tax			
	61%	50%	30%	0%
Necessary amount (US$)	3,886,424			
Allowable amount (US$)	3,886,424	3,150,000	1,890,000	0
Shortfall (US$)	0	736,424	1,996,424	3,886,424
Ratio of shortfall to development expenditure	-	0.5%	1.2%	2.4%
Collection of shortfall from carbon tax (MRf/kWh) (for 10 years)	-	0.003	0.007	0.014

Source : Prepared by the Study Team

(3) Amount to be paid by STELCO for Excess Power Purchasing

Conditions of excess power purchasing by STELCO, purchased amount and purchasing price are as follows.

Assumptions:

- The amount of excess power purchasing is 20 percent.
- Purchasing price is MRf 3/kWh, which is equivalent to the unit production cost.

Total purchased power (from 2015 to 2020) : 1,088,505kWh

Necessary budget for purchasing (from 2015 to 2020) : US$ 250,356

CHAPTER 6 DETAILED DESIGN OF THE PILOT PROJECT

6.1 Examination and Selection of Pilot Project sites

Comparative examination was carried out according to the "Evaluation of potential sites in Male' Island and Hulhumale' Island" at the beginning of the report on the 14 potential sites that were selected in Chapter 4.4, and the sites were ranked in the order of priority. 6 out of 14 sites were selected as pilot project sites after being ranked highly according to the following criteria. Table 6.1-2 shows the reasons behind the selection of the pilot project sites, Figure 6.1-1 shows the location map of the sites.

Table 6.1-1 Selection Criteria of Pilot Project sites

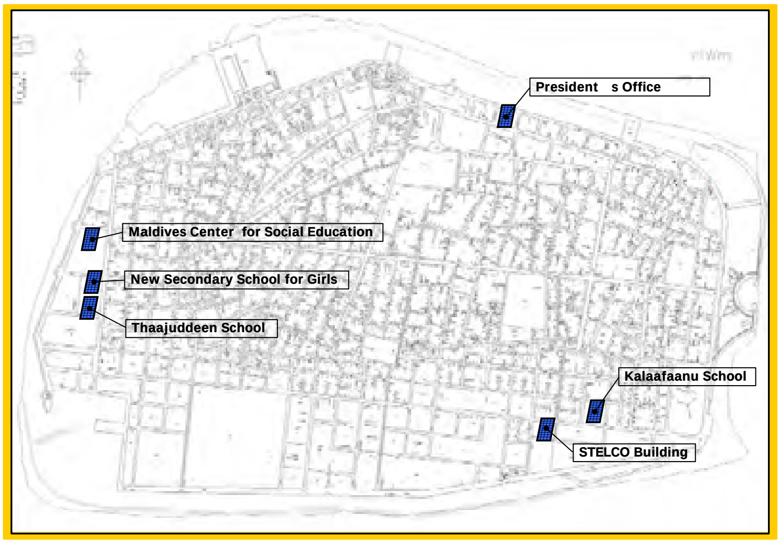
①	PV system capacity is relatively large.
②	Can be a model case for other potential sites.
③	Engineers or technicians who can appropriately implement PV system maintenance can be secured.
④	Reliability of the distribution system is not extremely low.
⑤	PR effect is large and access to the facilities is easy.

Source： Prepared by the Study Team

Table 6.1-2 Pilot Project Sites

No	Site	Output Capacity (kWp)	Reasons for Selection
1	STELCO Building	45 kWp	It satisfies selection criteria ②, ③, ④ and ⑤; there are no solar irradiation obstructions, and it is easy to establish a maintenance setup using the company employees.
2	Kalaafaanu School	85 kWp	It satisfies selection criteria ①, ②, ③ and ⑤, and it is easy to establish a maintenance setup because of proximity to STELCO. Moreover, being a school that was constructed under Japanese grant aid, As-built documents are available, making it easy to plan renovations and reinforcement. Also, the structural strength is deemed to be reliable.
3	Maldives Center for Social Education	100 kWp	It satisfies all the selection criteria. In particular, since sports events and so on are staged here, it will have a high PR effect. Moreover, being a school that was constructed under Japanese grant aid, As-built documents are available, making it easy to plan renovations and reinforcement. Also, the structural strength is deemed to be reliable.
4	Thaajuddeen School	130 kWp	It satisfies selection criteria ①, ②, ④ and ⑤ and has the largest PV output of the six sites. Moreover, being a school that was constructed under Japanese grant aid, As-built documents are available, making it easy to plan renovations and reinforcement. Also, the structural strength is deemed to be reliable.
5	New Secondary School for Girls	100 kWp	It satisfies selection criteria ①, ②, ④ and ⑤, and since it is located adjacent to Site No. 3, it will have a high PR effect. Moreover, being a school that was constructed under Japanese grant aid, As-built documents are available, making it easy to plan renovations and reinforcement. Also, the structural strength is deemed to be reliable.
6	President's Office	20 kWp	It satisfies selection criteria ②, ③, ④ and ⑤, and it is easy to establish a maintenance setup because the facility has its own maintenance staff. Also, installation a PV system in the presidential office will have a high PR effect.

Source： Prepared by the Study Team

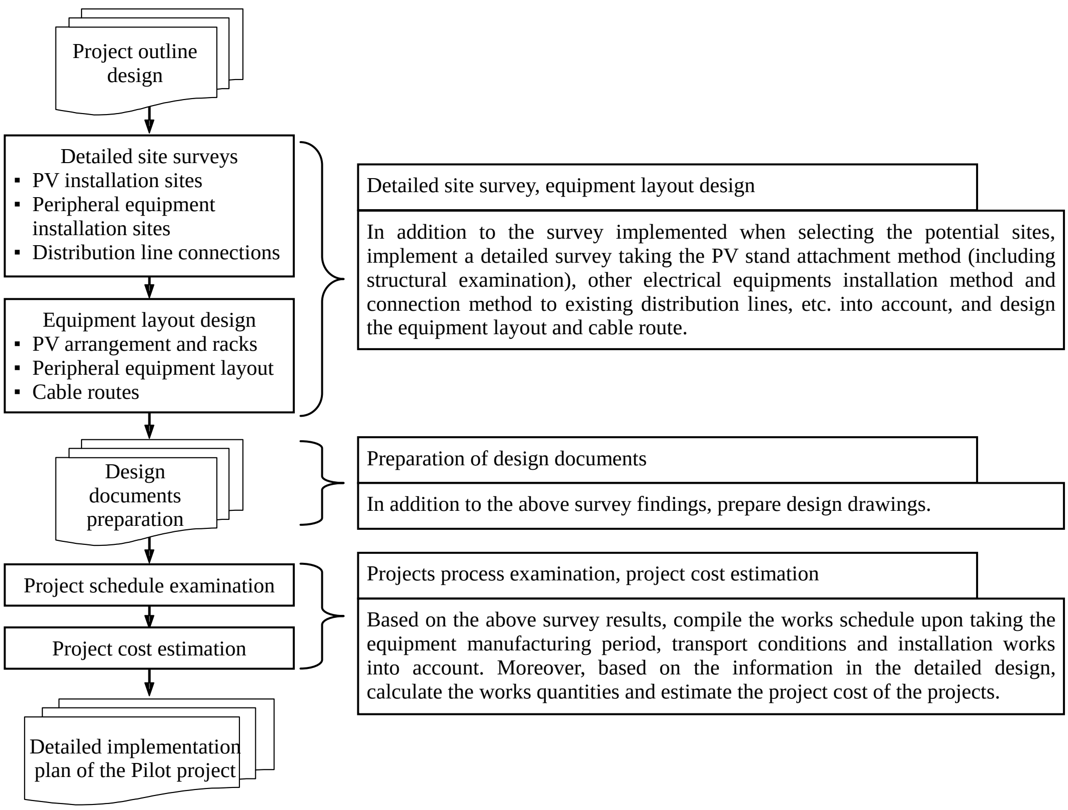


Source： Prepared by the Study Team

Figure 6.1-1 Map of the Pilot Project Sites

6.2 Detailed Design Procedure for the Pilot Project Sites

In conducting detailed design of pilot project sites, the detailed site surveys, the detailed specifications examination of equipment, equipment layout design and preparation of design documents, etc. will be carried out according to the following procedure.



Source： Prepared by the Study Team

Figure 6.2-1 Detailed Design Procedure of the Pilot project

6.3 Detailed design of Structure reinforcement

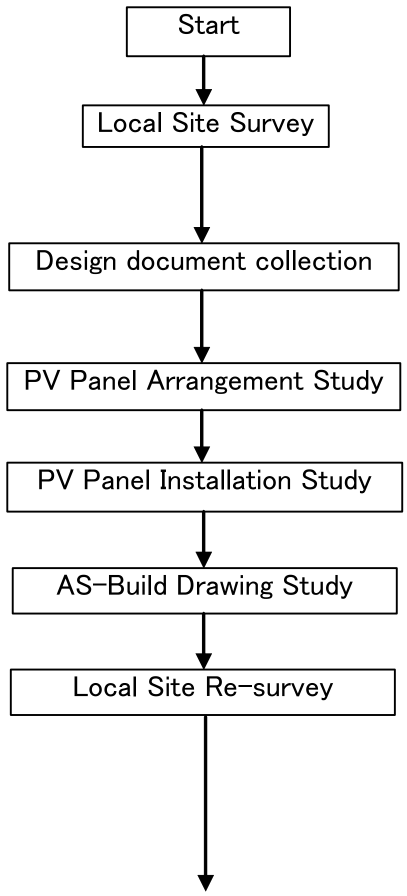
About the potential sites decide by the 1st and 2nd survey, Frame type and member section was an clear for field survey and AS-BUILD drawings. The safety of the these structure were confirmed with the Japanese standard, when the solar panels were installed on the building roof or roof floor. Reinforcement detail design is done if necessary. Solar panel weights is 0.35kN/m^2 (include base channel weight). As for the specification of the main member, by the next.

Concrete design strength : 21N/mm2

Reinforcing bar :JIS SD345

Steel :JIS SS400

Working flowchart which affects details design is shown in the following.



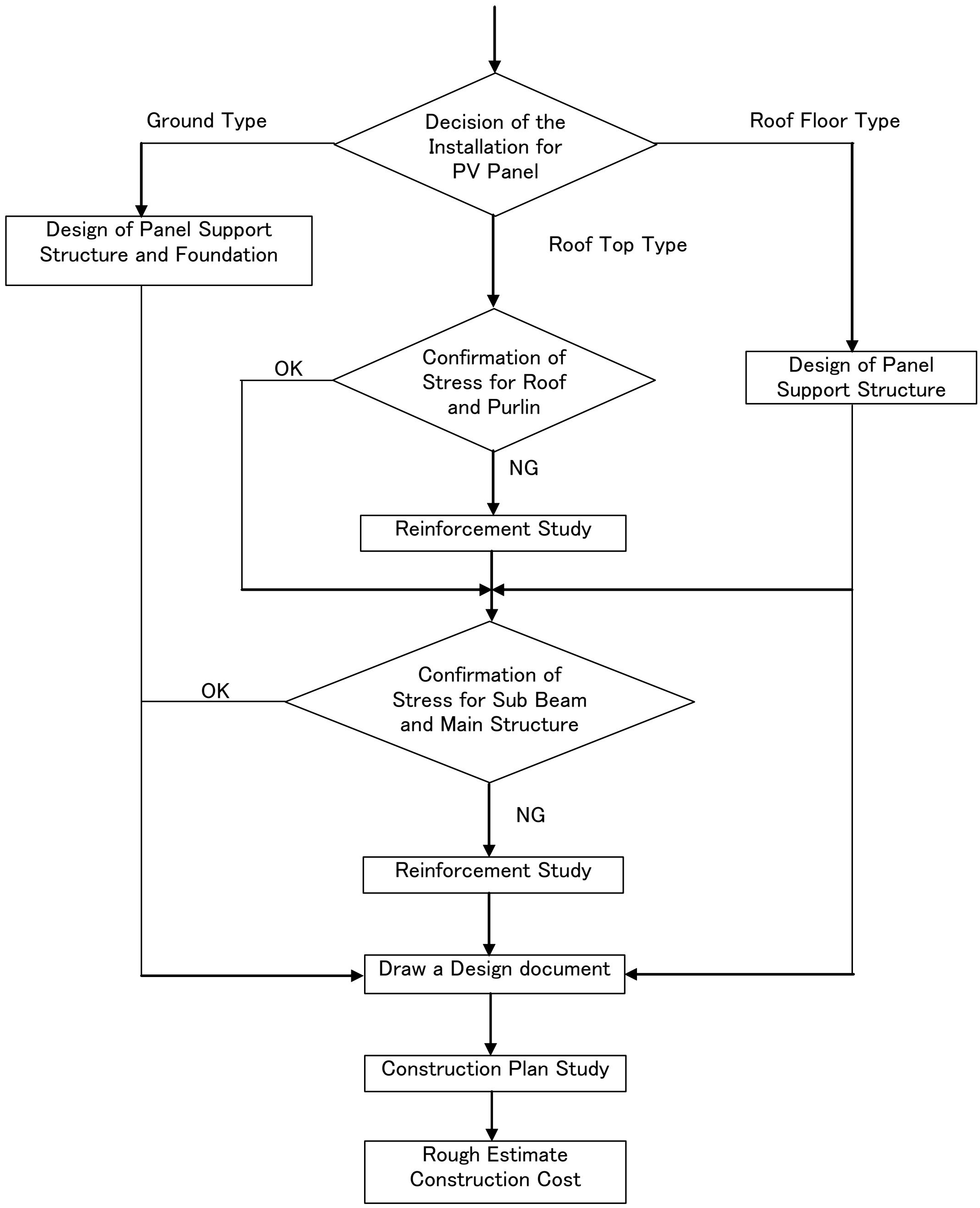


Figure 6.3-1 Working flowchart which affects details design

Table 6.3-1 Detail examination result for Building in the Pilot Project Sites

Site Name	AS-Build Drawing, Completed year	Support Type	Surface Condition	Contents of Repair and Reinforcement	Examination Result for Main Structure
STELCO Building	Ready,2000	Roof Floor	Some of the Tile come off	Construction of Panel Support Structure, Footing, and waterproofing	No problem
Kalaafaanu School	Ready,1989	Roof top	Bad Roofing	Exchange of the roof material	No problem
Maldives Center for Social Education	Ready,1992	Roof top	Depleted Roofing for age passes	Exchange of the roof material	No problem
Thaajuddeen School	Ready,2004	Roof top	No problem	Coating improvement of roof （Prevention of deterioration）	No problem
New Secondary School for Girls	Ready,2009	Roof top	No problem	Unnecessary	No problem
President's office	Ready,2002	Roof top	No problem	Coating improvement of roof （Prevention of deterioration）	No problem

As it is shown in the above table, the reinforcement of Main Structure is unnecessary in all site. However, completed year was not same in each building, and there was the deterioration of the roof material. So, It was decided that each building replaced all the roof materials. (Kalaafaanu School, Maldives Center for Social Education) Then, the roof of the Thaajuddeen School and the President's Office does coating improvement.

6.4 Technical Transfer of the Detailed Design Technique

6.4.1 Concept of the Technical Transfer for Detailed Design

Since the goal of the technical transfer for detailed design is to enable employees of MHTE and STELCO to understand the detailed design procedure of as described in 6.2, work was divided according to the technical level of each staff member and the technical transfer was conducted while jointly implementing the practical duties and field surveys.

6.4.2 Contents of the Technical Transfer for Detailed Design

The Study Team implemented technical transfer of the following field survey items and results analysis methods through the detailed design process.

(1) Information collection (acquisition of basic data)
(Existing design documents, existing distribution network drawings, solar radiation data, etc.)
(2) Field survey method
(Identification of connection parts, examination of solar radiation obstructions, confirmation of existing electricity rooms, etc., and examination of cable routes, etc.)
(3) Analysis of field survey findings
(Examination of panel arrangement, PV output, equipment arrangement, cable routes, etc.)
(4) Summarization of survey results
(Compilation of the technical specifications)

6.4.3 Report of the Technical Transfer for Detailed Design

(1) Information Collection

The Study Team offered the guidance to the counterparts on the method for collecting the minimum basic information required for advancing the field surveys and detailed design of the grid-connected PV systems, and the Study Team and counterparts jointly implemented the information collection work. The following photograph shows the data logger being attached for collecting solar irradiation data on Hulhumale' Island.

(2) Field Survey Method

The Study Team formed a working group with the staff of the MHTE and STELCO and jointly implemented the detailed study and design of the 45 kWp grid-connected PV system planned on the STELCO Company building. The planned cable rough drawings for this building and similar data, the field survey methods (equipment layout, cable routes, etc.) were conducted and the data needed for detailed design were collected.

STELCO Lecture and Survey Conditions at the STELCO Building

(3) Analysis of Field Survey Results

The results obtained from the above survey, the counterparts prepared the PV layout and structural drawings, and the Study Team assisted in calculating the work quantities from those drawings and finishing the work in a joint effort.

Guidance on Preparation of PV Panel Layout Drawing using CAD Software

Furthermore, in order to improve the understanding regarding operation and maintenance of the grid-connected PV system in addition to planning and design, the Study Team conducted guidance on operation and maintenance technology utilizing the PV and DEG hybrid system on Mandau Island and the grid-connected PV system on Lahm Atoll.

6.5 Beneficial Effects of Grid-Connected PV System Introduction

6.5.1 Estimated PV Power Generation

The annual power generation on each pilot project site was estimated by the following formula:

$$Ep = \Sigma H_A / Gs * K * P$$

Where, Ep = Estimated annual PV power generation (kWh/year)

H_A = Monthly average insolation at location (kWh/m^2/day)

Gs = Irradiance @ STC (Standard Testing Condition) (kW/m^2) = 1 (kW/m^2)

K = Loss coefficient = Kd * Kt * η_{INV}*ηTR

* PV loss coefficient Kd: Dirt on solar surface, loss caused by irradiance fluctuation, difference of PV characteristics. Usually 0.8.
* Temperature correction coefficient Kt : Correction coefficient to consider the change of PV efficiency by heat.

  Kt = 1 + α (Tm - 25) / 100

  Where,

  α: Peak output temperature coefficient (%・℃$^{-1}$) = - 0.5 (%-℃$^{-1}$) [Crystalline Silicon]

  Tm: Module temperature (℃) = Tav + ΔT

  Tav: Monthly average temperature (℃)

  ΔT: Module temperature increase (℃)

Open rear type	18.4
Roof installed type	21.5

* Inverter efficiency ηINV : Inverter efficiency: Usually 0.95
* Transformer efficiency ηTR : Transformer efficiency: set at 0.98 here considering that on-load and off-load loss are constant

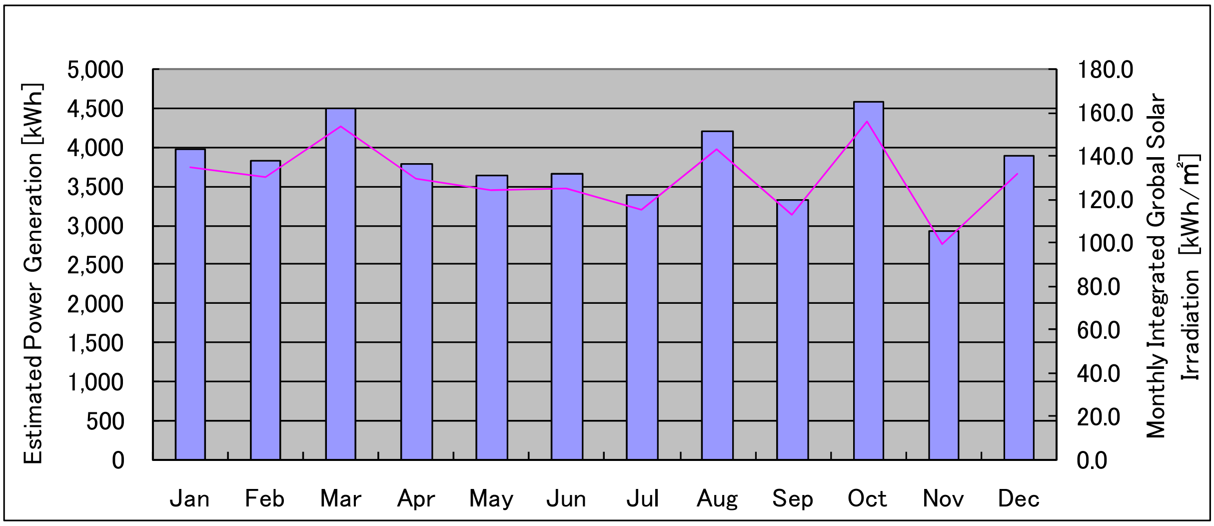
Σ indicates the integrated value of estimated power generation for each month.

For simplification, the horizontal surface amount of solar radiation was adopted when calculating the monthly average amount of solar radiation on the installed surface, and the impacts of obstructions discussed in 4.3 were taken into account. Concerning the impact of shade, this is conventionally examined upon considering the direct connection of PV modules, however, for the sake of simplification, in cases where roofs contain partial solar radiation obstructions; conservative values were calculated assuming the whole roof to be affected.

Table 6.5.1-1 Annual PV Power Generation at Each Pilot Project Site

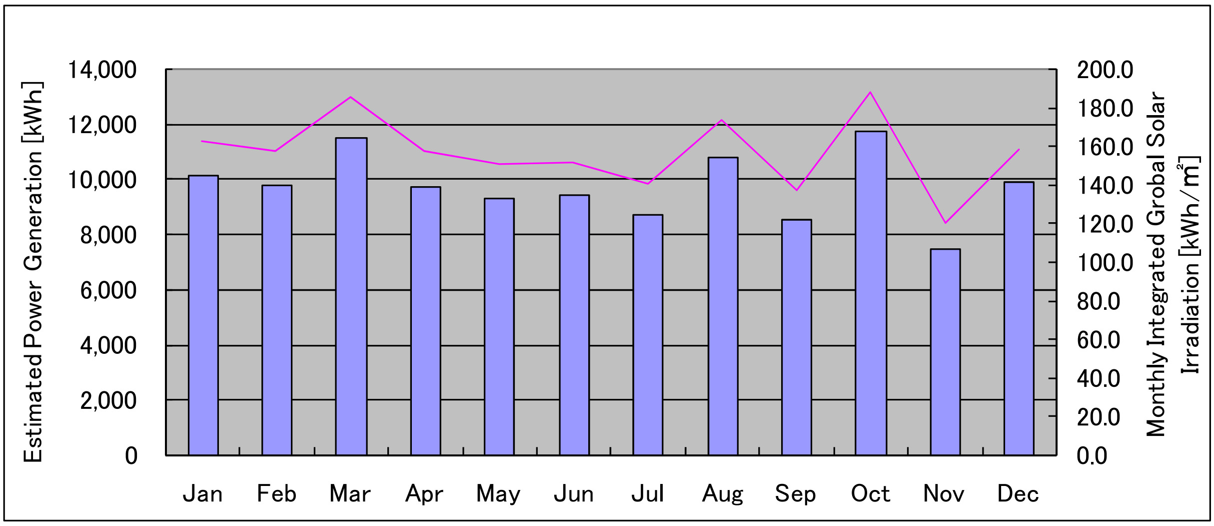
Island	Site Name	PV Capacity [kWp]	Annual Power Generation [kWh/year]
Male'	STELCO Building	45	45,739
	Kalaafaanu School	85	117,069
	Maldives Center for Education	100	120,945
	Thaajuddeen School	130	157,228
	New Secondary School for Girls	100	90,778
	President's Office	20	24,189
	Total	480	555,948

Source :Prepared by the Study Team



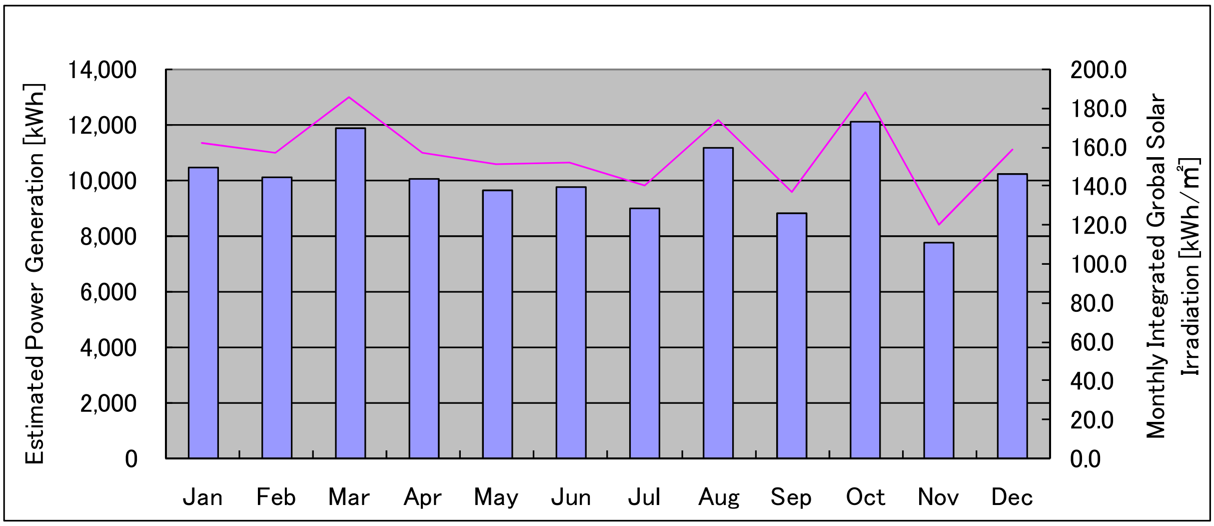
Source : Prepared by the Study Team

Figure 6.5.1-1 Estimated Monthly PV Power Generation (STELCO Building)



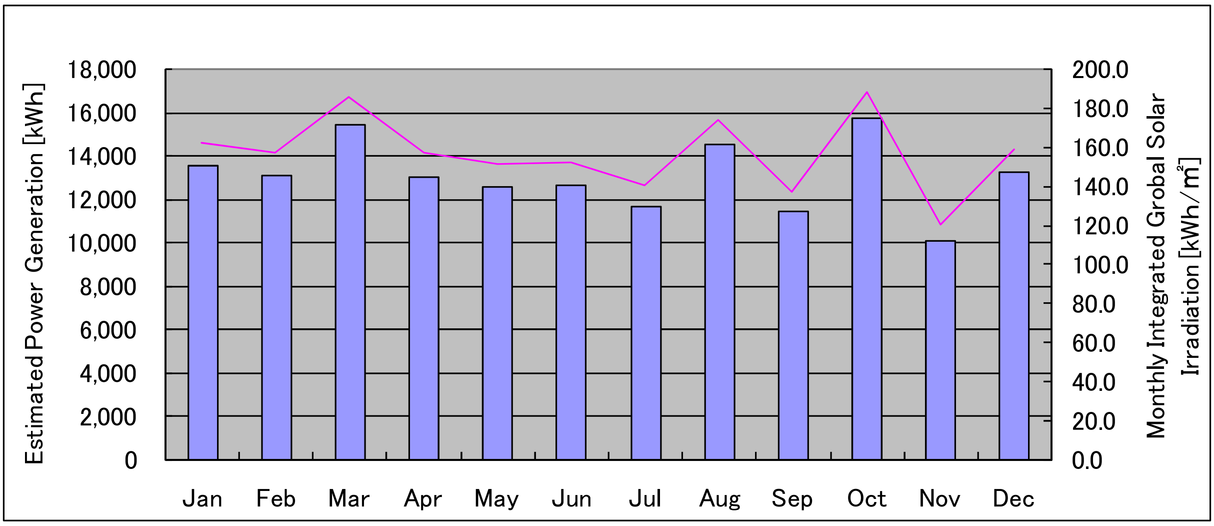
Source : Prepared by the Study Team

Figure 6.5.1-2 Estimated Monthly PV Power Generation (Kalaafaanu School)



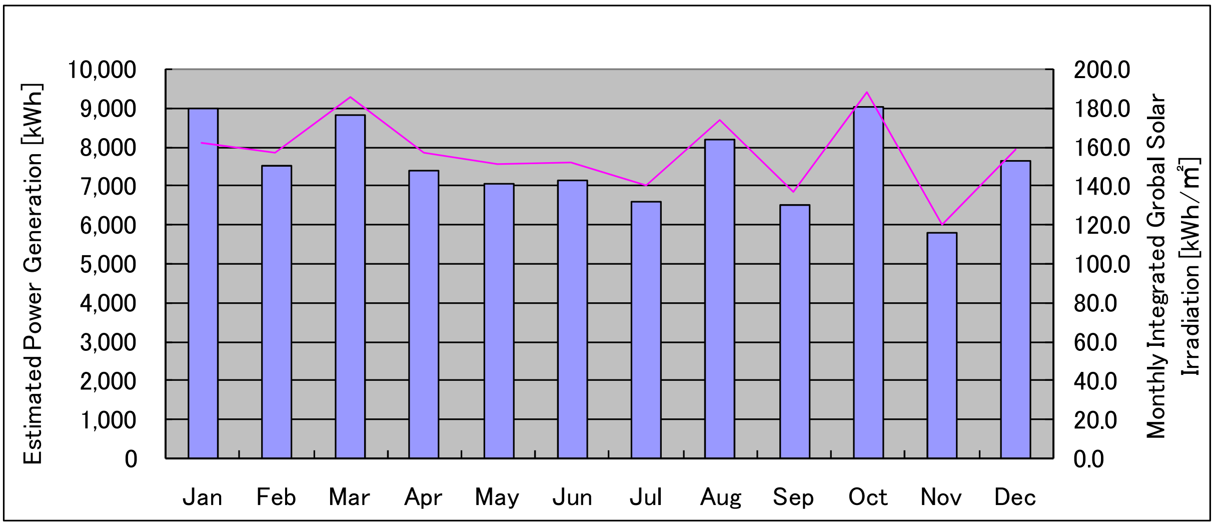
Source： Prepared by the Study Team

Figure 6.5.1-3 Estimated Monthly PV Power Generation (Maldives Center for Social Education)



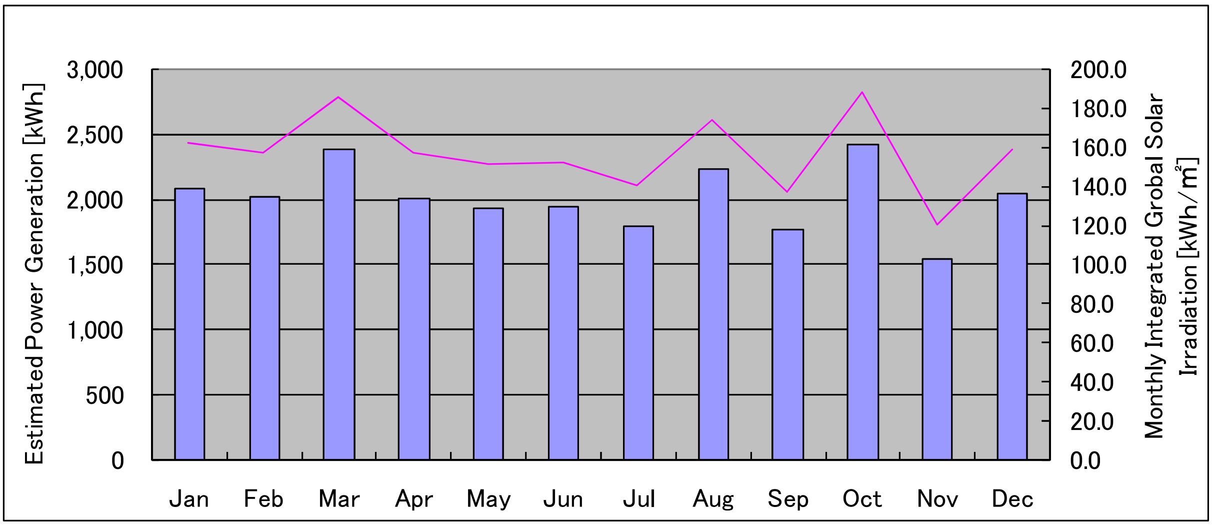
Source： Prepared by the Study Team

Figure 6.5.1-4 Estimated Monthly PV Power Generation (Thaajuddeen School)



Source： Prepared by the Study Team

Figure 6.5.1-5 Estimated Monthly Power Generation (New Secondary School for Girls)



Source： Prepared by the Study Team

Figure 6.5.1-6 Estimated Monthly PV Power Generation (President's Office)

Assuming that the installation of grid-connected PV systems to the pilot project sites on Male' Island is completed by 2011, the cumulative power generation will be as follows:

Cumulative power generation by 2020 = Pilot project of total annual PV Power generation x 10 years
= 555,948 kWh x 10
= 5,559,480 kWh

6.5.2 Saving on Diesel Fuel Consumption

Using the same technique as described in 4.11.2, the effect in terms of diesel fuel consumption saving was calculated. By using the fuel consumption coefficient on Male' Island of 0.26 [liter/kWh], the annual diesel fuel saving works out as follows:

Annual diesel fuel saving = Annual PV Power Generation on pilot project sites x 0.26
= 555,948 kWh x 0.26 liter/kWh
= 144,546 liter

Accordingly, the cumulative saving on diesel fuel consumption over than 10 years to 2020 are 1,445,460 liters.

6.5.3 CO_2 Emission Reductions

Based on the diesel fuel savings as calculated in 6.5.2, the following coefficient was used to calculate the amount of CO_2 emission reductions

CO_2 reduction [kg] = Light oil CO_2 emission coefficient* x Diesel fuel saving

= 2.62 [kg-CO_2/liter] x Diesel fuel saving [liter]

* Concerning to the emission coefficient, the Total Emissions Calculation Method Guidelines of the Ministry of Environment were quoted.

As a result, it is estimated that the annual CO_2 emission reductions at the pilot project sites are 379 tons, and that the total CO_2 emission reductions over than 10 years up to 2020 are 3,790 tons.

CHAPTER 7 EXAMINATION OF VALUE ADDED MEASURES

7.1 Examination and Recommendation of Measures for Education and Promotion of DSM (Peak Power Limitation and Energy Saving, etc.)

The demand for electricity is increasingly rapidly at an average of 11~15% per year on Male' Island and 50% per year on Hulhumale' Island, and the daily load curve has a sharp peak due to the recent spread of office equipment and air conditioners (hereinafter as "ACs") and the further increase in maximum demand. Meanwhile, the development of new power sources and so on for meeting the demand is becoming extremely difficult due to the land constraints, etc. Moreover, since PV power generation greatly depends on the weather, it cannot directly contribute to reducing the capacity of DEGs. Accordingly, for a country such as the Maldives, it is vital not only to introduce PV power generation, but also to practice the Demand Side Management (hereinafter as "DSM") geared to limit the peak output.

The examination here aims to determine the appropriate DSM techniques for the Maldives based on the previously implemented SMILE project combined with the techniques used in Japan, Europe and the US, to analyze the issues and the effects that can be expected from applying such techniques, and to propose the DSM from the medium to long-term viewpoint on Male' Island and Hulhumale' Island.

7.1.1 Current Conditions of DSM in the Maldives

The Study Team ascertained the contents of the Strengthening Maldivian Initiative for a Long-term Strategy (SMILE) project that was implemented by the former Ministry of Communication, Science & Technology (MCST), the French Agency for the Environment and Energy Management (ADEME) and the Utrecht Centre for Energy Research (UCE) of the Netherlands. This project was mainly implemented mainly with respect to the following three items:

- Examination of measures to control the rapid growth of electricity demand on Male' Island
- Examination of the renewable energy use potential on outlying islands
- Recommendations concerning the improvement of the public transportation on Male' Island

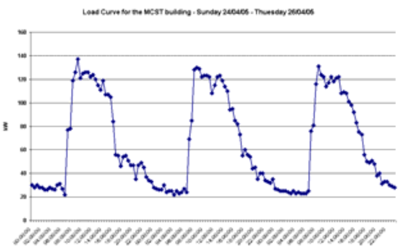
Concerning the first item, i.e. examination of measures to control the rapid growth of the electricity demand on Male' Island, the study was implemented on the actual state of power demand in major buildings and 27 households. As a result of this, it was found that ACs are the main element of the power demand, that peak demand occurs around 07:00 and coincides with the start of the morning rush hour, and that a uniform level of demand is sustained until the end of the working day.

Accordingly, the study focused on the steps to limit the demand by ACs and recommended the concrete techniques for that purpose.

This study, jointly implemented by STELCO and the MSCT, targeted 27 households and primary commercial and public facilities, and it investigated conditions of ownership and use of electrical equipment. The findings regarding ordinary households on Male' Island were as follows:

- Electrical appliance ownership in general households is on the same level as in Europe: households on average own a washing machine, refrigerator, TV and DVD player, etc.
- Electrical appliances are extremely new, indicating better lifestyles and improving products on markets in recent years.
- However, it is rare for ordinary households to own air conditioners.

Meanwhile, survey of commercial and public facilities (STELCO, Port Authority, Bank of Maldives and MCST) showed that air conditioners are used from 07:00 and a uniform level of power consumption is maintained during working hours.



Source： SMILE Project

Fig. 7.1.1-1 Results of Power Consumption Survey in 27 Households and Commercial and Public Facilities in the SMILE Project

Moreover, STELCO itself is working on the steps to educate people about DSM, and its major activities in this area are as follows. However, it has had to suspend activities since 2006 because of the deterioration in its financial situation. It hopes to resume these measures at some point, however, there is no immediate prospect due to the difficulty in raising funds.

<Main DSM enlightenment activities by STELCO>

- Placing of the DSM posters at key points (government buildings, hospitals, schools, trunk roads, etc.) through Male' City
- Staging of the DSM events and distributing of the DSM posters and stickers on artificial beaches
- Broadcasting of the commercials geared to promote the DSM on TV
- Implementing the DSM lectures by STELCO employees at schools

Source: STELCO

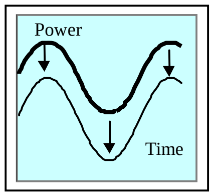
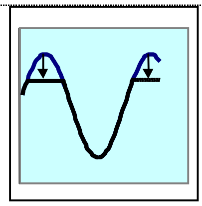
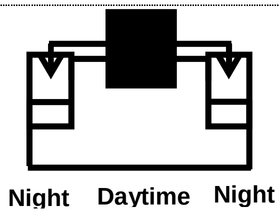
Fig. 7.1.1-2 DSM Education Poster

7.1.2 DSM Techniques Appropriate to the Maldives

(1) Analysis of DSM Techniques

The DSM techniques aim to form efficient and desirable supply and demand relationship by controlling the demand through the approaches to the consumers. Electric power company can realize postpone constructing new power plants, energy saving and reduction of the environmental burden by implement of energy efficiency and load leveling. Consumers also can reduce the expenditure for electricity by the installation of the electric equipment with high energy saving effect and the adjustment of time zone to utilize electricity. Table 7.1.2-1 summarizes the DSM techniques by its types.

Table 7.1.2-1 Purpose of DSM Techniques

	Type	Method	Image
①	Reduction of power consumption	Reducing actual power consumption through using high efficiency technology on refrigerators and TVs, etc.	
②	Reduction of peak load	Prohibiting use of washing machines and air conditioners, etc. at times of peak power consumption; and using low power consuming technology to reduce peak load	
③	Shifting of peak load	Shifting the peak power consumption time frame by adopting time-based electricity tariffs and seasonal tariffs	

Source： Prepared by the Study Team

(2) Examination of Concrete DSM Techniques (Supply Side and Demand Side) appropriate to Male' Island and Hulhumale' Island

Electricity demand seems to grow dramatically in Male' and Hulhumare' Island in the future, it is necessary to construct an ideal structure of the electricity consumption from the view point of the effectiveness of utilization of the power system by implementing the DSM shown in Table 7.1.2-1 comprehensively and effectively. Among them, to cover the future electricity demand by utilizing electricity in the night time, in the other words, ③Shifting of peak load in Table 7.1.2-1 can be said as the desirable load curve especially in Male island which has the difficulty in developing of new power sources due to the land constraints. Because this load curve can improve the load rate and the utilization rate of power generators and postpone the life time of power generators. The different DSM techniques are desirable for Male' and Hulhumare', because Male' and Hulhumare' Island have the difference in the situation of the demand and supply of electricity. However, we summarize the appropriate DSM techniques by focusing on not only Male' and Hulhumare' Island but also 7 provinces, here. Because now the new governmental manifest concept which divides the all land in the Maldives into 7 provinces is moving ahead step by step and the legal systems which regulate these provinces complementary are also being arranged step by step. In addition, the resort islands are not taken into this consideration here, because they are outside the government's jurisdiction at present.

Concerning the tight budget of the government and the tight man power in the Maldives, the appropriate DSM techniques are shown in Table 7.1.2-2.

Table 7.1.2-2 Examples of Concrete DSM Techniques (Supply Side and Demand Side) Appropriate to the Maldives

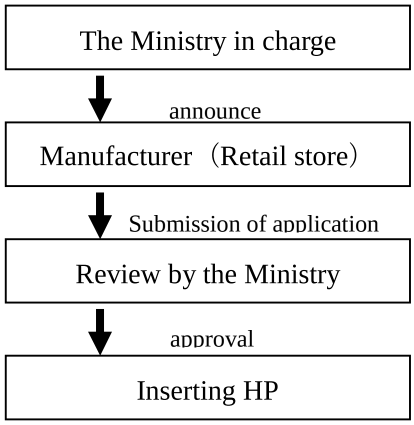
DSM Techniques		Implementer
Enlightenment Activities	・Introduction of Official recommended electric appliance	MHTE
Inserting in Compliance Document in Building Code	・Construction of building with High heat insulating effect ・Design of proper AC system, Air ventilation system and Lighting system	MEA
Revision of Building Code	・Obligation of Introduction of Official Authorized electric appliance	MEA
Introduction of Energy managers	・Implementation of Regular energy audit	MHTE Utility Co.
Construction of Energy Conservation Act	・Obligation of Introduction of 1 Energy managers in each Utility company, if necessary ・Obligation of Regular energy audit by Energy managers in each province ・Setting of standard value of Energy saving ・Introduction of Energy saving Grading	MHTE MEA
Addition of Type of Electric tariff	・Introduction of Basic rate according to Demand ・Introduction of Time of Using of Electricity	MEA Utility Co.

Source： Prepared by the Study Team

①Enlightenment Activities

Introduction of Official recommended electric appliance is proposed as the concrete strategy, here. This tries to enlighten DSM techniques by inserting official recommended electric appliances which the Ministry in charge of energy saving recommends on HP of that Ministry. Recommendation points, Energy saving effect and cost and so on with the energy labels also are inserted on the HP with the introduction of the official recommended electric appliances. They will contribute to enhance the enlightenment activities of the DSM through the HP. Regarding the selection way of the official recommended electric appliances, the Ministry in charge of the energy saving will announce the manufacturers or the retail stores to submit the applications which describe the recommended electric appliances, their effect of the saving energy and their costs, etc. and review the applications.

In the future, “Recommended” will be changed to “Authorized” at the time of the revision of the building code and the building code will obligate to install them when the new-building and the reconstruction of the public building



Source： Prepared by the Study Team

Fig. 7.1.2-1　Steps for inserting HP

②Inserting in Compliance Document in Building Code

Although this will be explained in 7.1.3 Legal Systems in detail, Revision of Building code including the construction of buildings with the high insulating effect, etc. is proposed, here. The revision of the building code can improve the efficiency of the operation of the electric appliances inside the building. It can contribute to mitigate the total energy consumption inside the building and peak load. Therefore, it can contribute to mitigate the rapid growth of the electricity demand and supply in Male’ island and Hulhumale’ island.

Although the building code has already been established in August 2008 in the Maldives, the compliance documents which describe the details are being made by July 2010. The ministry or the department in charge of issuing the compliance documents is described in the building code, and the Ministry in charge of these items (“Construction of building with High heat insulating effect” and “Design of proper AC system, Air ventilation system and Lighting system”) in Table 7.1.2-2 is MEA.（G8:Artificial light, H1:Energy Efficiency in the building code are corresponded to “Construction of building with High heat insulating effect” and “Design of proper AC system, Air ventilation system and Lighting system”）Therefore, we proposed to insert “Construction of building with High heat insulating effect” and “Design of proper AC system, Air ventilation system and Lighting system” into the compliance documents which are being made now.

③Revision of Building Code

“Obligation of Introduction of Official Authorized electric appliance” is proposed here as concrete strategy. As ①Enlightenment Activities has already described, this is mandate for “Introduction of Official Authorized electric appliance” when the new-building and the reconstruction of the public building by changing “Recommended” to “Authorized.” A few years will be necessary to collect the data and analyze them for changing “Recommended” to “Authorized”, therefore, “Revision of Building code” is estimated to be conducted in approximately 5 years.

④Introduction of Energy managers

“Energy managers” are the persons who implement the regular energy audit. The regular energy audit is the audit which can contribute to improve the efficiency of the energy use in the target facilities. The concrete contents of the energy audit are to check the temperature and the maintenance situation of the air conditioners, to introduce the government recommended/authorized electric appliances and the successful examples of the DSM, etc. It is desirable in our proposal that the energy audit is not the enforced style such as the inspection but is the acceptant style for the customers such as the diagnosis which can contribute to reduce the electric tariff.

The qualified system for the energy managers such as Japanese style does not exist in the Maldives and there are few engineers who have the knowledge of energy in the Maldives. Therefore, on the early step of “Introduction of Energy managers”, STELCO will introduce 2 persons as the energy managers and they will implement the trial energy audit in Male’ and Hulhumale’ island for the training of acquiring basic knowledge.

On the next step, by evaluating the result of the trial and by considering the necessity of the regular energy audit and the necessary cost, “Construction of Energy Conservation Act” will obligate to introduce 1 energy manager into each utility company in 7 provinces, if necessary and will be responsible for the main buildings which have more load than the standard in each province to implement the regular energy audit. Accordingly, 2 persons in STELCO, 1 person in each utility company except STELCO and 1 person in the Ministry in charge of energy saving will be introduced as the energy managers in the future. And the energy managers will be obligated to submit the annual report for their activities to the energy manager in the Ministry.

Although the setting of the standard value of the energy saving also is proposed together in “Construction of Energy Conservation Act”, the standard value will be set based on the analysis of the data which will be collected by the regular energy audit.

⑤Construction of Energy Conservation Act

As being explained in ④Introduction of Energy managers is proposed here, which will obligate to introduce 1 energy manager into each utility company in 7 provinces, if necessary and will be responsible for the main buildings which have more load than the standard in each province to implement the regular energy audit by evaluating the result of the trial energy audit in Male' and Hulhumale' island and by considering the necessity of the regular energy audit and the necessary cost. And the standard value of the energy saving also will be set in this Energy Conservation Act (e.g.; within 300W/m2 of the energy consumption for a large factory). In addition, the grading will be implemented according to the efficient rate compared with the standard value to enhance the voluntary effort for environment. (e.g.; 5 –star rank will be given to the building which has the energy saving rate more than half of the standard value). On the other hand, the setting of the penalty against the building which has the energy saving rate more than the standard value will be the effective measure.

⑥Addition of Types of Electric tariff

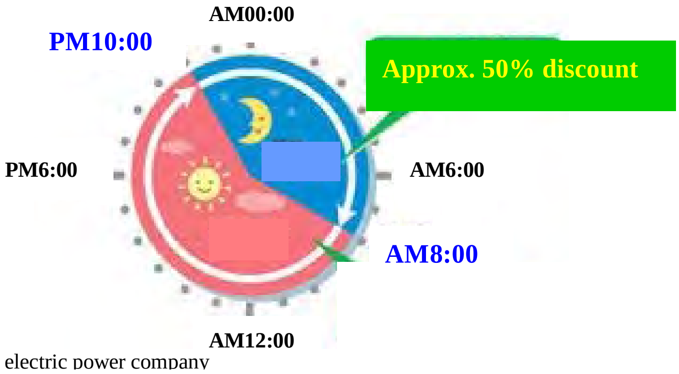
Here, "Introduction of Basic rate according to Demand" and "Introduction of Time of Using of Electricity" are proposed. The feature and effect of each electric tariff is as follows.

⑥-1 Introduction of Basic rate according to Demand

Although the present electric tariff in the Maldives is composed of only specific tariffs, "Basic rate according to Demand" is to conclude the demand contract according to the capacity of the electric facilities between customers and an electric power company, the basic rate is imposed according to the electricity demand (contract demand). This contract decides the power which a contractor can utilize at one time between a contractor and an electric company in advance and can contribute to control the electric demand by an electric power company. This electric tariff had been introduced in Japan from early on, and it can contribute for electric companies to control the electric demand in Japan. The suitable introduction of this electric tariff in Male' island and Hulhumale' island is to target the main commercial and public facilities, to install the demand meters into them and to impose the electric tariff according to the demand by applying the basic rate. Therefore, this electric tariff can be said the effective DSM in Male' island and Hulhumale' island for little burden to the cost and the man power, although there are a few items (e.g.; setting price of the basic rate) to be considered.

⑥-2 Introduction of Time of Using of Electricity

This sets the different electric tariff according to the time zone of using electricity. The electricity tariff is approx. 2.2 MRf/kWh in the daytime and approx. 1.1MRf/kWh in the night time in Japan.



Source：Shikoku electric power company

Fig. 7.1.2- 2 Example of Shikoku Electric Power Company

As Fig. 7.1.2-1 shows, the different electricity tariff between the daytime and the night time can enhance the using-time change of the electric appliances (ex; refrigerators and irons, etc.) from the daytime to the night time. In Japan, the shifting of peak load to the night time has been achieved on some level by the introduction of Time of Using of Electricity. This electricity tariff also can be said the effective DSM in Male' island and Hulhumale' island for little burden to the cost and the man power, although there also are the items to be considered shown in Table 7.1.2-3.

Table 7.1.2- 3 The items to be considered regarding Introduction of Time of Using of Electricity

Items	Concrete contents
Setting of Electric tariff	Increasing the electric tariff in the daytime or decreasing the electric tariff in the night time
	Increasing the electric tariff in the daytime slightly and decreasing the electric tariff in the night time
	How much the difference in the electric tariff between in the daytime and in the night time is set
Application range	Applying this electric tariff to only installer who introduce the electric facilities (ex; thermal storage AC system) that can utilize the Time of Using of Electricity effectively or to all of customers

Source ：Prepared by the Study Team

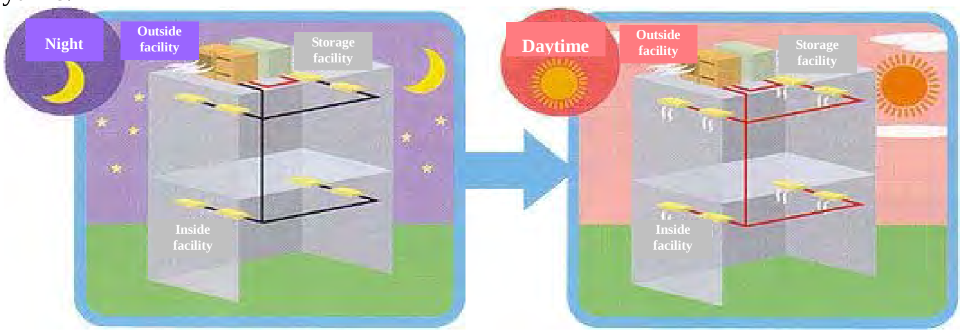
⑥-3 Introduction of Thermal storage AC system which can utilize Electricity tariff menu

In Japan, the introduction of the thermal storage AC system has been carried out on as the certain measure for shifting the peak load from the daytime to the night time by utilizing the time of using of electricity, because the shifting the peak load from the daytime to the night time depends on the lifestyle of the customer. This thermal storage AC system is necessary to improve the power consumption in the daytime by utilizing the electricity in the night time to storage the heat energy or to make ices and this can mitigate the power consumption in the daytime. This thermal storage AC system can be said the effective DSM, because the daily load curve has the daytime peak in Male' island and Hulhumale' island

and approx. 50% of it is AC system load in the commercial and public facilities. And this thermal storage AC system can contribute to mitigate the capacity of AC system and can utilizes the basic rate according to the demand effectively.

⑥-3-1 Thermal storage AC system

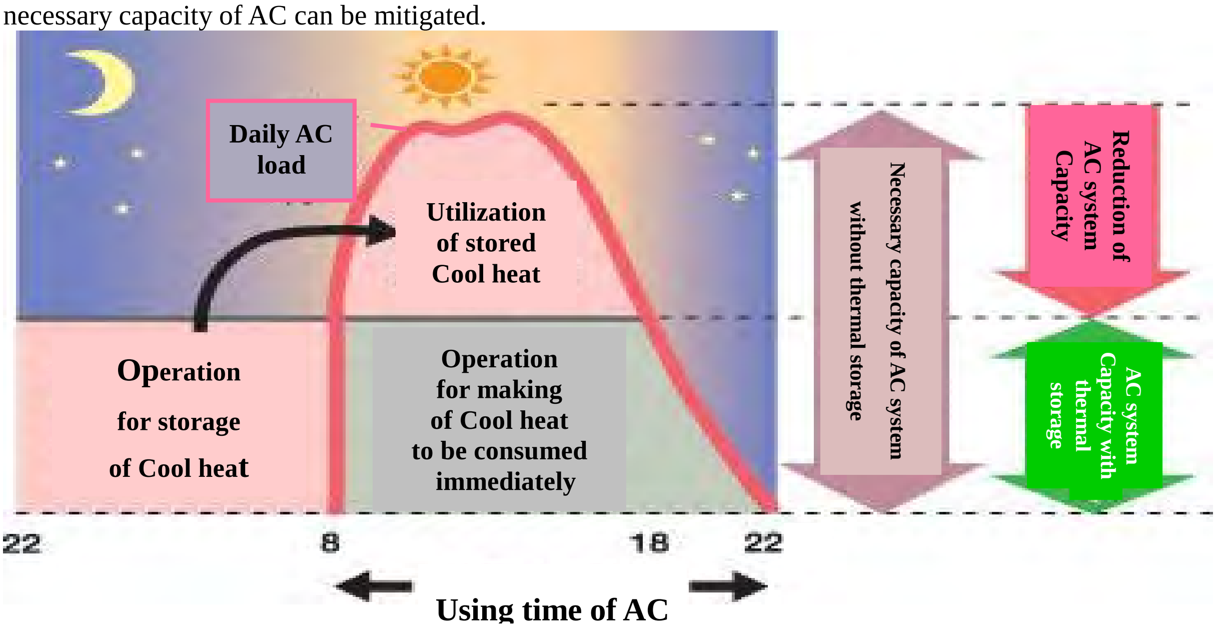
This system is the high efficient and the clean energy system, because this system utilizes the heat energy stored in the night time by the electricity in the night time for the operation of ACs in the daytime.



Source：Shikoku electric power company

⑥-3-2 Concept of Thermal storage AC system operation

This system utilizes the heat energy stored in the night time for the operation of ACs in the daytime. The necessary energy of the operation of AC in the daytime can be mitigated. In the other words, the necessary capacity of AC can be mitigated.



Source：Shikoku electric power company

⑥-3-3 Merits of Thermal storage AC system

a） Cost reduction

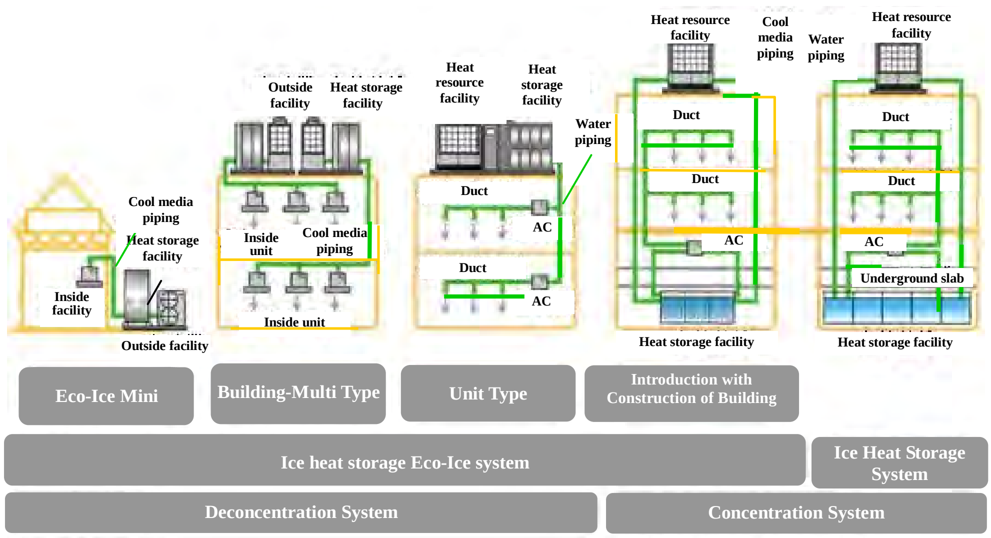
The Japanese electricity tariff has two types; “basic rate according to demand” and “cheap electricity tariff for the night time.” The thermal storage AC system can mitigate the capacity of AC and can reduce the basic rate. And the thermal storage AC system also can reduce the cost for the operation of AC by covering the part of the necessary power of AC in the daytime by the cheap electricity tariff in the night time.

b）Capacity reduction

As ⑥-3-2 Concept of Thermal storage AC system operation shows, The thermal storage AC system can mitigate the capacity of AC by utilizing the heat energy stored in the night time for the operation of AC in the daytime.

c）Wealth of types

The suitable type or size of thermal storage AC system according to the target building can be selected, because there are many types. “Eco・Ice mini” and ”Building Multi Type” are small size and can be installed easily when not only new-built but also reconstruction. It can be thought that these two types will be able to produce enough effect. Because the densities of the buildings are very high and the total floor spaces of them are very small in Male’ Island.



Source：Shikoku electric power company

d）Contribution to Energy saving

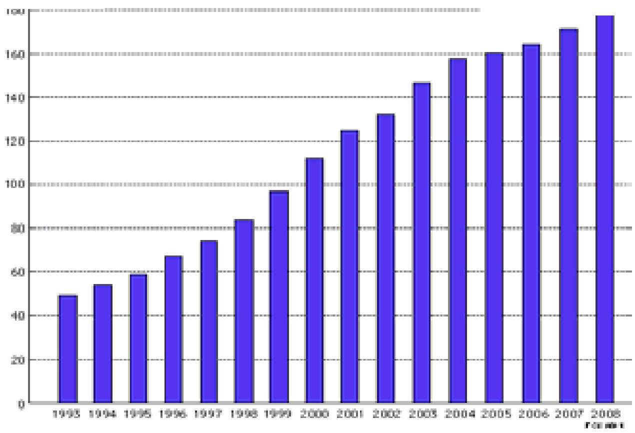
This system can contribute to the energy saving, because this system can store the heat energy by the efficient rated operation in the night time.

e）Environmental friendly

The load factor of the power generators can be improved by the efficient rated operation in the night time and contribute to reduce the CO_2 emission.

⑥-3-4 Installation record for Thermal storage AC system in Japan

From the information in Heat Pump and Thermal Storage Technology Center of Japan, the accumulative number of the introduction of the thermal storage AC system in Japan is approximately 30,000 sites as of 2008 and the capacity of the shifting of the peak load is approximately 1.8 million kW in 2008. The shifting of the peak load is approximately 1% compared to 0.18 billion kW in the electricity demand in the summer in Japan in 2008. The introduction has been increased step by step under the initiative of the Japanese government. Therefore, the further introduction can be expected in the future.

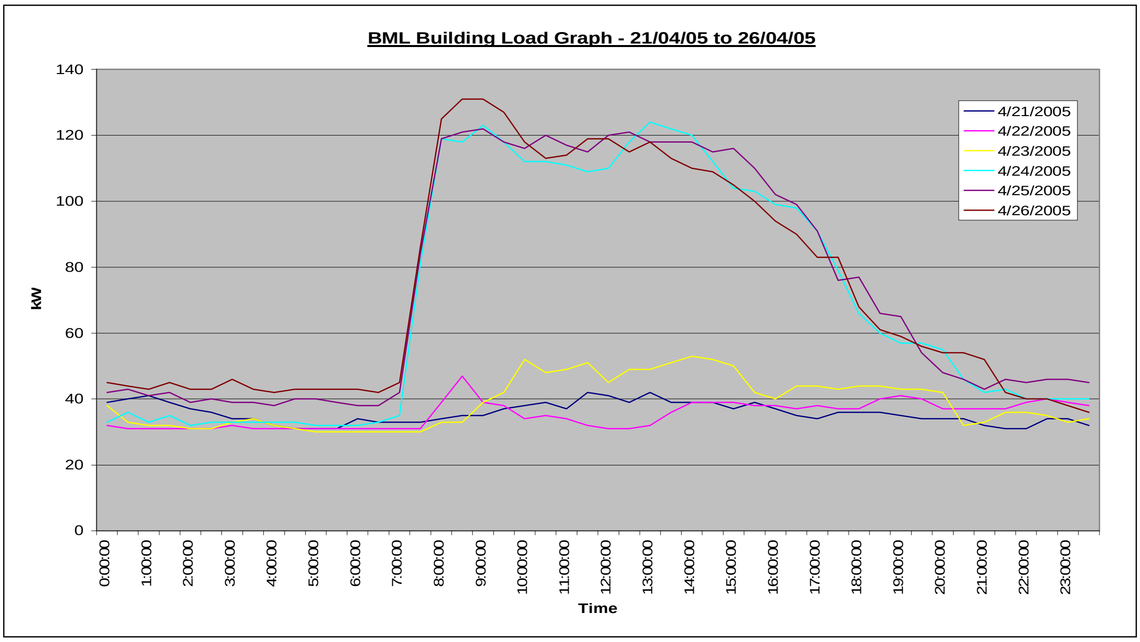


Source：Heat Pump and Thermal Storage Technology Center of Japan

Fig. 7.1.2- 3　Record of shifting peak load in Japan by introducing the thermal storage AC system

⑥-3-5 Examination of introduction of Thermal storage AC system in Male' Island

Here, based on the assumption of introducing the thermal storage AC system in Male' Island, the introduction of the thermal storage AC system into the Bank of Maldives is examined. The daily load curve of the Bank of Maldives which was measured in the SMILE project is shown in Fig. 7.1.2-4. It has the peak load in the day time. And it was also found out from the results of SMILE project that the AC system and the lighting system caused to increase the daily load on the weekday compared to the load on the weekend and the ratio of the AC system to the lighting system is 60:40. The effect and the cost of introducing this thermal storage AC system in Male' Island is examined roughly based on the following premises.



Source：SMILE project

Fig. 7.1.2-4　Daily load curve in the Bank of Maldives

＜Premises＞

１．Estimation conditions

（１）AC system area：600 ㎡　（AC system area ＝ total floor area）

（２）Temperature　：Max temperature in Summer 31℃

：Min temperature in Winter　26℃

：Setting temperature indoor　24～26℃

（３）Hours of using AC system：15 hours（7o’clock ～ 22 o’clock）

（４）Hours of storing cool heat： 9 hours（22 o’clock ～ 7o’clock in the next morning）

（５）Hours of operating AC system：250 days／year　（only operation on the weekday）

（６）Load factor of AC：at peak load/day ＝ 0.8

：annual ＝ 0.8

２．Electric tariff（US＄1＝MRf12.8（May 2009））

（１）Basic rate　：not set

（２）Specific tariffs：Daytime　（8 o’clock～22 o’clock）

US＄0.27/kWh（MRf3.45/kWh）

Night time（22 o’clock～8 o’clock in the next morning）

US＄0.14/kWh（MRf1.80/kWh）

３．Electricity of Bank of Maldives

（１）Peak load　　：approx. 135ｋW
（２）Off-peak load：approx.　40ｋW
（３）Rate of power consumption of AC system and Lighting system：60％:40％
（４）Shifting of power consumption：shifting 30% of power consumption in the day time to the night time
（５）Reduction amount of Peak load：30%

４．Introducing facilities（applying the system cost ant the installation cost in Japan）
（１）System type　　：Ice storage Building-Multi AC system（Cooling capacity 56kW）3units
（２）System cost　　：US $ 48,000/unit
（including only the outside facilities and the storage system (not including the inside facilities)）
（３）Installation cost：US $ 2,700/unit
（４）O&M cost　　：1% of System cost ＋ Installation cost

５．STELCO
（１）Investment for introducing the diesel generators：US $ 2,520/kW

６．Electricity in Male' Island
（１）Peal load in Male　　　　　　：approx. 32MW（2008）
（２）Rate of main buildings　　　　：　80％
（３）Rate of capacity of AC system and Lighting system：60％:40％
（４）Rate of power consumption of AC system and Lighting system：60％:40％
（５）Diversity factor of peal load　　：0.8
（６）Generated electric energy in Male：195,106MWh（2008）

〇**Effect**

Electric power for AC system in peak load　:（135kW － 40kW）＊ 0.6 ＝ 57kW
System capacity of AC system in peak load：57kW ＊ 3 ＝ 171kW
Daily energy for AC system　　　　：171ｋW ＊ 15ｈ ＊ 0.8 ＝ 2,052kWh/day
Shifting electric power for AC system to the night time
：2,052kWh/day ＊ 0.3 ＝ 616kWh/day

〇**Cost**

<u>Customer</u>

System cost　　：US $ 48,000/unit ＊ 3units ＝ US $ 144,000（1,843,200MRf）
Installation cost：US $　2,700/unit ＊ 3units ＝ US $　 8,100（ 103,680MRf）
O&M cost　　：　　　　　　　　　　　　US $　 1,521（　19,469MRf）
Total　　　　：　　　　　　　　　　　　US $ 153,621（1,966,349MRf）

Amount of difference of electric tariff per day：
616kWh/day ＊ (US＄0.27/kWh — US＄0.14/kWh) ＝ US＄80/day

Amount of difference of electric tariff per year：
US＄80/day ＊ 250days ＊ 0.8 ＝ US＄16,000/year

Payback period：US＄153,621 ÷ US＄16,000 ＝ approx. 10years

From the result of the above rough examination, the effect is to shift approx. 620kWh/day to the night time based on the assumption of introducing the appropriate type and size of the thermal storage AC system（Ice storage Building-Multi AC system）for the Bank of Maldives and of shifting 30% of the power consumption from the daytime to the night time. And the cost of the customer is to pay back the cost of this system in approx. 10 years, if the electricity tariff in the night time is set half of the electric tariff in the daytime.

Electric power company

In the above, the cost for the customer（Bank of Maldives） was estimated. Here, the cost for the electric power company is estimated.

○Rescheduled equipment investment by mitigating the peak load

The reduction amount of the peak load is 30%, if the thermal storage C system is introduced into the Bank of Maldives, the introduction of the appropriate size of the thermal storage system into 30% of the main buildings, and the same kind of the effect are assumed, here.

The amount of mitigating the peak load in Male’：

32MW ＊ 0.8（Rate of main buildings to peak load）＊ 0.6（Rate of capacity of AC system to peak load）＊ 0.8（Diversity factor of peal load）＊ 0.3（30% of main buildings）＊ 0.3（Reduction amount of Peak load）＝ 1.1MW

Rescheduled equipment investment by mitigating the peak load：
1.1MW ＊ 1000 ＊ US＄2,520/kW ＝ US＄2,772,000

○Income reduction by introducing the Time of Using of Electricity

Shifting electric power for AC system to the night time in the case of introducing the thermal storage AC system into the Bank of Maldives is estimated 616kWh/day. The introduction of the appropriate size of the thermal storage system into 30% of the main buildings and the same kind of the effect of the Bank of Maldives are assumed, here. And the power consumption in the main buildings is assumed as the Business(27%) + the Business Special(7%) + the Government(17%) in Fig. 3.3.2-7.

Shifting yearly electric power for AC system to the night time in Male'：

195,106MWh/year ＊ 0.51(Power consumption of main buildings)＊ 0.6（Rate of power consumption of AC system）＊ 0.3（30% of main buildings）＊ 0.3（Shifting of power consumption）＝ 5,373MWh/year

Income reduction by introducing the Time of Using of Electricity：

5,373MWh ＊ 1000 ＊ (US＄0.27/kWh － US＄0.14/kWh) ＝ US＄698,490/year

From the result of the above rough examination, in the view point of the cost for the electric power company, on the assumption that 30% of the main buildings in Male's Island will introduce the appropriate sizes of the thermal storage AC systems, the merit of rescheduled equipment investment by mitigating the peak load is approximately US＄3 million, and the income reduction by introducing the Time of Using of Electricity is approximately US＄0.7 million/year.

7.1.3 LEGAL SYSTEMS

Here, the necessary legal systems for the dissemination of the DSM in the Maldives are analyzed. As described in 3.1.1, the legal systems regarding the energy and power sector in the Maldives are only "Law governing public services" and "Regulations on public supply of electricity in Male' and outer Atolls", therefore, the legal system concerned with the DSM directly does not exist. And regarding the construction, although the building code was established in August 2008, it provides just a rough performance stipulation. Therefore, the legal system concerned with the DSM does not actually exist as well.

The Japanese legal system regarding the DSM is "Act on the Relational Use of Energy（hereinafter as "Japanese Energy Conservation Act"）." For the purpose of securing the efficient use of the fuel resource in the outside and inside economic and social aspect regarding energy, the measures and the penalties regarding the relational use of energy in factory, building and machinery and appliances, etc. are prescribed in this act, and this act can be useful for "Construction of Energy Conservation Act," " Inserting in Compliance Document in Building Code" and " Revision of Building Code" in Table 7.1.2-2. Regarding "Construction of Energy Conservation Act", the useful parts in the Japanese Energy Conversation Act are, by picking up from the parts regarding the factories, to obligate the factories which have the annual energy consumption more than a certain value to introduce the energy manager, to make and submit the medium & long-term plan regarding the energy use and to report the results regularly. Although these elements are very effective in the Maldives due to the land constraints, but "Construction of Energy Conservation Act" is proposed as the more appropriate DSM measure from the view point of the cost and the man power, which will obligate to the main buildings which have more load than the standard in each province to implement the regular energy audit by energy managers introduced in each utility company based on evaluating the result of the trial energy audit in Male' and Hulhumale' island and considering the necessity of the regular energy audit and the necessary cost. And the standard value of the energy saving also will be set in this Energy Conservation Act (e.g.; within 300W/m2 of energy consumption for large factory). In addition, the grading will be implemented according to the efficient rate compared with the standard value to enhance the voluntary effort for environment (e.g.; 5 stars will be given to the building which has the energy saving rate more than half of the standard value). On the other hand, the setting of the penalty against the building which has the energy saving rate more than the standard value will be the effective measure.

The main elements in the Japanese Energy Conservation Act are shown in Table 7.1.3-1 as the reference.

Table7.1.3-1　The main elements for the designated factories in the Japanese Energy Conservation Act

Article	General outline
Article 5 The judgmental standard for business person	Concerning the decision way of the judgmental standard for business person （Decision way of the judgmental standard : The minister of Economic, trade and industry settles the judgmental standard for the business person who utilizes the energy in the factory and publishes it in order to rationalize and utilize the energy efficiently in the factory.）
Article 7 The designation of the energy management factory	Concerning the designation of the energy management factory （Designation : The minister of Economic, Trade and Industry designates the factory which consumes the energy more than the standard value prescribed in the government ordinance as the factory which needs to promote the energy using rationalization in specific.）
Article 8 Energy managers	Concerning the introduction of the energy managers （Introduction : The designated factory is obligated to introduce the energy managers.）
Article 14 The formulation of the medium and long-term plan	Concerning the formulation of the medium and long-term plan （Plan formulation : The designated factory should submit the medium and long-term plan for the energy using rationalization to the minister in charge.）
Article 15 Regular report	Concerning the regular report （Report : The designated factory should report the energy consumption, the utilization situation for the other energy, the equipments which consume energy , the introduction, the improvement and the elimination of the equipment regarding the energy using rationalization.）

Source：created by the Study team from the Act on the Relational Use of Energy in Japan

Regarding “Inserting in Compliance Document in Building Code” and ” Revision of Building Code”, the useful parts in the Japanese Energy Conversation Act are to prevent the heat loss from the outer wall of the construction, etc. and to make an effort to introduce the efficient air-conditioning facilities. To regulate the construction of the buildings which can save energy and the introduction of the energy efficient electric appliances is very effective measure like the Japanese Energy Conservation Act. Therefore, based on the Japanese Energy Conservation Act, the inserting the construction of the building with high heat insulating effect and the design of the proper AC system, the proper air ventilation system and the proper lighting system in the compliance document in the building code” by focusing on the new-built and the reconstruction is proposed, here. And to obligate the introduction of the official authorized electric appliance when the public buildings will be new built or reconstructed by the revised building code is proposed as well.

Table7.1.3-2　The main elements for the construction
in the Japanese Energy Conservation Act

Article	General outline
Article 72 The effort of the constructors, etc.	Concerning the effort of the constructors （Effort target : The constructors should make their effort to contribute to the energy using rationalization in the construction by preventing the heat loss through the outer wall or the windows and implementing the measures of the energy using rationalization for AC in the construction.）
Article 73 The judgmental standard for the constructor and the owner of the specific construction	Concerning the judgmental standard for the constructor and the owner of the specific construction （Judgmental standard : The minister in charge settles the judgmental standard for the constructor and the owner of the major construction and public it in order to rationalize and utilize the energy efficiently in the construction.）
Article 75 The application and the direction, etc. for the specific construction	Concerning the application and the direction for the specific construction （Application : The specific construction should submit the application concerning the items of the design and the construction to the administrative government agency.）
Article 76 The admonition and the mandate for the improvement of the performance	Concerning the admonition and the mandate for the improvement of the performance （Admonition : The minister in charge can admonish the constructor to improve the performance of the new construction, if the necessity of the improvement can be recognized in the new construction.）

Source：created by the Study team from the Act on the Relational Use of Energy in Japan

7.1.4 Staging of Seminars

Enlightenment activities are essential for effectively advancing the DSM. Therefore, in the Study, enlightenment activities will be implemented with so as to widely inform the people of the Maldives about the DSM and ensure that power consumption limitation and shift measures efficiently produce results. In order to effectively disseminate information, seminars on methods for improving use of major electrical appliances were conducted in this study, targeting general citizens and resort operators. Through these seminars, the understanding and the awareness of the importance of the DSM was enhanced in the Maldives. The specific example is to issue the letter with the sign of the minister of the MHTE to the government and the government-affiliated agencies, which requests to set the temperature of the ACs above 25℃.

7.1.5 DSM Recommendations

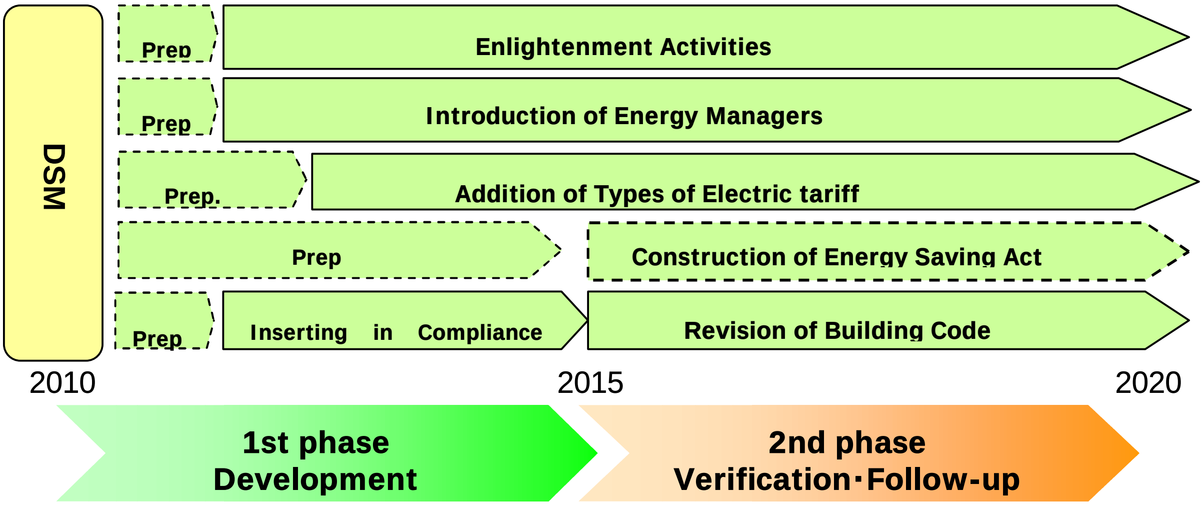
Based on the above examination findings, the DSM techniques appropriate to Male’ Island and Hulhumale‘ Island will be proposed from the medium to long-term viewpoint. When promoting the DSM, as is shown in Fig. 7.1.4-1, rather than simply implementing power consumption limitation and shift measures, it is essential to also conduct the enlightenment activities to ensure there is widespread understanding of the need for such measures. A fundamental problem on Male' Island and Hulhumale' Island at present is that citizens do not accurately understand that the electric power infrastructure is unable to keep up with economic development and this is creating a highly strained demand and supply situation.

Therefore, it is recommended that an enlightenment activity be conducted with a view to widely informing citizens of the current demand and supply situation and simple the DSM techniques that can be practiced in homes, commercial and public facilities. The concrete strategy is "Introduction of Official recommended electric appliance" as Table 7.1.2-2 shows. This is the inception of the enlightenment activities.

Under the situation which desires the rapid DSM due to the tight demand and supply, "Introduction of Energy managers" is proposed as the DSM measure which does not require the budget and the man power too much. The energy audit by this energy manager on the early stage will be implemented as the trial in Male' and Hulhumale' Island. If the evaluation result of the trial is effective, the introduction of 1 energy manager into each utility company in each province and the implementation of regular energy audit by the energy manager introduced in each utility company in the main building will be obligated in the Energy Conservation Act.

On the next step, at that time when the enlightenment activities and the regular energy audit activities will be coming to stay, "Introduction of Basic rate according to Demand" and "Introduction of Time of Using of Electricity" are proposed in order to promote the above 2 activities. The introduction of the basic rate according to the demand can contribute the utility company to simplify the controlling of the electricity demand and the introduction of the cheaper electricity tariff in the night time can be the incentive for the customers to promote the shifting of the using time of electric appliances. In addition, the introduction of the electric facilities (e.g.; Thermal storage AC system) which can utilize the above 2 electricity tariffs efficiently will be implemented in the HP of the Ministry in charge of energy saving, when these electricity tariffs will be introduced. However, there is the difficulty in increasing the electricity tariff again, because the next electricity tariff increase has already been decided on Nov 1st in the STELCO territory. Therefore, it can be desirable that the target point of introducing these 2 new electricity tariffs is the next electricity tariff increase after the next, because the introduction of the cheaper electricity tariff in the night time can mitigate the impact of increasing electricity tariff. And the introduction of these 2 new electricity tariffs in other provinces will be implemented by evaluating the result in the STELCO territory.

When the level of the awareness among the citizens reaches a certain level by the enlightenment activities and the above DSM measures, since the groundwork for adopting compulsory measures and so on will have been laid, if necessary from the result of the trial, the construction of the energy conservation act will be implemented and the energy conservation act will obligate to implement the energy audit by the energy managers. In addition, the revision of the building code will be implemented together and the building code will obligate the introduction of the official authorized electric appliance when the public buildings will be new built or reconstructed. These will enhance the DSM measures to come to stay in the Maldives further.



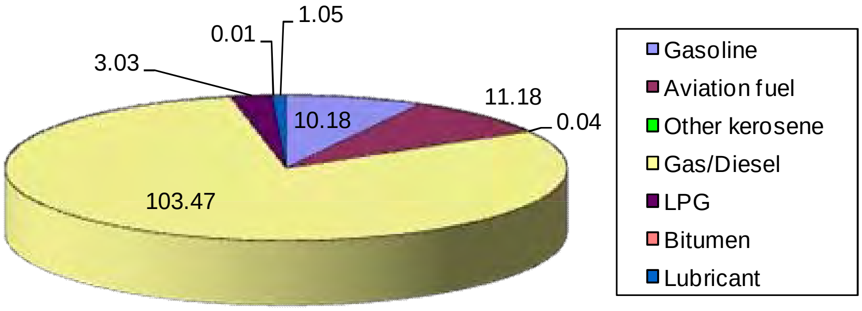
Source：created by the Study team

Fig. 7.1.5- 1 Proposal schedule in the view point of the medium & long-term

7.2 Examination and Recommendation of CDM Project Implementation

7.2.1 CDM Activities in the Maldives

As a country faced with the risk of becoming submerged (especially outer atolls) due to rising sea level caused by global warming, Maldives is actively involved in measures to counter climate change. It ratified the United Nation Framework Convention on Climate Change (UNFCCC) in 1993 and the Kyoto Protocol in 1998, and has established the Ministry of Home Affairs as its Designated National Authority (DNA). Under funding from the Global Environmental Facility (GEF), the government completed the First National Communication of Maldives to the UNFCCC in 2001 and has compiled a national strategy and action plan concerning the CDM. According to this document, the latest inventory of greenhouse gas (GHG) emissions is derived from the results of the baseline survey implemented in 1994 calculated using the reference approach of IPCC. According to these results, in the energy sector, which is the large source of GHG emissions, 129 g of CO_2 is emitted, and of this approximately 80% is derived from gas and diesel fuels.



(Note) Unit: Tons
Source： Prepared by the Study Team

Figure 7.2.1-1 Breakdown of CO_2 Emissions in the Energy Sector

According to the First National Communication of Maldives to the UNFCCC, apart from the energy field, emissions of methane (CH_4) from solid waste buried underground are calculated as 1.1 g, while concerning the transport, industry, agriculture and solid waste management sectors, etc., not enough data have been obtained to calculate an inventory; moreover, no inventory has so far been compiled regarding N_2O emissions. Furthermore, although there is no experience of CDM projects in the past, the following CDM potential projects have been proposed (funding has not yet been fixed). Virtually, after publication of the First National Communication of Maldives to the UNFCCC, no other official documents have been issued concerning CDM.

Table 7.2.1-1 CDM Potential Projects

No.	Project
1	Appraising Coastal Erosion in the Maldives: Laying the Foundation for Adaptation to the Sea Level Rise and Climate Change
2	A Coastal Erosion Management Strategy for the Maldives
3	Feasibility Study for a National Population Consolidation strategy and Program
4	Upgrading of Gan Airport for International Operations
5	Program for Fisheries Conservation Measures and Community-Based Reef Resource Management
6	Development of Food Security in the Maldives
7	The Use of Infiltration Galleries to Supply Ground Water in the Islands
8	Climatic Influences on the Spread and Transmission of Vector Borne Diseases
9	Alternate / Renewable Energy Sources for the Outer Islands of the Maldives
10	The Use of Solar Distillation as a Source of Freshwater for Outer Islands and Male’
11	Development of Sustainable Inter-Island Sea Based Mass Transportation System
12	Development of Sewerage Treatment Facilities
13	The Integrated Waste Management System Designed to Mitigate GHG Emissions

Source： “First National Communication of Maldives to the UNFCCC”

Table 7.2.1-2 shows policies, systems and surrounding conditions related to the promotion of CDM. When it comes to promoting CDM in the future, it will be necessary to conduct capacity building, enlightenment and dissemination activities not only for MHTE (the Ministry in charge of CDM activities), but also stakeholders including government agencies, financial agencies and facilitators, etc. concerned with the CDM.

Table 7.2.1-2 Policies, Systems and Surrounding Conditions concerning CDM Promotion

Large Item	Medium Item	Survey Contents and Findings
Basic information	CDM potential	In the energy field, projects for utilizing renewable energy on outer islands in order to reduce GHG emissions from DEGs have been proposed, however, no concrete project sites, renewable energy introduction quantities or GHG emission reduction quotas, etc. have been decided.
	GHG emissions	In the First National Communication of Maldives to the UNFCCC compiled in 2001, it is computed that 129 g of CO_2 is emitted in the energy sector and 1.1 g of methane (CH_4) is emitted from underground solid waste, however, not enough data have been obtained to compile an inventory concerning the transport, industry, agriculture and solid waste management sectors, etc.; moreover, no inventory has so far been compiled regarding N_2O emissions. Moreover, this document includes no examination of environmental efficiency (energy consumption and GHG emissions, etc. per unit GDP).
	Activities of related Japanese agencies	There are no support activities by Japanese official agencies or project formation activities by private enterprises.
	Activities of other donors, etc.	In the energy field, there are no CDM project support activities or plans by other donors and international agencies, etc.
Policies, institutional framework	Climate change and global warming countermeasures policy	According to the National Action Program of Adaptation (NAPA) which was compiled in 2006, capacity building for coastal preservation, coastal management and flood control is given as the most important measure in the adaptation field.
	UNFCCC / Kyoto Protocol	The Maldives ratified the United Nation Framework Convention on Climate Change (UNFCCC) in 1993 and the Kyoto Protocol in 1998.
	CDM policy direction	According to "An Environmental Sustainability Linking CDM into National Development Planning (2006)," the following fields are regarded as promising priority sectors for CDM: - Transport and energy - Coastal preservation - Preservation of biological diversity - Integrated coral reef management - Integrated water resources management - Solid wastes and sewerage management - Pollutants and hazardous solid wastes management - Tourism development - Land resources management - Population concentration, relocation to urban areas
	CDM related laws	Domestic legal systems related to CDM application, approval, CER issue and transfer and CDM implementation have not yet been established.
	Investment-related systems	Overseas investment is actively received mainly in the tourism sector, and activities are stipulated in the Law on Overseas Investment in the Maldives (No. 25/79) and the Law on Imports and Exports (No. 31/79), etc. On the other hand, provisions relating to levies on CERs and other aspects of the CDM investment environment have not been established.
Current capacity of stakeholders	DNA	The designated national agency (DNA) has been established in the Ministry of Home Affairs. However, the Ministry of Home Affairs conducts no activities at all as the DNA for CDM projects. In reality, only three employees of the MHTE Climate Change, Sustainable Development and Energy Department act as focal points for the UNFCCC and are engaged in CDM project affairs. These employees have experience of visiting the United Nations agencies, however, they do not have a deep understanding of concrete CDM procedures and the necessary documents, etc.

Large Item	Medium Item	Survey Contents and Findings
		Since no CDM projects have been reviewed in the past, no stipulations exist concerning the documents and processes required for review.
		No documents or procedures have so far been decided with a view to issuing an approval letter.
	Government agencies	The Ministry of Home Affairs is not functioning as the DNA. Only the MHTE Climate Change, Sustainable Development and Energy Department manages CDM activities but it does not collaborate with other government agencies.
		There is no liaison window established concerning CDM, and information and so forth is not provided to project participants.
	DOE	The Maldives has no DOE, nor any plans to develop a DOE.
	Financial agencies	Since no CDM projects have been implemented in the past, no financial agencies in the Maldives possess know-how concerning the CDM.
	Facilitators	There are no industrial associations, research agencies or researchers with know-how of the CDM in the Maldives, and the only CDM stakeholder is the government (MHTE).
		The Maldives does not transmit any information concerning CDM potential and stakeholders to investor nations.
		No education or enlightenment activities are carried out with respect to officials in the Maldives.

Source： Prepared by the Study Team

7.2.2 Organizations and Institutional Preparations for Implementing CDM Projects

(1) Organizations

As was mentioned previously, Maldives has no existing procedures or documents, etc. concerning CDM application, approval, CER issue and transfer and CDM implementation. Therefore, when it comes to implementing the CDM in the future, it will be necessary to conduct capacity building for institutions and policies. The following paragraphs describe issues and initiatives surrounding CDM implementation and make recommendations for capacity building in this area. Approval for following proposed institutions has also been received from the MHTE Climate Change, Sustainable Development and Energy Department, and it is scheduled for detailed regulations to be decided concerning CDM implementation in the future.

As the organization responsible for implementing CDM projects, the Ministry of Home Affairs has been assigned as the Designated National Authority (DNA) of UNFCCC. However, the Ministry of Home Affairs conducts no activities at all as the DNA for CDM projects. In reality, only three employees of the MHTE Climate Change, Sustainable Development and Energy Department, including the Director General Mr. Amjad Abdulla, act as focal points for the UNFCCC and are engaged in CDM project affairs. Accordingly, the MHTE claims that there are plans to transfer the DNA from the Ministry of Home Affairs to the MHTE in the near future, although no concrete schedule has so far been decided.

(2) Institutional Preparations

In order to implement CDM projects in the future, in addition to the above institutional arrangements, it will be urgently necessary to grasp the potential for CDM projects and compile an inventory of GHG emissions. After that, it is required to widely inform donors and private enterprises of the information garnered, and make preparations and establish procedures to accept proposals. Towards this end, the Study Team and MHTE held discussions and agreed to propose the following contents, which are due to be authorized by the MHTE and related agencies from now on.

1) Sustainable Development Criteria (SD Criteria)

According to the Article 12.2 of Kyoto Protocol, it is clearly mentioned that pursuing Sustainable Development (SD) of developing countries is a major objective for CDM. However, it is difficult to uniformly define SD around the world as the definition of SD should depend on each country or region. Thus it is required for developing countries to define SD criteria for their own and judge whether each project follows such criteria. In case of Maldives, there is no existing official SD criterion. Therefore, the Study Team proposed following SD criteria in order to promote formulation of CDM project in the future.

Table 7.2.2-1 Sustainable Development Criteria (SD Criteria) (Draft)

Field	Targets	Indicator
Environment	- To contribute to environmental improvement and GHG emission reductions - To contribute to reduction of natural resources such as groundwater and fossil fuels, etc. - To present plans over a life cycle	Approval is obtained for an EIA (if required by law) or IEE.
		Contribution to environmental improvement including the following items: - Reduction of GHG emissions - Reduction of atmospheric pollutants such as SO_2, NOX and PM10, etc. - Water resources management - Solid waste management - Land contamination
		Plans for maintaining biological diversity are included.
		Plans for groundwater preservation are included.
		Contribution is made reducing consumption of fossil fuels.
		Contribution is made to sustainable utilization of other natural resources.
		Plans for mitigating environmental impact are included.
Society	Participation by ordinary citizens is an important element in sustainable development. In order to avoid clashes with residents, the project implementing parties must obtain permission and approval from government officials on the national and local levels.	Laws, regulations and rules concerning EIA are conformed to.
		Information provision to ordinary citizens
		The following benefits are fairly owned by communities: - Health - Education

		- Skill improvement of workers - Other benefits
Economy	To have a beneficial effect on the national economy through improving the local economic conditions in the area where the project site is located.	Long-term employment

Source： Prepared by the Study Team

2) Documents required for CDM Application

Proponents for a CDM project is required to submit following application form to MHTE. Application Form for ② Project design document (PDD) can be obtained via UNFCCC website, and ③ EIA or IEE application form is released by Environmental Protection Agency (EPA). Therefore, the Study Team proposed the draft of application form for ① in consultation with MHTE as on Table 7.2.2-2.

① CDM project application form
② Project design document (PDD)
③ EIA or IEE application form

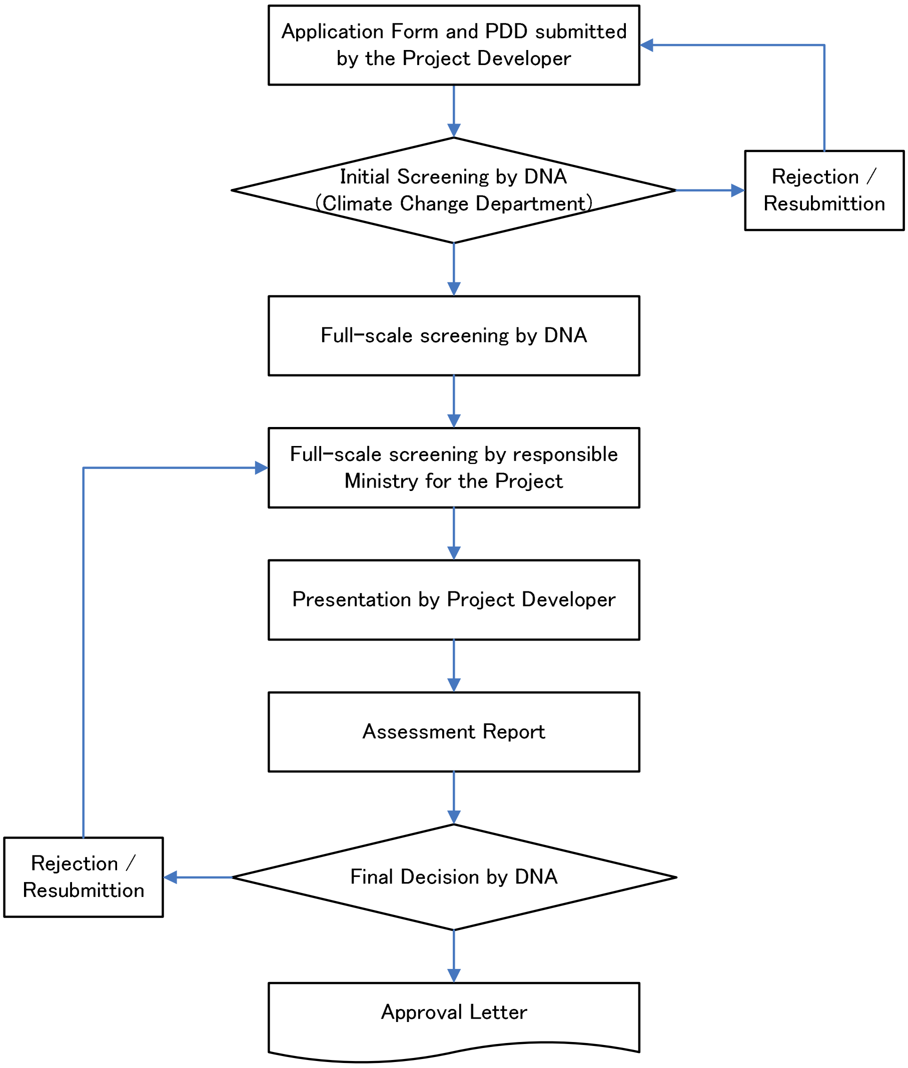
Table 7.2.2-2 CDM Project Application Document Format (Draft)

1. Basic Information on the Project	
Project Name	
Location of the Project	Name of Atoll and Island
General Description of the Project	
2. Basic Information on the Project Participants	
Contact Person for the CDM Project Activity	Name of contact person: Address: E-mail: Telephone: Fax:
Business license of the Project Participants	Photocopy shall be attached (in case of private company)
Annual Report	
Foreign Partner(s) (CERs acquirer)	Partner(s) name: Registered country of the foreign partner: Contact person: Address: E-mail: Telephone: Fax:
2. Basic Information on the Proposed CDM Project Activity	
General Information (Please check the appropriate item.)	(1) Type of the Project; ( ) new, ( ) expansion, ( ) reconstruction (2) Stage of development: ( ) Feasibility Study, ( ) Detail Design, ( ) Procurement, ( ) Under construction, ( ) Operation (3) EIA or IEE procedures; ( ) not applied, ( ) in process, ( ) approved, ( ) rejected

Contributions to Sustainable Development in Maldives	Please indicate the relevant information on the Sustainable Development Criteria in Maldives.
CDM Project Type (Please check the appropriate item.)	( ) Energy conservation and Energy efficiency, ( ) Renewable energy, ( ) Fuel switching, ( ) Methane recovery and utilization, ( ) Others
Project Period	(1) Commissioning *(DD/MM/YYYY)* (2) Expected lifetime of the Project; ( ) years
Baseline Methodology	Applied Baseline Methodology; ( ) Approved by the CDM Executive Board Series Number: ( ) New Methodology
GHG Emission Reductions	(1) GHG type; ( ) CO_2, ( ) CH_4, ( ) N_2O, ( ) Others (2) Estimated annual emission reductions; ( ) tCO_2 equivalent per year
3. Information on CERs Transfer	
CERs Transfer Agreement	( ) signed on *(DD/MM/YYYY)* (Photocopy of the Agreement shall be attached.) ( ) no
Transfer Information	(1) Price: ( ) US$/$tCO_2e$ (2) Total transfer amount: ( ) tCO_2e (3) Expected transfer period: from *(DD/MM/YYYY)* to *(DD/MM/YYYY)*
Source of Funds for CERs	( ) Additional to the current Official Development Assistance (ODA) and the financial obligations of the development country parties under the UNFCCC ( ) Not additional to the current Official Development Assistance (ODA) and the financial obligations of the development country parties under the UNFCCC
Declaration of the applicant	
I hereby declare that all information provided above and information included in the CDM PDD and general information on the Project and financing scheme are correct and complete. I understand that I shall take the legal obligations caused by any false information intentionally for the purpose of obtaining the approval for the Project. Signature of the legal representative: ______________________ Date: ______________________	

Source： Prepared by the Study Team

3) Review Process to Issue of the Approval Letter by the DNA



Source： Prepared by the Study Team

Figure 7.2.2-1 CDM Project Application and Approval Process (Draft)

7.2.3 Program CDM Application

Program CDM is a new system that was approved at the COP/MOP1 conference staged in 2005. Under Program CDM, it is possible for enterprises or public entities to implement independent or coordinated policies, measures and targets as a unified Program of Activities (PoA), and to implement multiple CDM Program Activities (CPAs) within such PoA as a single CDM project.

Under this scheme, since the effects of PV equipment subsidy systems and preferential tax systems, etc. are treated as CDM projects, and projects involving facilities targeted by government programs can be implemented as a single program, it was thought that the burden of individual project implementing parties would be alleviated. However, following subsequent examination by the CDM

Board, it was decided that Non-Annex I countries will need to prepare the following three PDDs[1] in order to apply this system, and that it will be necessary to prepare a separate PDD[2] when registering additional CDM Program Activities after initial registration.

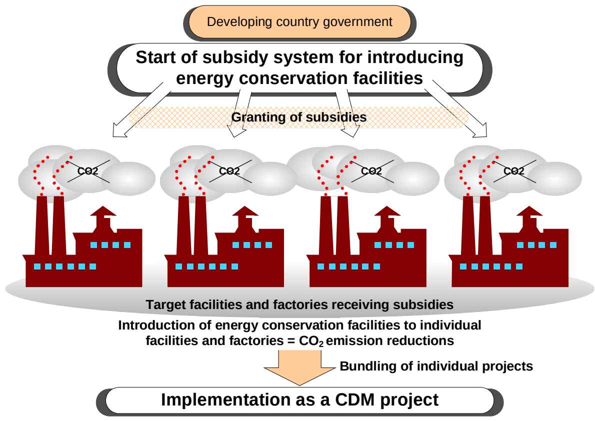
① An entire PDD (CDM-POA-DD) regarding program activities

② PDD (CDM-CPA-DD) that includes general information concerning all the envisaged CDM Program Activities.

③ An entire PDD (CDM-CPA-DD) corresponding to actual CDM Program Activities

Moreover, in order to register as a Program CDM, it is necessary to form a coordinating/managing entity to act as the implementing agency of the program activities that has been approved by the DNA of the signatory country concerned. The coordinating/managing entity must prepare a plan for the operation and monitoring of program activities, and all CDM program activities must be monitored according to this, while steps must be taken to avoid the double counting of CDM Program Activities.

As was mentioned above, application, registration and monitoring under Program CDM requires more strict screening than conventional CDM and an organized approach is necessary even in Non-Annex I countries. In case of Maldives, first of all, it will be desirable to implement a conventional CDM project and to build up the necessary organizational and institutional know-how, and then to examine the possibilities of registering under the Program CDM system in the next step.



Source： CDM/JI Standard Text Version 2.0, Ministry of Economy, Trade and Industry

Figure 7.2.3-1 Image of Program CDM

1 "Procedures for Registration of a Program of Activities as a Single CDM Project Activity and Issuance of Certified Emission Reductions for a Program of Activities" UNFCCC Website

2 Registration fees are not required for CDM Program Activities that are added later.

7.3 Introduction of PV Power Generation to Resort Islands

As of March 2009, 92 resort islands are operated and a further 68 are planned for development in Maldives. Since the resort islands rely almost exclusively on diesel power generation, the Ministry of Tourism, Arts and Culture aims to vigorously pursue renewable energies including PV power generation in order to reduce consumption of imported diesel fuel and mitigate the environmental impacts of noise and exhaust gases. Solar water heaters are already widely disseminated, however, there have been no examples of PV introduction, and there is great potential for installing such systems if continuous awareness raising activities can be conducted for resort owners. According to the Ministry of Tourism, Arts and Culture, the issues for resort owners when they consider introducing PV systems are as follows: ① Initial investment costs are high, and ② Responding to system failures is difficult, and so on. Accordingly, the second seminar for awareness raising and dissemination of PV and DSM was held during the third field survey for representatives of the Ministry of Tourism, Arts and Culture, the Maldives Association of Tourism Industry (MATI) and resort owners, etc.

CHAPTER 8 RECOMMENDATIONS FOR DISSEMINATION OF THE GRID-CONNECTED PV SYSTEM

8.1 Legal Systems concerning Dissemination of New Energies in the Maldives

As was described in 3.1.2, under the Maldivian legal system, policies and institutions are specified in different levels starting with the Constitution and moving down through Laws or Acts and Regulations. Currently, there are no legal systems related to new energies, although the MHTE and MEA (regulatory agency) are preparing an Act geared to the introduction of renewable energies including PV power generation. This Act is thought to correspond to the Japanese New Energy Law (Special Measures Law concerning Promotion of New Energy Usage, etc.). For reference purposes, Table 8.1-1 shows the laws in Japan that relate to new energy, while Table 8.1-2 shows the new energy legislation items thought to be required when applying to the case of the Maldives.

Table 8.1-1 Japanese Laws concerning New Energies

New Energies
- Law concerning Promotion of Development and Introduction of Petroleum-Substitute Energies
- Special Measures Law concerning Promotion of New Energy Use, etc. (New Energy Law)
- Special Measures Law concerning Utilization of New Energies by Electricity Utility Operators (RPS Law)

Table 8.1-2 Necessary Items of the Japanese New Energy Law when Applying to the Maldives

Article	Outline
Article 1 Objective	Concerning the objective of the New Energy Law (Objective: To take necessary steps in order to promote efforts by citizens concerning new energy use and facilitate use of new energies, with a view to securing the stable and appropriate supply of energy according to the socioeconomic environment).
Article 2 Definitions	Definition of new energies and scope of application of the law (Applicable scope: Energies that are not sufficiently disseminated due to economic constraints but need to be promoted in order to introduce petroleum-substitute energies)
Article 3 Basic Policy	Concerning the method of deciding basic policy (Determination method: The basic policy must be proposed by the Minister of Economy, Trade and Industry and receive Cabinet approval with consideration given to the long-term prospects for energy demand and supply, characteristics of new energy utilization, etc., technical standards and environmental impacts, etc.)
Article 4 Efforts of energy users, etc.	Concerning efforts of energy users, etc. (Effort: Energy users must strive to use new energies, etc. while paying attention to the basic policy).
Article 5 New energy use guidelines	Concerning the method of deciding new energy use guidelines (Determination method: The new energy use guidelines shall be determined by the Minister of Economy, Trade and Industry with consideration given to the long-term prospects for energy demand and supply, characteristics of new energy utilization, etc., technical standards and environmental impacts, etc.)
Article 6 Guidance and advice	Concerning guidance and advice (Guidance and advice: The Competent Minister can implement guidance and advice concerning the items to be established in the new energy use guidelines).

Article	Outline
Article 8 Authorization of use plans	Concerning authorization of use plans (Authorization: Parties seeking to use new energies, etc. in business activities must prepare a use plan concerning the energy in question and receive authorization for it).
Article 9 Revisions, etc. of use plans	Concerning revision of use plans determined in Article 8 (Revision: When authorized parties revise use plans concerning the authorization in question, they must receive authorization from the Competent Minister).
Article 14 Collection of reports	Concerning reporting on the state of implementation with respect to authorized operators (Report: The Competent Minister shall be able to seek reports from authorized operators concerning the state of implementation of authorized use plans).
Article 15 Competent Minister(s)	Concerning the definition of Competent Minister(s) (Definition: The Competent Minister(s) shall be the Minister of Economy, Trade and Industry and the Minister(s) with jurisdiction over operations conducted by users).
Article 16 Penalties	Concerning penalties concerning the above agreements (Penalty: Persons who do not give the report stipulated in Article 14 and those who give false reports shall receive penalties).

Source : Prepared by the Study Team from Japan's Special Measures Law concerning the Promotion of New Energy Use, etc.

8.2 Dissemination Promotion Policies and Systems (Incentives)

The following paragraphs examine appropriate dissemination policies and systems for promoting grid-connected PV systems in the Maldives based on systems geared to the introduction and dissemination of renewable energies, in particular PV power generation, and the operating condition of such systems in overseas countries.

8.2.1 Outline of Dissemination Promotion Measures

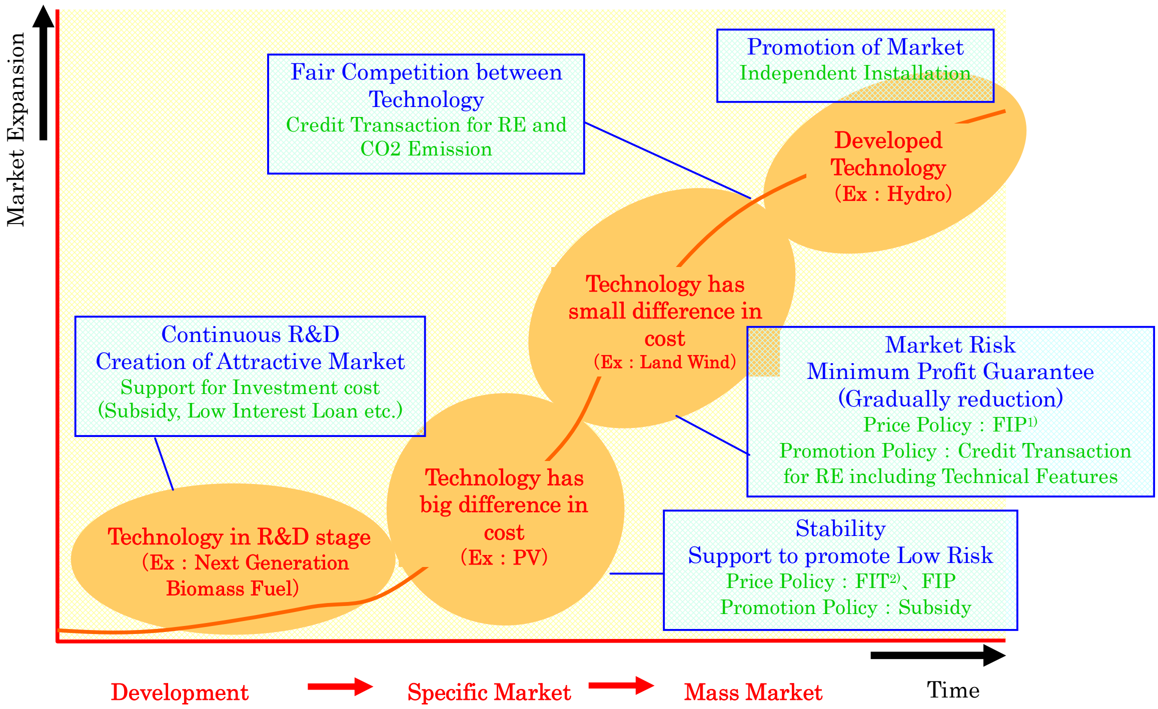
In "Deploying Renewable 2008" of the International Energy Agency (IAE) and "The Support of electricity from renewable energy sources" by the EC, survey and analysis are carried out on policies for disseminating renewable energy in each country, in particular the Renewable Portfolio Standard (RPS) and the fixed price purchasing system (FIT system). Here, based on existing literature in overseas countries and studies made by the Japanese Ministry of Economy, Trade and Industry[1] and the Ministry of Environment[2], the features and issues of general options that may be considered as policies for the promotion of renewable energy including PV power are organized.

According to the IEA, in terms of economic theory, under the ideal conditions, policy for fixing the amount of new energy introduced (RPS system) and price fixing policy (FIT system) display the same level of efficiency. In both systems, accurate system design and fine system adjustments are important elements for success, and it is regarded as important to combine the following dissemination promotion measures according to the level of technology (development stage, verification stage, practical application stage, etc.) and conditions for market introduction (initial introduction stage, dissemination stage, maturation stage, etc.).

---

1 "Concerning measures for promoting introduction of renewable energy in key countries," February 13, 2009

2 "Concerning measures for disseminating renewable energy geared to construction of a low-carbon society (recommendations)," February 2009



Note : 1) FIP (Feed-in Premium) : Purchasing Price is to add the fixed premium (Bonus) to the market price
2) FIT (Feed-in Tariff) : Purchasing Price is the fixed price
Source : "Deploying Renewables 2008" IEA

Figure 8.2.1-1 Combining Policies for Disseminating Renewable Energies

The following paragraphs describe representative dissemination promotion measures based on reference to Japan's experience and advanced examples in Europe and America.

(1) RPS System

RPS stands for Renewable Portfolio Standard, a system whereby the government makes it compulsory for electricity operators to supply a certain ratio of electric power from renewable energies. Concerning the introductory price, it is possible to realize introduction and expansion with high cost effectiveness through utilizing the market to promote cost competition between different renewable energies. Meanwhile, since various renewable energies which comprise different technical standards and cost levels are exposed to the same competitive environment, little progress tends to be made in introducing PV power and other renewable energies that have relatively high introductory costs. Moreover, since it is not possible to predict purchase prices in the future, another issue is that the investment recovery period cannot be fixed.

(2) Fixed Price Purchasing System (FIT System)

In this system, electric power generated from renewable energies is purchased at a fixed price by power companies over a certain period. If an appropriate purchase price is set in consideration of the technical standard and cost level of each renewable energy, since it is possible to predict the investment recovery period, investment in renewable energy is accelerated. Moreover, through enhancing transparency concerning the cost burden of the markup on electricity tariffs, it becomes possible to conduct stable system operation over the long term.

The important design factor in the FIT system is the purchase price setting. If the price is set too low, the effect of promoting introduction is low, while if it is too high, the high price is passed onto consumers in electricity tariffs, thereby leading to perennial tariff inflation. In addition, it is necessary to periodically review the purchase price according to the pace of dissemination and cost reductions arising from technical development.

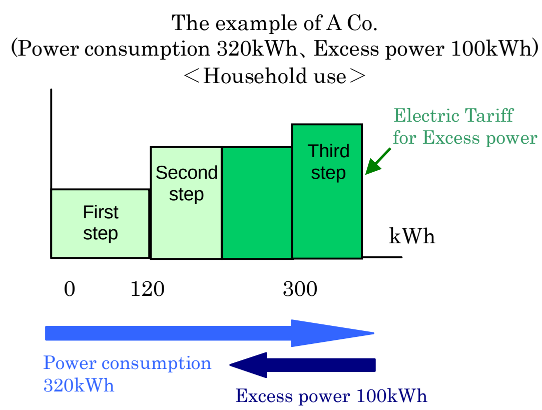
(3) Surplus Power Purchasing System

In this system, surplus electricity that is not consumed within consumer premises is autonomously purchased by electric utility operators based on individual contracts. This appears similar to the FIT system, however, whereas all generated electricity is purchased at a fixed price making it easier for investors to compile business plans in the FIT system, the surplus power purchasing system has a major drawback in that it is difficult to project revenue and expenditure balance because only surplus electricity that isn’t consumed is made available for purchase. Moreover, since the purchase price of surplus power by electric utility operators is frequently set at the same level as the sale price, leading to extremely long investment recovery periods (around 25~30 years), and the system doesn’t guarantee purchase over the long-term since it depends on the autonomous efforts of operators, it doesn’t provide an incentive for introducing new energies in large amounts.

The example of the unit price in Excess power purchasing system for Residential solar power system

(Unit : JY/kWh)

	A Co.	B Co.
Mater rate lighting	24.13 22.86 17.87	25.00
Time-of-day lighting	32.48 30.74 23.87	25.00



Source : “Concerning measures for promoting introduction of renewable energies in key countries,” Resources and Energy Agency

Figure 8.2.1-2 Outline of Japan’s Surplus Power Purchasing System

(4) Introduction Subsidy System

This system entails the government subsidizing part of the costs of introducing renewable energies. It is effective for directly compensating price differentials in the stage where initial introduction costs are high, however, there is a limit to the total amount of subsidies that can be provided each year. Moreover, under single-year budgets, a drawback to this system is that it isn't clear how long it can be continued and it is difficult to compile long-term investment plans. Furthermore, problems are pointed to regarding the administrative cost of operating subsidies and the fact that administrative procedures are concentrated into certain times during the year.

8.2.2 Examples of Policy Introduction in Advanced Countries

(1) Japan

Japanese policies and systems for promoting the introduction of PV power generation comprise the surplus power purchasing system and RPS system, which have conventionally been implemented by electric power companies, and a subsidy system for introducing PV systems to homes. Furthermore, in February 2009, the Ministry of Economy, Trade and Industry announced introduction of a Japanese FIT system, whereby electric power utility operators will have to purchase surplus electricity at approximately two times the current surplus electricity purchasing price (around 50 yen/kWh) for around 10 years, in order to promote the dissemination of PV power, which requires higher introduction costs than other renewable energies. This system will only target systems intended for private consumption in general households and public facilities; it will not target large-scale PV power plants installed with the intention of selling electricity. Concerning the detailed system design, it is scheduled for examination on a draft bill for sophistication of the energy supply structure to be conducted and the system to be introduced from fiscal 2009 at earliest.

Concerning the Japanese RPS system, based on the Special Measures Law concerning Use of New Energies by Electric Utility Operators" (the RPS law), the government establishes eight-year use targets every four years and, following introduction of the system in April 2003, it allocates compulsory quotas according to the amount of electricity supplied by utility operators. Moreover, concerning PV power, which requires comparatively higher introduction costs than other renewable energies, a proviso has been adopted to count electricity from PV systems as double between fiscal 2011 and 2014. The electric utility operators (36 companies) targeted for obligations will be able to fulfill their obligations by one of the following methods:

① Own power generation

Retail electric utility operators (obligated parties) generate electricity using their own facilities and acquire electricity and the RPS amount[3].

② Purchase from other generators

Operators purchase electricity and an amount corresponding to the RPS from power generators.

③ Purchase of the amount corresponding to the RPS from other generators, etc.

Only purchase the amount corresponding to the RPS from generators, while other retail electric utility operators purchase electricity.

Regarding the current state of the RPS system in Japan, electricity companies have attained levels far in excess of targets, and such surpluses are being repeated year after year, meaning that market expansion is in reality limited. Moreover, since the target amount of power for introduction in 2014 is low at 16 billion kWh (approximately 1.6% of total generated electric energy), system introduction is not growing and cost reductions enabled by mass production are not being realized. Moreover, although it was originally forecast that RPS prices would go down due to competition between generators amidst market principles, in reality only a few electricity companies have purchased the RPS capacity and the market pricing function is not working. Moreover, as with other power sources, the cost of introducing renewable energies is recovered via electricity tariffs within the principle of multiple costing. For this reason, in the event where the target capacity for introduction increases in future, a problem will arise concerning the fact it is not clear who will bear additional costs and to what extent.

(2) Germany

Germany introduced a FIT system in 1991. Under this, grid operators are required to purchase electricity from renewable energies at a fixed price or higher for 20 years. In order to avoid unnecessary cost inflation for consumers, to provide incentives for cost reduction and to support comparatively expensive energy sources, purchase prices were revised so that the level of support corresponds to the cost of introducing each renewable energy (the new costs will be applied to facilities going into operation from 2009). Moreover, according to data disclosed by the German federal environment ministry, the burden of domestic power consumers under the FIT system in

[3] The RPS amount (amount corresponding to electricity from new energy sources) can be traded between operators separate from electricity. This can be utilized for fulfilling obligations and is equivalent to the value of the so-called new energy portion.

2007 is approximately 5% of overall electricity tariffs, representing more than a tenfold increase over the burden in 1998.

(3) United Kingdom

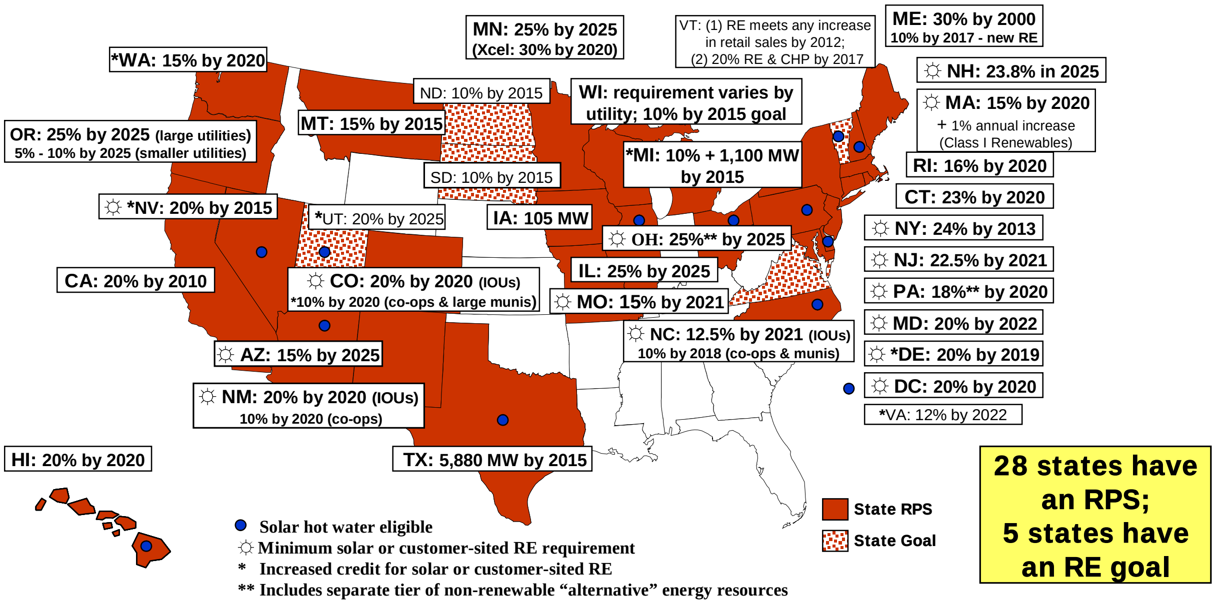
In the United Kingdom, the Renewables Obligation (RO) system was introduced in England and Wales and the Renewables Obligation Scotland (ROS) system was introduced in Scotland from April 2002. Both systems are essentially a variation on the RPS system. The target is to introduce power derived from renewable energies equivalent to 15.4% of sold electricity by 2015, however, a buy-out system has been introduced whereby obligated operators can purchase shortfalls at 3p/kWh (approximately 4 yen/kWh) and paid amounts are refunded according to achieved quotas, and introduced capacity in recent years is not attaining the target capacity. Moreover, from 2010, it has been decided to introduce a FIT system targeting renewable energy power generating facilities of no more than 5,000 kW from 2010.

(4) Spain

In Spain, a FIT system whereby power distribution operators (five power companies) will purchase electricity from renewable energies at a fixed price for 25 years was introduced in 1994. However, because solar heat utilization and PV power generation did not advance as expected, the purchase price underwent a large hike under Edict No. 661/2007 in June 2007, while it was made compulsory for certain buildings undergoing construction and renovation and commercial facilities of a certain area to install solar heat hot water systems and PV power generation systems from September 29, 2006. Following the introduction of these measures, the amount of capacity introduced under PV power generation suddenly increased and the cumulative installed capacity reached the stipulated threshold of 200 MW. In September 2008, it was decided to reduce the purchase price of electricity generated by equipment going into operation after 2009 from the conventional level of approximately 53 yen/kWh to approximately 41 yen/kWh.

(5) United States

In the United States, introduction of the RPS system was previously examined on the federal level, however, introduction was postponed in the Energy Policy Act of 2005 and the Energy Independence and Security Act of 2007. The Obama administration has announced New Energy for America and aims to raise the ratio of renewable energies to 10% by 2012 and 25% by 2025 based on introduction of a federal RPS system. Currently, 28 states and special districts have introduced RPS systems making it compulsory to use renewable energies on the state government level (as of March 2009).



Source： Database of State Incentives for Renewable Energy (DSIRE)

Figure 8.2.2-1 RPS Systems Introduced in the United States

8.2.3 Dissemination Promotion Policies (Draft) in the Maldives

On March 15, 2009, President Nasheed announced a plan for the Maldives to become the world’s first carbon-neutral state based on conversion to renewable energies within 10 years. Accordingly, legal systems should be enacted in line with this concept. In the stage prior to the start of field surveys, the Study Team considered that dissemination measures (RPS system, subsidies, preferential tax system, surplus power purchasing system, feed-in-tariff system) would be required according to each mode of introducing the grid-connected PV system (Measure A). However, findings from the technical feasibility study revealed that capacity for grid-connected PV system introduction would be restricted to 12.6 MW on Male’ Island and 0.89 MW on Hulhumale’ Island. The technical feasibility study also concluded that, from the viewpoint of maintaining power quality following the introduction of grid-connected PV systems, it would be ideal for STELCO to initially take the initiative and to phase in systems in cooperation with the Government of the Maldives. Therefore, a plan to successively introduce 3.97 MW (Male’ Island and Hulhumale’ Island) under STELCO initiative over the coming 10 years including the pilot project period (Measure B) was formulated and, following consultations with the Maldivian side, willingness to cooperate was confirmed from the CEO of STELCO. On the other hand, the Government of the Maldives is successively advancing the privatization of STELCO with a view to attracting private sector capital including foreign investment and thereby improving the financial standing of the electric power sector in general. According to a high-ranking official in the Ministry of Finance, in line with the privatization of STELCO, government subsidies for deficit-covering that have been provided since 2005 will be cut or phased out, and in that event STELCO will have little choice but to enforce major electricity tariff hikes. Moreover, since the government cannot afford to provide subsidies, this means that no subsidies for initial cost will be available from the government to support PV introduction after STELCO becomes privatized. Accordingly, judging that the 3MW of PV introduce capacity is realistic due to the smallest impact to the Maldives finance and assuming a measure based on STELCO initiative, methods for disseminating PV introduction without subsidies were considered (Measure C). The Government of the Maldives is considering building systems for promoting all areas of renewable energy for decades to come. When it comes to introducing and disseminating grid-connected PV systems, although it can be appreciated that entrusting activities to STELCO is a realistic approach, opportunities should also be given to other entities. Therefore, starting from the base of Measure C, examination was conducted assuming additional introduction to the private sector (Measure D). In Measure C, the following support measures for mitigating initial investment, which is the biggest obstacle to introducing PV, were proposed to and jointly examined among the Ministry of Finance, MHTE, MEA, STELCO and other agencies concerned:

(a) Application of preferential tax measures to PV facilities
(b) Utilization of Green Tax
(c) Utilization of Development Expense
(d) Introduction of Carbon Tax
(e) Revision of Electricity Tariff

As a result of discussing these methods with a high-ranking official in the Ministry of Finance, the agreement was generally obtained. Therefore, the Measure D is our final proposal created by considering the measures for mitigating PV introduction initial cost with the wishes of the Government of the Maldives. However, following the privatization of STELCO, since there is a possibility that reshuffling of top management may result in a major change in policy direction, it will be necessary to continue the discussions and pay close attention to the developments regarding privatization of STELCO.

Examination Procedure

Measure A	Introducing entity ▪ STELCO ▪ Private Sector	Select the RPS system, introduction subsidy system, preferential tax system, excess power purchasing system and feed-in tariff system according to the form of introduction.

↓ From the results of the technical feasibility study, potential PV introduction capacity is limited to 12.6 MW on Male' Island and 0.89MW on Hulhumale' Island.

Measure B	Introducing entity ▪ STELCO	Phased introduction under STELCO initiative (establishment of the introduction subsidy system, model of introduction is only ① and ②).

↓ Following privatization of STELCO, existing subsidies for deficit-covering to STELCO will be curtailed or phased out, and I will be difficult to provide new subsidies for initial cost of PV introduction.
And we judge from financial aspect that 3MW is proper as the potential PV introduction capacity.

Measure C	Introducing entity ▪ STELCO	Examine ways to minimize the burden of PV introduction initial cost (if initial cost mitigation measures are realized, subsequent conditions will be the same as Measure B).

↓ Reflect government thinking that all areas of renewable energy should be introduced with private sector participation.

Measure D	Introducing entity ▪ STELCO ▪ Private Sector	Based on Measure C, also examine introduction to the private sector

Source : Prepared by the Study Team

Figure 8.2.3-1 Examination Procedure for Measures geared to Supporting Introduction of Grid-Connected PV Systems

The result of Measure D as our final proposal is shown as follow.

Measure D Examination Results

①Measures for mitigating PV introduction initial cost

In the Measure D, based on the findings of Measure C, the examination was conducted assuming that both STELCO and the private sector introduce the grid-connected PV systems and that introduction to the private sector begins in 2015. The following measures (a)～(e) was examined in the Measure C as the measures for mitigating the PV introduction initial cost. These measures will be applied in the

Measure D for only STELCO after 2015 from the financial conditions in the Maldives (Only (a) will be applied for the private sector as well.) And the grid-connected PV system introduction capacity in the private sector is assumed to 100kW per year from 2015 to 2020.

Measures for mitigating PV introduction initial cost

(a) Adaptation of Preferential Tax Measure Exemption for PV facilities
(b) Utilization of Green Tax
(c) Utilization of Development Expense
(d) Introduction of Carbon Tax
(e) Revision of Electricity Tariff

(a) Adaption of Preferential Tax Measure Exemption for PV facilities

「The Import Tax Exemption」 is proposed, here. The import tax in the Maldives imposes 25% to the equipment price. As a result of the discussing the possibility of the import tax exemption for the PV facilities with a high-ranking official in the Ministry of Finance, the agreement was generally obtained with the feasible. And when the preferential tax will be adapted, the exemption price concerning 2.4MW which STELCO will introduce will be approximately US$9.2million, although the total exemption price concerning 3.0MW is approximately US$11million.

(b) Utilization of Green Tax

「Green Tax」 is the plan which collects US$3 per tourist and foresees to increase the tax income of US$6.3 million（MRf80.6 million）per year in that announcement based on the assumption of 700,000 tourists per year and 3 days as the average staying day. The utilization of the green tax for grid-connected PV system can be thought to relate to the purpose of the green tax, because the power generation by grid-connected PV system can contribute the CO_2 emission reduction. And this green tax is thought as the first priority, because this tax is being imposed from now on and the target of the utilization has not been clarified yet.

(c) Utilization of Development Expense

「The Development Expense」 is the development expense in the capital expense as the resource for the infrastructure development and the equipment investment and is expected as the resource of the financial support for mitigating the PV introduction initial cost by STELCO. This Development Expense can be thought as one of the measures for mitigating PV introduction initial cost, because the introduction of grid-connected PV system as the measure for reduction of the diesel fuel relates to the carbon-neutral policy announced by the Maldives government. However, this development expense is thought as the second priority, because this is the existing resource and there might be the necessity of changing the existing plan.

(d) Introduction of Carbon Tax

「Carbon tax」 generally refers to the system of taxing fossil fuels with a view to the limiting demand, while at the same time using tax revenues for the environmental countermeasures. When this tax is introduced in the Maldives, it is proposed that a tax of a few percentage points be levied on the fossil fuels such as gasoline and diesel so that the collection can be widely implemented. The introduction of the carbon tax which has also the effectiveness as the environmental measures is reasonable, because in the Maldives, especially on Male' Island, there is a high concentration of motorbikes and cars despite the restricted land area, the traffic environment and the public sanitation are in appalling condition. When the carbon tax is introduced, its impact will reach the commodities and the electricity tariff and so on. However, judging from the current standard of living in the Maldives, the minor tariff rises are thought to be acceptable; moreover, the tariff rises will have the effect of enhancing the awareness of the environmental load among the ordinary citizens. However, if this carbon tax is arranged, the imposed rate should be considered as small as possible, because the carbon tax might have the possibility of triggering the increasing electricity tariff again, although there is the new electricity tariff structure was applied on Nov 1st.

(e) Revision of Electricity Tariff

「Revision of Electricity Tariff」 which increases the electricity tariff to cover the shortage which can not be covered by the measures (a)～(d) is proposed as the final measure, here. The reason why this measure is though as the final measure is that it is not realistic to increase the electricity tariff again in the near future against the decision of increasing the electricity tariff on Nov 1st in the STELCO territory.

Table 8.2.3-1 Necessary amount of price in Green Tax, Development Tax and Carbon Tax after Import Tax Exemption in Measure D

Installation by STELCO and private sector (STELCO's portion: 2.4MW)	Contribution Rate from the Green Tax			
	61%	**50%**	**30%**	0%
Necessary amount（US$）		**3,886,424**		
Allowable amount（US$）	3,886,424	**3,150,000**	**1,890,000**	0
Shortfall（US$）	0	**736,424**	**1,996,424**	3,886,424
Ratio of shortfall to the national development expenditure	-	**0.5%**	**1.2%**	2.4%
Collection of shortfall from carbon tax (MRf/kWh)	-	**0.003**	**0.007**	0.014

Source： Prepared by the Study Team

Based on the result of Table 8.2.3-1 and the previous examination, it can be judged that the adoption of 50% or 30% of the green tax would be realistic. That reason is composed of the following 3 items.

① The green tax has the enough remaining part and it can be utilized for the other plans after utilizing for the PV system

② The ratio of the shortfall to the national development expenditure is 0.5% or 1.3%, their ratios are very small and can be thought realistic.

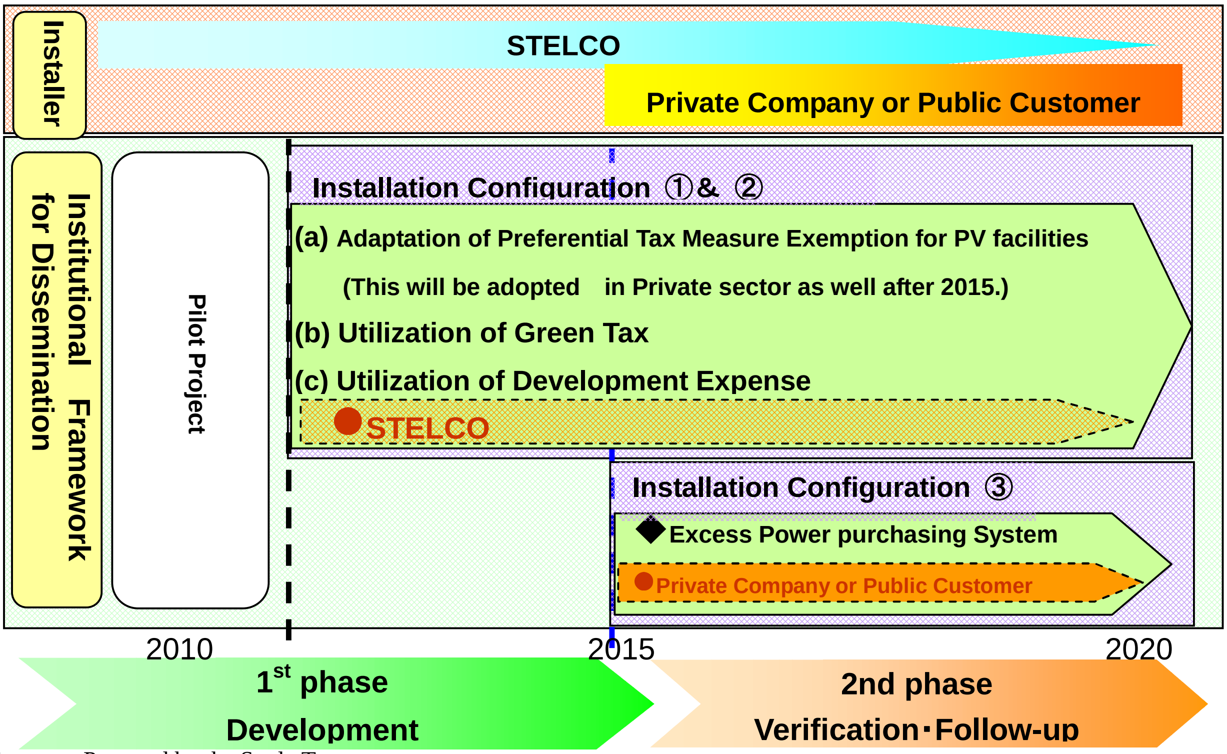
③ The collection of the shortfall from the carbon tax can be mitigated in the small amount.

②Purchasing system for introducing into the private sector

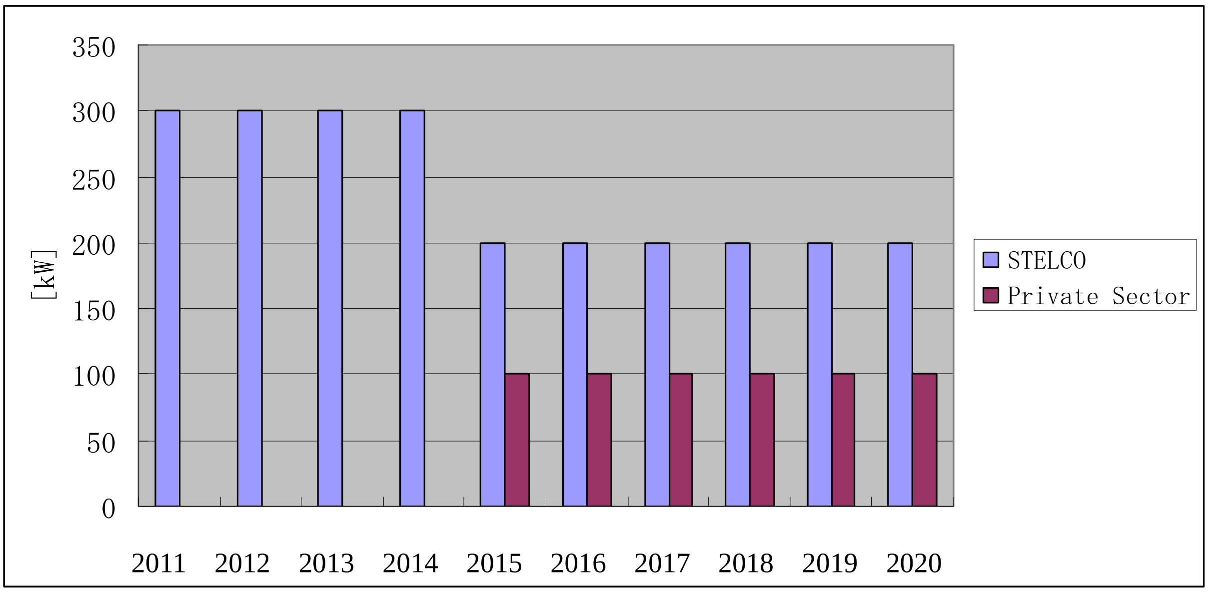
When it comes to introducing to the private sector, two methods, i.e. the total power purchasing system and the excess power purchasing system, are available, however, the latter of these shall be assumed here. This is because, amidst the tight electricity demand and supply situation and difficulties in securing the land for new power generation facility sites, implementation of the excess power purchasing system can be expected to have a secondary effect of limiting the demand for power.

Regarding the purchasing price, it has been concluded that it is appropriate that the purchasing price is set as the same as the unit price of the generating cost or less than the unit cost of the generating cost. Because it is not realistic that if the purchasing price is set t several times of the average of electricity tariff, the payback period will be so long due to the small area in the building roof in the Male' and Hulhumale' Island, the small capacity of the introduced PV system and the small excess power from the introduced PV system. Concerning STELCO, STELCO will not be able to gain any merits if the purchasing price is set higher than the average of electricity tariff. On the other hand, from the result of our hearing investigation to the private sector, it was found out that there are some implementers, etc. who desired to introduce the PV system to gain the merit only by mitigating the energy consumption inside house thanks to the next increasing electricity tariff (Nov. 1st). Accordingly, if the purchasing price is set, it will be able to be the small incentive for the implementers such as the persons who the previous sentence says and STELCO also will be able to gain the merit to purchase the excess power at the cheaper price than the unit cost of the generating cost. Consequently, regarding the purchasing price, the previous conclusion has been achieved, here.

Figure8.3.2-2　Conceptual Image of Dissemination Measures and Systems Introduction in Measure D



Source： Prepared by the Study Team



Source： Prepared by the Study Team

Figure 8.2.3-3　Introduction amount of Grid-connected PV system

Table 8.2.3-2 Projected Form of Policies and Systems for Introducing and Disseminating Grid-Connected PV Systems in Measure D

No.	Mode of Introduction	Installation Site	PV Equipment Owner	Features, Issues, Requirements, etc.	Dissemination Policies, Systems
①	STELCO introduces PV equipment as its own equipment into its own buildings.	Own buildings, etc.	STELCO	- Since the PV equipment and peripheral equipment belong to STELCO, design of the PV installations is easier. - There is some freedom in selecting PV installation sites.	- Revision of electricity tariffs - Establishment and operation of a renewable energy fun - Pooling of revenues derived from electricity tariffs in the pilot project - Application of preferential tax measures to PV facilities
②	STELCO installs its own PV equipment on roofs, etc. leased from other companies.	Other parties' buildings, etc.	STELCO	- Constraints and rental fees on PV installation sites are predicted. - Consultations regarding equipment management and security are required. - Since the PV equipment belongs to STELCO, there is no need to consider charges.	- Revision of electricity tariffs - Establishment and operation of a renewable energy fun - Pooling of revenues derived from electricity tariffs in the pilot project - Application of preferential tax measures to PV facilities
③	Building owners install PV equipment as their own power sources and sell excess power to STELCO.	Other parties' buildings, etc.	Building owners, etc.	- Since systems are normally used for private consumption, there are relatively few backflows of excess power and the impact on distribution lines is small. - Guidelines, etc. concerning technical requirements for protective devices, etc. when connecting to the grid need to be established as fair standards.	- Revision of electricity tariffs - Establishment and operation of a renewable energy fun - Pooling of revenues derived from electricity tariffs in the pilot project - Application of preferential tax measures to PV facilities - Excess power purchasing system

Source : Prepared by the Study Team

8.2.4 Future Issues for Examination regarding the Grid-Connected PV System Dissemination Promotion Policies and Systems

The Measure D is our final proposal in this study which incorporates methods for mitigating the PV introduction initial cost with the wishes of the Government of the Maldives. Table 8.2.4-1 summarizes the future examination issues regarding the dissemination policies and systems.

Table 8.2.4-1 Future Examination Issues regarding Dissemination Policies and Systems

Dissemination Policies and Systems	Future Examination Issues
Application of a preferential tax system to PV installation	- Continuous discussion for realization and clarification of procedure will be necessary.
Utilization of Green Tax	- Evaluation of amount of utilization and continuous discussion will be necessary.
Utilization of Development Expanse	- Evaluation of amount of utilization and continuous discussion will be necessary.
Introduction of Carbon Tax	- Clarification of target, evaluation of amount of utilization and continuous discussion will be necessary.
Revision of electricity tariffs	- Electricity tariffs from Nov 1st will be increased by STELCO, continuous discussion concerning how far tariffs can be raised for PV introduction will be necessary.
Excess power purchasing system	- It is necessary to set the purchase price. - It is necessary to establish criteria for installing excess power measuring meters, etc. - In the event where PV systems are scattered throughout the private sector, it will be necessary to conduct technical support in order to maintain the demand and supply balance and quality of power. - In the event where commercial consumers on Male' Island introduce private power generation, since power supply by STELCO will be suspended, it will be necessary to revise the existing system which makes it impossible to receive STELCO power supply while operating private power generation. - Examination of the maintenance setup is needed.
Other	- Arrangement of guideline for grid-connected PV system for private sector, etc. will be necessary.
General	Concerning dissemination policies and systems necessary for the future introduction and dissemination of PV, the main points have been identified and agreed with the Maldivian side. In future, it will be necessary to discuss these in more detail while carefully watching developments in the privatization of STELCO.

Source： Prepared by the Study Team

7 For details on dissemination promotion policies, see 8.2 (Dissemination Promotion Policies and Systems (Incentives)).

8.3 Technical Criteria and Guidelines, etc. for Introduction of Grid-Connected PV Systems

In the Maldives, connecting private generating equipment to the power grid is currently prohibited, and corporations and individuals who own private generators can only conduct private power supply without receiving power from STELCO. Interconnection is not permitted because private generators are not fitted with adequate synchronous control functions and protective devices and there is concern over negative impacts on the STELCO grid. Moreover, the technical criteria and requirements concerning interconnection are not clearly specified.

When it comes to connecting PV power generation systems to the grid, it will first be necessary to revise these regulations and examine the requirements that are needed for interconnection. Table 8.3-1 shows the current conditions and technical requirements from the viewpoints of stable supply, power quality, network protection, security and operation (based on the Japanese Grid-Connection Requirements and Guidelines related to Securing Power Quality, October 1, 2004, of the Natural Resources and Energy Agency) that will need to be examined in the Maldives from now on.

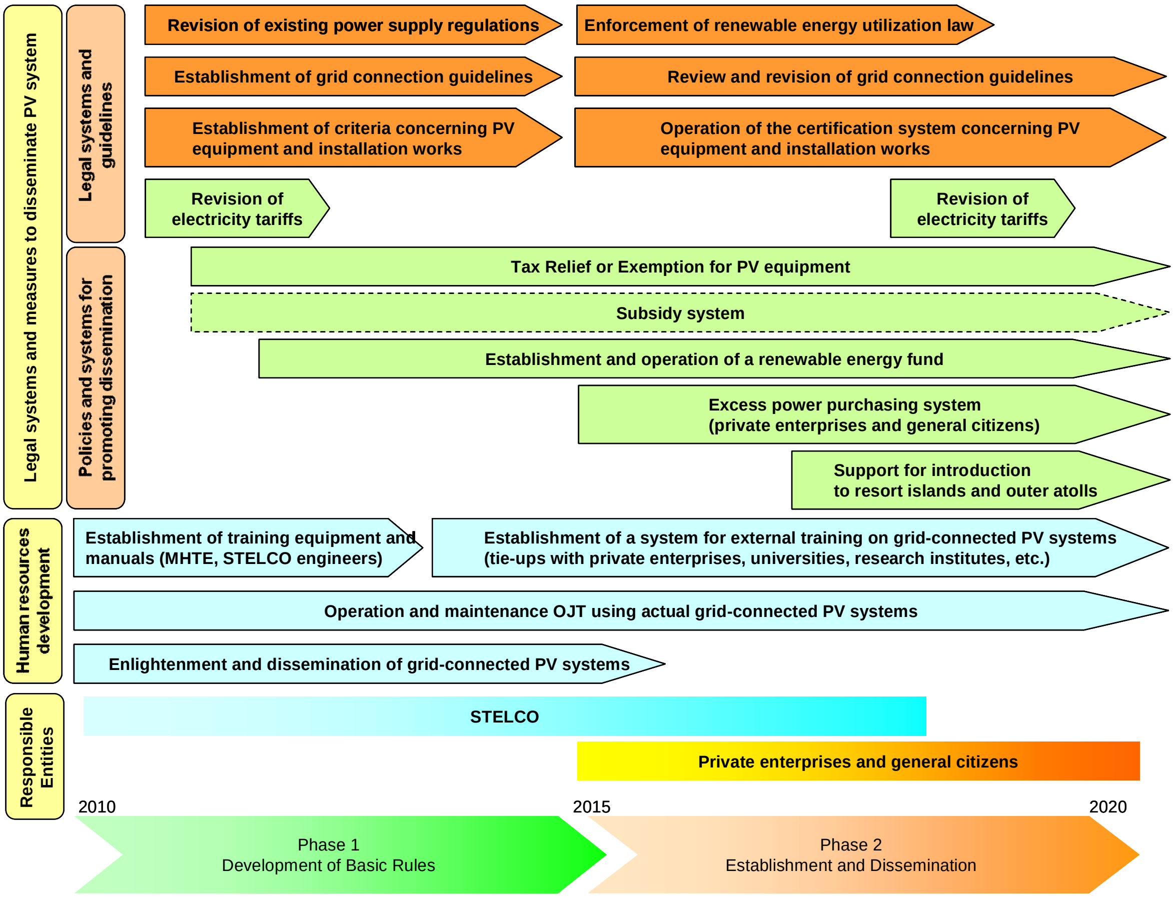
Table 8.3-1 Technical Requirements of Grid-Connection Guidelines and Results of Examination of Application to the Maldives

Item						Examination Issues
Power capacity		Less than 50 kW	Less than 2,000kW (Including special high voltage distribution lines (no more than 35 kV) less than 10,000 kW)	Less than 10,000 kW	2,000kW or more	As a result of the potential study, there is no possibility of connecting 2,000 kW or more at 1 site.
Voltage class		Low voltage distribution lines	High voltage distribution lines	Spot network distribution lines	Special high voltage distribution lines	Low voltage (230/400V) or high voltage (11,000 V) interconnection. Examine separately for each grid-connected system without establishing capacity divisions.
		100/200V	6,600V	22kV or 33kV	7kV or more	
Protective equipment		Over voltage relay (OVR) Under voltage relay (UVR) Over frequency relay (OFR) Under frequency relay (UFR)	Same as left	Same as left	Same as left	Only in cases of three-phase interconnection concerning overvoltage (OVR), undervoltage (UVR), over frequency (OFR) and under frequency (UFR) and overvoltage ground (OVGR)
		-	Overvoltage ground relay (OVGR)			
Islanding operation (Detection method)		Prohibited			With reverse power: Possible (frequency relay or transfer trip system is required)	For security and operation reasons, prohibit islanding operation and adopt both active and passive detection functions as standard.
		Both active and passive method	Same as left	Reverse power relay (RPR)	Without reverse power: Prohibited (Frequency relay or reverse power relay)	
Power factor	With reverse power	・As a rule, power factor at the receiving point shall be 85% or more seen from the grid side and shall not be the leading power factor. ・If necessary for preventing voltage increase, the power factor can be held to 80%. ・When using a small output inverter or in cases where the receiving point power factor is deemed appropriate as in general households, the generating facility power factor shall be at least 85% when controlling with reactive power and at least 95% when not controlling.			Value to sustain an appropriate voltage on the grid	Adopt a power factor where the voltage fluctuation at the interconnection point is within the scope of voltage control criteria (nominal voltage±10%).
	Without reverse power	Generating facilities power factor is 95% or more.	As a rule, power factor at the receiving point shall be 85% or more seen from the grid side and shall not be the leading power factor.			
Automatic load control			When there is danger of interconnected power lines or transformers going into overload when generating facilities drop out, take automatic limiting measures.			As a rule, do not install automatic load control, and secure equipment capacity that ensures there is no overload even when the generating equipment drops out.
Countermeasures for Constant voltage fluctuation		When there is danger of deviation from appropriate values for low voltage consumers due to reverse power, take steps to automatically adjust voltage by using the reactive power control function or output control function. (However, this function may be omitted in small output inverters). If the above steps cannot be taken, reinforce distribution lines and so on.	When there is danger of deviation from appropriate values for low voltage consumers connected to general distribution lines, take automatic load control measures. If these are insufficient to resolve the problem, reinforce distribution lines or connect with dedicated lines. When there is danger of deviation from appropriate values for low voltage consumers due to reverse power, take steps to automatically adjust voltage through using the reactive power control function or output control function.	When there is danger that voltage fluctuation caused by drop-out of generating facilities will deviate from the constant voltage by more than 1-2%, take measures to automatically limit load.	When there is danger that voltage fluctuation caused by drop-out of generating facilities will deviate from the constant voltage by more than 1-2%, take measures to automatically adjust voltage.	Secure equipment capacity to ensure that the scope of voltage control criteria (nominal voltage±10%) is not deviated from even when the generating equipment drops out. If there is risk that back flows will cause deviation outside of the voltage control criteria scope, equipment with the reactive power control function or output control function.
Instantaneous voltage fluctuation countermeasures		Adopt a self-exciting inverter possessing automatic synchronizing function.				Same as left
Prevention of unexpected parallel-off		Adopt a system whereby parallel off doesn't arise and operation can be continued or automatic return can occur when instantaneous voltage drop time and setting time are within the under voltage relay setting time.	Ensure that parallel off doesn't arise in cases of failures outside of the connected grid. If parallel off does occur, adopt a system whereby unwanted breaking (breaking other than that if independent operation) can be avoided in the generating facilities due to excessive power fluctuation within a time shorter than the automatic switching time of parallel off caused by reverse power relay or under voltage relay, etc.	Ensure that parallel off doesn't arise in cases of failures outside of the connected grid. With respect to failures in the interconnected grid and up to the protector circuit breaker, open the protector circuit breaker in the failed line and maintain the connection with sound lines without conducting parallel off.	Ensure that parallel off doesn't arise in cases of failures outside of the connected grid. If parallel off does occur, adopt a system whereby unwanted breaking (breaking other than that if independent operation) can be avoided in the generating facilities due to excessive power fluctuation within a time shorter than the automatic switching time of parallel off caused by reverse power relay or under voltage relay, etc.	Protective relay settings (including time settings) shall be variable. Adopt the settings established by STELCO to prevent parallel off due to faults on other feeders.
Communication system		Install security communications telephone facilities (dedicated security telephone equipment, telecommunications operator special line, general telephone or mobile phone, etc.) between the business offices or dispatching centers of electric operators on the grid side and installers of generating facilities, etc.			Connect with a special high voltage power line of 60 kV or more and, in cases where there is reverse power flow, install supervision or telemeter equipment between dispatching centers of operators on the grid side and installers of generating facilities, etc.	As a result of the study, communications equipment such as security phone equipment, etc. is deemed to be unnecessary. Concerning online measurements, etc., examine separately according to the grid operating needs.

Source：Prepared by the Study Team based on data of the Natural Resources and Energy Agency in Japan

8.4 Medium to Long-Term Plans for Introducing Grid-Connected PV Systems

When it comes to introducing grid-connected PV systems and promoting dissemination over the medium to long-term, the first thing to do is to establish a single roadmap (see Figure 8.4-1) for related agencies and organizations including other donors and to clarify the respective roles of each. The Study regards 2020 as the target year and divides the coming 10 years into Phase 1 (2010~2015) and Phase 2 (2016~2020), and the medium to long-term plans to disseminate grid-connected PV systems in each phase are as indicated below. Furthermore, an examination of human resources development based on capacity assessment of organizations and personnel concerned with the introduction of grid-connected PV systems is given in 8.6.



Source： Prepared by the Study Team

Figure 8.4-1 Roadmap (Draft) geared to Dissemination of Grid-Connected PV Systems

(1) Phase 1: Development of Basic Rules (2010~2015)

In this Phase 1, immediately after completion of the Study, utilizing the outputs of the pilot project which is planned and designed in the Study, it is desirable to actually introduce and start operating grid-connected PV systems as early as possible, with a view to utilizing the outputs of dissemination measures, human resources development and technology transfer. Moreover, through accumulating and assessing implementation design, tender and consultant supervision know-how and operating data acquired during the pilot project, it will be important to prepare for the introduction of grid-connected PV systems by private sector enterprises and ordinary households in the Phase 2 period. At this stage, since it is still too early to introduce grid-connected PV systems by private enterprises and households, the plan is for STELCO to take the initiative in introducing systems to government buildings and public facilities such as schools and hospitals, etc. in Male' Island and at the same time to widely inform the citizens of the Maldives about the effects of PV systems. Also, when STELCO promotes the introduction of grid-connected PV systems, it will be necessary to train and educate possible retailers and contractors for PV equipment who will take the initiative in installing systems to private sector in the future.

1) Establishment of Legal Systems and Guidelines

In order to promote the introduction of grid-connected PV systems to private sector enterprises and general households in the Phase 2 period, it will be necessary for the government to establish the following regulations and guidelines concerning power supply reliability and quality, public safety and safety for electrical works during this Phase 1 period.

① Revision of existing electric power supply regulations

The legislation regulating the electric utility in Maldives is the Law governing public services (Law No. 4 of 1996). According to Article 2, this law defines public services as electric power, telephones, public water supply, and sewerage. According to Article 3 of this law, parties that implement public services (government agencies, state-owned enterprises, private operators) must register with government regulatory agencies and comply with the regulations imposed by such agencies.

Based on Article 3 of the Law governing public services, the specific contents of regulations pertaining to the electric utility are stipulated in the "Regulations on public supply of electricity in Male' and outer Atolls (1993)" established by the Maldives Energy Authority (MEA), which is the regulatory agency for the electric utility. According to Article 1 of this regulation, entities that aim to operate electric utilities must register to MEA and receive the necessary approval. These regulations prescribe the basic technical items that need to be followed by electric utility operators concerning power generating and distribution facilities. For power generating facilities, since existing regulations were compiled only for diesel power stations, it will be necessary to stipulate the minimum required criteria from the viewpoint of quality control for PV equipment assuming the case where entities other than STELCO introduce grid-connected PV systems.

② Grid-connection guidelines

After Phase 2 period, since grid-connected PV systems will be introduced through private sector enterprises and ordinary households, it will be necessary to establish technical requirements concerning grid connection and provide guidelines that facilitate fair technical discussions between entities to install PV system and the electric utility (STELCO). The Japanese Grid Connection Technical Requirements and Guidelines, which were announced in 1986, have undergone numerous revisions reflecting technical development trends and changes to the electric utility law, and the original guidelines were divided into the “Interpretation of Technical Standards for Electric Facilities” and the “Technical Requirements and Guidelines for Grid Interconnection for Securing Quality of Power Supply” in 2004. Similarly, it is forecast that guidelines in Maldives will need to undergo revisions from Phase 2 onwards to reflect changes in the environment.

③ Technical criteria concerning PV instruments and installation works

Standards of the IEC (International Electrotechnical Commission) are widely applied as international standards for PV generating instruments, however, in Japan, designs based on JIS criteria are more common. IEC Technical Committee 82 (PV generating systems) is currently surveying applied standards in each country and is seeking to promote common standards with the IEC standards. In Maldives, since the potential capacity for system introduction is relatively limited, it is unrealistic to expect the establishment of new domestic standards. Rather, it is more important to ensure thorough quality control of PV-related products through applying international standards (IEC, etc.) and establishing the product inspection setup when works are complete. The existing STELCO workshop on Male’ Island is the ideal place for implementing PV product inspections, however, it will first be necessary to receive MEA authorization for the applied standards and to establish a manual for product inspections. In addition, when purchasing grid-connected PV systems, rather than purchasing PV modules and power conditioners as isolated items, it is better to select manufacturers who can procure, install, test and adjust total systems, and thereby ensure that poor quality products from emerging countries do no enter the domestic market.

2) Dissemination Promotion Policies and Systems

During Phase 1 period, the target will be for STELCO to achieve the PV installation capacity for 2015 in accordance with the plan proposed in the technical feasibility study while utilizing experience from the pilot project. Accordingly, the MHTE (or MEA) shall establish a pool system utilizing generated electric energy returns from the grid-connected PV systems installed under the pilot project, and use this to subsidize the initial investment required to introduce grid-connected PV systems as scheduled. Other methods for mitigating initial investment include exemption or reduction of import duties for PV products, introduction of Green tax or Carbon tax, establishing a Renewable Energy Fund, revising electricity tariffs, and so forth[7]. When it comes to the Phase 2 activity of introducing grid-connected PV systems to private sector enterprises and ordinary households, it is planned to encourage introduction through the excess power purchasing system, so it will be necessary to start examinations into methods for setting the excess power purchase price, measuring surplus power and reading meters under this system.

(2) Phase 2: Establishment and Dissemination (2016~2020)

1) Establishment of Legal Regulations and Guidelines

The legal regulations and guidelines for introducing grid-connected PV systems which were established in Phase 1 will undergo amendment and revision during Phase 2 period based on actual operating performance. This will be important for building a regulatory setup which corresponds to actual conditions. Towards this end, regular meetings (around once every six months) will be held between the MHTE, MEA, STELCO and entities who install grid-connected PV system to discuss issues in current legal regulations and guidelines, impediments to future large-scale system introduction and necessary improvements. The MEA will probably take the initiative in these examinations, however, since MEA doesn't currently possess the organizational or personnel capacity to do this, it will be necessary to consider the utilization of technical cooperation by Japan and other donors as well as the recruitment of foreign consultants.

In Japan, "Act on the Promotion of New Energy Usage (New Energy Law)" and "Act on Special Measures concerning New Energy Usage by Electric Utilities (RPS Law)" contain the basic government policy concerning the comprehensive promotion of new energies. In the rest of Asia, Renewable Energy Act of 2008, R.A.9315 was established in the Philippines on December 16, 2008, and based on this the Philippine government is promoting renewable energies through the establishment of the State Renewable Energy Department and provision of tax exemptions. In Maldives, no such legal systems exist, and there are no legal stipulations concerning numerical targets for introduction of renewable energies including grid-connected PV systems, provisions in the event where targets are not met, and the division of roles between related organizations and so on. Moreover, in order to attract major investment in the future, it will be necessary to examine preferential tax systems concerning income tax and indirect taxes, etc., and legislative measures will be essential in such case. However, since the potential capacity for grid-connected PV system introduction on Male' Island and Hulhumale' Island by 2020 is limited, it may be more realistic to reexamine the necessity for more strict measures based on a renewable energy law while considering the actual dissemination after Phase 1 period.

2) Establishment of Dissemination Promotion Policies and Systems

As was mentioned in 8.2, the Study Team has proposed excess power purchasing system for promoting the introduction of grid-connected PV systems to private sector and general households in tandem with planned introduction to STELCO in Phase 2. When it comes to applying such a system, it may be necessary to adjust the unit purchase price while regularly monitoring the scale of PV systems being introduced by general households. Under the Study, PV introduction targets are set for each year with a view to achieving the target capacity by 2020, and it will be necessary to review the target years and capacities for introduction while taking the government's latest renewable energy policies and actual introduced capacities into account. Also, since Maldives does not have a master plan of energy supply including renewable energies, it will be desirable to compile a nationwide medium to long-term master plan which includes outer atolls taking into account dissemination of grid-connected PV systems in the Male' metropolitan area during Phase 1. In addition, another future issue will be the widespread education and awareness raising of PV system and DSM techniques to people including MATI and resort owners, etc.

8.5 Action Plan for Introduction of Grid-Connected PV Systems

This section describes the action plan for implementing the medium to long-term plan indicated in 8.4 by the entities involved in grid-connected PV system introduction, i.e. the MHTE, MEA and STELCO. In Maldives, PV systems have been introduced under donor support in the past, and the MHTE, as the policy planning department, follows up system maintenance conditions and conducts troubleshooting, etc. However, expected roles and responsibilities among the said three organizations are unclear. Therefore, as is shown in Table 8.5-1, the Study Team has prepared the action plans required of each entity for grid-connected PV system and has obtained the consent of each entity in separate consultations.

As is shown in the table, the MHTE, which is the supervisory agency in charge of energy administration, manages the formulation and implementation of policies for promoting the dissemination of grid-connected PV systems, while the MEA compiles and manages the necessary regulations, guidelines and technical criteria, etc. based on the said policies. It is desirable that the electricity utility, STELCO, compiles demand and supply plans that take the future introduction of grid-connected PV systems into account, plans and designs systems, and takes charge of maintenance.

In this way, when introducing grid-connected PV systems, it is necessary to clarify the roles of each organization and to establish the work flow starting from the upstream ministry (MHTE) and moving down through the independent monitoring agency (MEA) to utility (STELCO).

Table 8.5-1 Action Plans for Dissemination of Grid-Connected PV Systems

		MHTE	MEA	STELCO
Role required as an organization [Note]		➢ Compilation and implementation of energy and electric power policy ➢ Setting of medium to long-term development plans and development targets ➢ Collaboration with multinational agencies and donors ➢ **Planning and implementation of dissemination promotion policies for introducing PV power generation**	➢ Compilation and implementation of energy and power supply regulations (for implementing the policies compiled by the MHTE) ➢ Authorization with respect to power generation and retailing electric utility operators ➢ Approval for grid-connected PV installation applications ➢ Totaling and management of energy statistics ➢ **Compilation and operation of regulations and guidelines necessary for introducing grid-connected PV systems**	➢ Power supply according to the regulations compiled by the MEA ➢ **Compilation of demand and supply plans that take the introduction of grid-connected PV systems into account** ➢ **Design of grid-connected PV systems according to the regulations and guidelines prepared by the MEA** ➢ **Operation and maintenance of grid-connected PV systems**
Action plan	Short-term	➢ Completion of national energy policy that integrates the manifesto of the ruling party (Maldivian Democratic Party) ➢ Establish a pool system for accumulating future investment funds, and save profits calculated from the generated electric energy in the pilot project. ➢ In accordance with the recommendations of the Study, compile and implement support measures (subsidies, surplus power purchasing system) for promoting introduction of grid-connected PV systems. ➢ Enlightenment and dissemination activities targeting private enterprises and ordinary citizens based on the pilot project ➢ Renew the F/S contents and update future grid-connected PV introduction plans.	➢ Compilation and implementation of legal regulations and guidelines for implementing support measures for promoting grid-connected PV system introduction as compiled by the MHTE ➢ Compilation of PV equipment technical criteria and installation criteria. ➢ Revision of electricity tariffs for making up the initial investment required for introducing grid-connected PV systems ➢ Assessment and monitoring of grid-connected PV systems installed in the pilot project ➢ Preparation of application and consultation procedures and documents assuming applications for connection from private enterprises and general consumers	➢ Enhancement of operation and maintenance capacity via the operation of grid-connected PV systems installed in the pilot project ➢ Addition of training items related to grid-connected PV system operation and maintenance in the external training system. ➢ Preparation of electricity demand and supply plans that assume introduction of grid-connected PV systems ➢ Preparation of measuring and tariff collection methods that assume introduction of grid-connected PV systems ➢ Activities for enlightenment of private sector enterprises and ordinary citizens via implementation of the pilot project ➢ Preparation of methods for determining feasibility of grid connection regarding applications for connection from private sector enterprises and ordinary citizens
	Medium to long-term	➢ Support for establishment of a Renewable Energy Fund (provisional name) by the Ministry of Finance ➢ Compilation of a National Energy Master Plan integrating grid-connected PV systems and isolated PV systems ➢ Compile and implement support measures for promoting introduction of grid-connected PV systems in outlying atolls. ➢ Promote introduction of PV power generation and DSM to resort islands in cooperation with the Ministry of Tourism, Art and Culture.	➢ Preparation of legal regulations for introducing PV systems to outlying atolls and resort islands ➢ Establishment of an authentication system concerning PV-related equipment and installation works ➢ Implementation of authorization for tariff setting, measuring and tariff collection in the surplus power purchasing system ➢ Establishment of a monitoring setup for PV systems installed on outlying atolls (for example, liaison offices, agents, etc.)	➢ Staging of seminars for enhancing the design capacity of private enterprises and works contractors in grid-connected PV system projects ➢ Implementation of tariff setting, measuring and tariff collection in the surplus power purchasing system

(Note) The roles required when introducing grid-connected PV systems are indicted in bold lettering.

Source： Prepared by the Study Team

8.6 Human Resources Development Plan

8.6.1 Capacity Assessment of Counterpart Agencies, etc.

(1) Capacity on the Individual Level

The Energy Section, which is responsible for energy administration within the MHTE, has ten employees, of them only two engineers the Assistant Director, Ahmed Ali, is an engineer (MA in engineering), while the other seven are graduates of high school regular courses. Of these seven, two studied for a year at a technical institute and obtained electrical and electronic engineering certificates, however, they do not possess a technical skill based in practical work. Accordingly, the MHTE wants to send these personnel overseas in order to learn energy policy and regulation, energy economics, energy security and renewable energies, etc. However, because the Energy Section does not have a plan or budget for human resources development, it will be necessary for prospective government employees to apply for and succeed in overseas study programs.

MEA has four employees including one engineer. He has worked as a lecturer of electrical and electronic engineering at a college of higher education.

STELCO has a workforce of 449 employees, however, there are only 20 electric engineers who are qualified as Professional Engineers, while only two engineers have experience of PV planning and operation. One of these engineers worked on the RETDAP project under UNDP, while the other has worked in the telephone company Dhiraagu. Both these engineers have acquired technology while using resources outside of STELCO.

In all organizations, the counterparts for the Study Team are willing to cooperate with the Study Team on Fridays and Saturdays even after regular working hours, and they displayed a lot of interest in the Study, high willingness to participate and adequate awareness of the need to introduce grid-connected PV systems. However, top managers tend to be swamped in everyday work and have little prospective or incentive for medium to long-term. As they have depended on donor support in the past, they generally display little ownership on projects.

(2) Capacity on the Organization Level

Capacity on the organization level refers to material, human and intellectual resources, ownership, organizational management setup and organizational culture[8] necessary for resolving issues and achieving goals that have been imparted to an organization or taken on by the organization itself. Concerning human resources, in order to introduce grid-connected PV

8 “Case Analysis concerning Capacity Development (CD), Energy Efficiency and Conservation”

systems to Maldives, it is important for MHTE, MEA and STELCO to secure adequate employees, and for these employees to have incentive to fulfil their duties and accumulate skills inside the organization. However, MHTE and STELCO employees frequently undergo transfers (overseas training is especially frequent) and skills that are acquired in manufacturer training programs, etc. tend to stay with individuals. The intellectual resources management is also inadequate and document and electronic data storage methods are left on individuals, meaning that organizations cannot deal with the situation when staff members are absent or transferred.

Although the MHTE has a Human Resource Section, it only gathers the training (overseas study) needs of each section and presents them to the Ministry of Human Resource, Youth and Sports, however, it needs to prepare a setup for developing human resources in a planned manner. Similarly, as for MEA, collecting applications for OJT and overseas study programs is the main activity of human resources training, and no organized setup has been established.

Human resources training in STELCO consists of the following activities: ① Off-JT by internal and external experts (consumer services, computer skills, cable connections, DEG maintenance, general affairs, linguistics, financial affairs, etc.), ② OJT by senior staff, and ③ training by consultants and manufacturers when handing over projects. In the past, STELCO utilized the overseas training system to allow between two and five employees to obtain degrees in Australia, the United Kingdom, Malaysia and Singapore, etc. every year, however, this system was discontinued in 2003 due to deterioration of financial condition. The STELCO Human Resource Department is composed of six employees and works on gathering annual training needs and compiling training plans in each department, however, the training budget was cut in 2009 due to the worsening financial situation. Table 8.6.1-1 shows the Off-JT contents that were implemented in 2008.

Table 8.6.1-1 Off-JT by STELCO (Fiscal 2008)

Training Mode	Training Contents	Period	Trainees
In-house training	Computers (basics)	9 days	23 people
	High and low voltage cable connections, terminal processing methods	2 days	35 people
	Firefighting training (Male' Island, outlying atolls)	7 days	All employees
	Consumer relations (basics)	3 days	27 people
	Consumer relations (applied)	4 days	30 people
	Language (English)	8 months	21 people
External training and seminars (domestic)	Invitation to the Islam capital market	1 days	3 people
	Management of corporate reform	2 days	1 person
	International accounting standard	2 days	2 people
	Islam credit seminar	1 days	2 people
	4 roles of leaders	2 days	20 people
	Computers (applied)	2 months	14 people
External training (overseas)	Energy management (Pakistan)	8 days	1 person
	Cummins Co. engine repair and maintenance (India)	1 month	10 people
	Wartsila Co. engine repair and maintenance (India)	19 days	9 people
	Electric power market development program (Sri Lanka)	7 days	1 person

Source： STELCO

Concerning teaching materials for human resources development and training, manuals are distributed for training in consumer services, computer skills and cable connections, while no teaching materials are used for Off-JT training. As for post-training evaluations, there are some external lecturer programs where post evaluations are implemented, however, the Human Resource Department has no consistent training evaluation system.

(3) Capacity on the Social and Institutional Levels

Concerning capacity on the social and institutional levels, the Study Team ascertained the capacity of government agencies (stakeholders) which have jurisdiction over public facilities (schools, stadiums, hospitals, etc.) expected to be among the first to introduce grid-connected PV systems, and also legal systems and the mechanism to introduce grid-connected PV system.

1) Government Agencies

The public facilities that were confirmed as potential sites in the Study are owned by the following agencies:

√ Government offices, etc.: Ministry of Finance and Treasury
√ Hospitals: Ministry of Health and Family
√ Schools: Ministry of Education
√ Social Center, National Stadium: Ministry of Human Resources, Youth and Sports

Courtesy calls were made to the above agencies and, upon explaining the contents of the study and requesting cooperation, they expressed a strong interest in grid-connected PV systems and cooperated with the site surveys. These government agencies do not adopt an organized approach to climate change and global environmental problems like their Japanese counterparts, however, it would be difficult to expect such capacity in Maldives too. In order to advance the introduction of grid-connected PV systems, it will first be necessary to conduct organized awareness raising activities that involve these government agencies.

2) Legal Systems and Mechanisms

The Maldives has no Laws or Acts for promoting the introduction of renewable energies including PV power generation (equivalent to the New Energy Law and RPS Law in Japan), however, the MHTE recognizes the need to immediately establish a legal system.

8.6.2 Direction of Human Resources Development

In this section, examination is carried out on the direction of human resources development based on the aforementioned capacity assessment findings. On the individual level, during the course of the Study, capacity building has been conducted based on planning and design capacity to introduce grid-connected PV system. Through implementation of the pilot project, it is anticipated that necessary skills for supervision, operation and maintenance for grid-connected PV systems are acquired primarily among STELCO engineers. Concerning capacity on the organization level, in the case of STELCO, it is possible to achieve a certain level of capacity building through adding training programs on grid-connected PV system planning, design, operation and maintenance by external experts (overseas manufacturers and power companies). In case of MHTE and MEA, it is first necessary to establish mission statements and division of duties including conventional energy supply, and then to examine the direction of human resources development for introducing renewable energies and grid-connected PV systems (see 8.4). As for the social and institutional level, after completion of the Study, it will be necessary to advance preparations for introducing regulations and guidelines concerning the Renewable Energy Law (provisional name) and grid connections.

Table 8.6.2-1 Direction of Human Resources Development (Draft)

	Individual	Organization	Social Systems
①Capacity Assessment			
Current issues	→ Since staff have no practical experience of introducing grid-connected PV systems, they cannot conduct the planning and design required for new system introduction. → Staff do not known what to do if existing grid-connected PV systems break down. → Each staff member has a strong sense of responsibility and mission, but they are so inundated with everyday work that they cannot think ahead in the medium to long-term. → Staff have long depended on support from donors and thus have little sense of ownership towards projects.	→ There is no training system for technical employees. → There is a shortage of engineer-class employees equipped with knowledge of renewable energies and PV. → Employees do not stick with the organization due to overseas study and job transfers.	→ There are no Acts geared to the introduction of renewable energies. → Current regulations only target DEGs, but there are no regulations for PV. → There are no standards equivalent to the grid connection standards that exist in Japan.
Capacity needed to resolve issues (short-term)	→ Grid-connected PV system planning and design capacity → Grid-connected PV system maintenance and operation capacity	→ Review the division of roles of each organization and confirm duties that can be implemented under the current setup. → Confer incentives to encourage employees to continue working and to accumulate knowledge and skills within the organization.	→ Resolution of technical issues necessary for grid connection of distributed power sources.
Capacity needed to resolve issues (medium to long-term)	→ The ability to execute work with strong incentive and ownership	→ Establish a training system for technical employees.	→ Introduce a Renewable Energy Act. → Revise existing regulations to include stipulations on PV.
②Issue resolution through the development study			
	→ Improvement of grid-connected PV system planning capacity based on F/S joint work, and enhancement of ownership over plans. → Improvement of detailed design capacity through Pilot Project design → Transfer of operation and maintenance techniques utilizing existing PV systems	→ Recommendation of division of duties and setups for each organization necessary for introducing grid-connected PV systems → Extension of knowledge and skills within the organization utilizing counterpart training	→ Recommendations concerning response to technical issues necessary for grid connection of distributed power sources.
③Issue resolution following completion of the development study			
	→ Learning of grid-connected PV system installation works supervision and operation and maintenance techniques via the Pilot Project. → Learning of grid-connected PV system technology through internal OJT and self-development. → Conferral of incentives (internal recruitment, awards, etc.) for encouraging self-development, and provision of necessary teaching materials and documents, etc.	→ Establish a training system for technical employees based on internal lecturers and lecturers from PV makers.	→ Introduce the Renewable Energy Act. → Revise existing regulations to include stipulations on PV.

Source： Prepared by the Study Team

8.6.3 Human Resource Development Plan

Human resources development comprises three major components: they are ① OJT conducted through everyday work, ② intensive training outside the workplace (in-house training, external training, training at education agencies, and overseas training) i.e. Off-JT, and ③ Self-development. Since all three types are interlinked, it is desirable to combine all three when developing human resources.

In case of Maldives, since there are hardly any people with experience of introducing grid-connected PV systems, it will be difficult to acquire skills through OJT. On the other hand, operation and maintenance technology for conventional power generation and distribution equipment is largely diffused in the workplace via OJT. Accordingly, concerning grid-connected PV systems, potential workplace lecturers who can conduct OJT have been selected and the technical transfer contents indicated in Table 8.6.3-1 are being conducted through jointly conducting technical F/S and detailed design during the Study. Also, major counterparts from MHTE, MEA and STELCO have participated in counterpart training in Japan to learn the subjects such as renewable energy policy, incentive measures to introduce PV system, plan and design of grid-connected PV system. Therefore, those counterparts are expected to disseminate the knowledge and skills inside their organization.

Table 8.6.3- 1 Contents of Technical Transfer Implemented in the Study (including Counterpart Training)

Classification	Contents	Targets
Energy and electric power utility in general	Structure of the electric power utility in Japan	MHTE, MEA
	Policies and systems for introduction of renewable energies in Japan and other advanced countries	MHTE, MEA
	Thinking behind introduction of measures and systems for introducing PV power generation	MHTE, MEA
	Issues and countermeasures for CDM project plans	MHTE, MEA
PV power generation in general	Types and characteristics of PV systems	MHTE, MEA, STELCO
	Legal systems related to PV power generation	MHTE, MEA
	Consideration of social and environmental impacts of PV power generation introduction	MHTE, MEA
	Economic assessment of PV power generation	MHTE, MEA
	Measurement of PV system characteristics	STELCO
	Solar radiation data measurement and utilization methods	MHTE, MEA, STELCO
	Techniques for measuring solar radiation obstructions	STELCO
	Technique for planning layout of PV panels	STELCO
	PV technology research and development	MHTE, MEA, STELCO
Grid-connected PV power generation	Component instruments and their roles in grid-connected PV power generation systems	MHTE, MEA, STELCO
	Issues and technical items in grid connection	MHTE, MEA, STELCO
	Method for measuring power source quality at grid connection points	STELCO
	Technique for selecting sites for introducing grid-connected PV systems	MHTE, MEA, STELCO
	Detailed design technique for introducing grid-connected PV systems	STELCO
	Grid-connected PV system operation and maintenance techniques	STELCO

Source： Prepared by the Study Team

After completion of the Study, it will be necessary to carry out technical transfer of the items indicated in Table 8.6.3-2 taking the above contents into account. However, MHTE, MEA and STELCO will find difficulty to appoint the candidate instructor (trainer) for the technical transfer. Thus first of all “Trainers’ Training” to develop the core of human resource development will be necessary. Concerning the method of Trainers’ Training, Off-JT is effective, and it will be realistic to transfer technology through periodically inviting external lecturers from overseas ministries, power companies and PV system manufacturers and using actual equipment. Together with Off-JT, it will also be necessary to adopt incentives (internal promotions, awards, etc.) to encourage self-development among employees and provide necessary teaching materials, manuals and so on. Already the Study Team has prepared and explained the contents of “Design Manual for Grid-connected Photovoltaic System” in Attachment-6. Now Maldives side is expected to develop their own materials and manuals in reference to the above-mentioned materials, taking into consideration of engineering and technical capacity of their own organization.

Table 8.6.3-2 Contents of Technical Transfer Required in Future

Classification	Contents	Target
Basic knowledge of PV systems	Types and features of PV systems	MHTE, MEA, STELCO
	Roles and operating principles of PV system component instruments	MHTE, MEA, STELCO
	Characteristics of PV panels (solar radiation, temperature and I-V characteristics)	MHTE, MEA, STELCO
	Solar radiation data measurement and utilization methods	MHTE, MEA, STELCO
	Economy of PV systems	MHTE, MEA, STELCO
Design of grid-connected PV systems	System installation site survey techniques	MHTE, MEA, STELCO
	PV module selection and array examination methods	MHTE, MEA, STELCO
	Installed capacity calculation and specifications examination methods	MHTE, MEA, STELCO
	Stand design techniques	MHTE, MEA, STELCO
	Generated electric energy potential estimation techniques	MHTE, MEA, STELCO
	Design software (HOMER, RET screen, etc.) utilization methods	MHTE, MEA, STELCO
Grid-connected PV system operation and maintenance	System functions and operating methods	STELCO
	System routine inspections and periodic inspections	STELCO
	System maintenance	STELCO
	Troubleshooting	STELCO
PV power generation-related legal systems	Legal regulations for introducing PV power generation	MHTE, MEA
	Legal systems for disseminating PV power generation	MHTE, MEA
	Requirements for grid-connection guidelines	MHTE, MEA, STELCO
	PV power generation economy examination techniques	MHTE, MEA, STELCO
	Standard specifications of PV power generation equipment	MHTE, MEA, STELCO
DSM/Energy saving	DSM promotion measures	MHTE, MEA, STELCO
	Energy saving promotion measures	MHTE, MEA, STELCO
	SSM thinking	MHTE, MEA, STELCO

Source： Prepared by the Study Team

8.6.4 Collaboration with Faculty of Engineering Technology (FET)

It is highly possible to collaborate with Faculty of Engineering Technology (FET) in Maldives for human resource development on planning, designing and operation of grid-connected PV system. FET holds approx. 400 students (of which nearly 80 students are from Electrical and Electronics Engineering), and approx. 50 teachers including part-time staff. Also FET maintains necessary equipment and materials for experiment in addition to holding lectures.

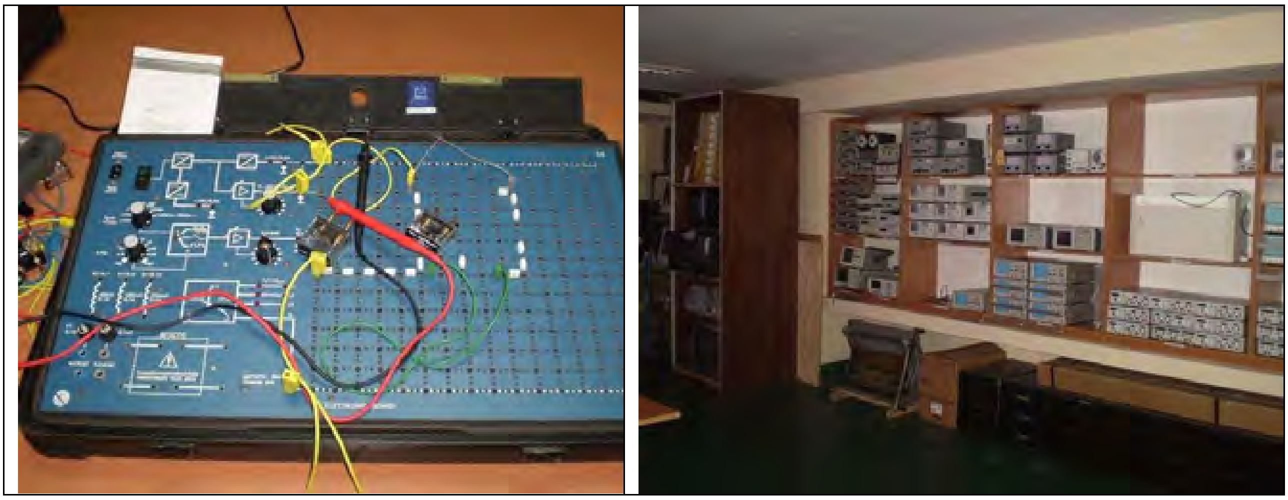


Figure 8.6.4- 1 Equipment for Practical Training at Faculty of Engineering Technology (FET)

Now FET is preparing to hold the new subject “Renewable Energy Systems and Maintenance” to teach how to plan, design and maintain renewable energy systems including PV system. It is one of the project components for Renewable Energy Technology Development and Application Project (RETDAP) under the assistance by UNDP. UNDP plans to hold the course in order to raise the public awareness utilizing the facilities and human resources in FET, since the application for Fund for RE System Application (FRESA) under RETDAP is not growing as expected.

Table 8.6.4-1 shows the outline topic for the course. It is composed of both lecture and practice, and students can obtain the certificate in one semester (15 weeks).

Table 8.6.4- 1 Outline Topic for the “Renewable Energy Systems and Maintenance” (Draft)

Topic	Hours
1. Electrical Energy Sources	
1.1 Scientific forms of Electrical Energy	3
1.1.1 What is Energy	
1.1.2 Forms of Energy	
1.1.3 Law of Conservation of Energy	
1.1.4 Energy Efficiency	
1.1.5 Sources of Energy	
1.2 Non-Renewable Energy Sources	3
1.2.1 Oil	
1.2.2 Natural Gas	
1.2.3 Coal	
1.2.4 Uranium	
1.3 Renewable Energy Sources	3
1.3.1 Solar	
1.3.2 Wind	
1.3.3 Geothermal	
1.3.4 Biomass	
1.3.5 Hydropower	
2. Design and Installation of Solar Power System	
2.1 Basic Principles	3
2.1.1 Volts, Amps and Watts	
2.1.2 Photovoltaic Effect	
2.1.3 PV Modules	
2.1.4 Energy Storage	
2.1.5 Control and Conversation	

2.1.6 Operation of Solar Stand Alone System 2.2 Suitability 2.2.1 Energy Requirement 2.2.2 Other Power Sources 2.2.3 Solar Resources 2.3 System Components 2.3.1 PV Modules 2.3.2 Batteries 2.3.3 Controllers 2.3.4 Inverters 2.4 Design Procedure 2.4.1 Design Process 2.4.2 Initial Estimates 2.4.3 Site Survey 2.4.4 System Sizing 2.4.5 Component Selection 2.4.6 Wiring 2.5 Installation and Commissioning 2.5.1 Safety 2.5.2 PV Array 2.5.3 Battery 2.5.4 Control Equipment 2.5.5 System Commissioning 2.6 Maintenance Field Visit (Trip to Faafu Magoodhoo and Noonu Randhoo)	 3 3 3 3
3. Wind Power System 3.1 Introduction of Wind Energy 3.1.1 History of Wind Energy 3.1.2 Current status and Future prospects 3.2 Wind Power Generators 3.2.1 Tower 3.2.2 Rotor 3.2.3 Gear Box 3.2.4 Power Regulation 3.2.5 Safety Brakes 3.2.6 Induction Generator 3.2.7 Synchronous Generator 3.2.8 Fixed and Variable Speed Operation 3.2.9 Grid-interconnection	 3 3
4. Inverters and Accessories 4.1 Charge Controllers and Batteries 4.2 Power Inverters 4.3 Hybrid and Interactive grid-interconnection Systems 4.4 Net-Metering	 3 3
5. Protection and Safety 5.1 Lightning and Surge Protection	 3

Source : Faculty of Engineering Technology (FET)

FET plans to accept various human resources for instructors even outside from FET for the above-mentioned course. Furthermore, it is advised that some of the topic shall be instructed by engineers from MHTE, MEA and STELCO to make the subject more practical. Also it is expected that students from FET could learn the basic knowledge of renewable energy before they start working at MHTE or STELCO. In the medium-term, more practical training course designed for engineers from MHTE, MEA and STELCO (approx. 2 weeks duration) will be required as the continuous focal point of Off-the-Job Training for the counterparts. Also, further collaboration with technical institutes in third countries (such as India or Sri Lanka) to develop the curricula for renewable energy will be considered as an option.