7. Evaluation of the Project

7.1 Installed System

(1)Monitoring and Evaluation of PV system:

For monitoring PV systems, continuous measurement is generally made for voltage and current, but to do this a mains AC power supply is usually needed. On North Tarawa, a mains type AC power supply is not available to operate the measuring equipment and conventional measuring instruments were not provided.

Recently, a controller has been developed which makes it possible to estimate the remaining service life of the storage battery and to measure the integrated flow of current out of the battery. Two of these units were installed for monitoring the operating state of two systems, and the date from these measurements are used in evaluating this project.

The outline of the controller characteristics is in Table 7.1-1.

Table 7.1-1 Summary of Parameters Monitored by the Special Charge Controller

Monitoring Parameters	Measurement and Control Range	
Battery Temperature	Below 55°C	Over 55°C
Battery Capacity	Less than 30%--90%	Above 90%
Solar array Voltage	Over 19V	
Battery Voltage	(10.9V)	Above 14.4V
	Charging from Solar Turned On	Charging from Solar Turned Off
Battery Temperature	Below 55°C	Over 55°C
Battery Capacity	Over 30%	30%
Solar array Voltage		
Battery Voltage	Over 10.9V	10.9V
	Switch on at Load side	Switch off at Load side

Data Available for Evaluation

Summation of Charging and Discharging Ampere-hours

Calculation of Estimated Remaining Battery Life

Monitoring of Temperature

Detection of Battery Faults (temperature or low voltage)

Accumulation of Remaining Battery Life Estimates for Management

(2)State of System Monitoring and Evaluation Equipment

(a)Setting place

·Name of Village : Abaokoro

·Name of Householder

1) Makin Ngatau (A27) 2) Bauro(Tika)

(b)State of monitoring systems (Measurement Date:28/Jul/93 and 4/Feb/94)

State of the systems are as follows:

The remaining life estimate has been reduced from initial value:26,280 hours (3 years), and was 2.98 years(A27) and 2.55 years(Bauro) as of July 28, 1993, and was 2.53 years(A27) and 2.73 years(Bauro) as of Feb 4, 1994 respectively.

In this case of Bauro, the remaining life estimate reduction is alittle because of absence.

The deference between this July 24 and 28, each shows 92 hours (A27) and 95 hours (Bauro). Thus, the system is operating properly with respect to the load conditions.

These 2sets of evaluation equipments weres changed to normal type controllers and batteries that are same type as used in general houses at Feb,94. This should be easy to check and maintain each equipments at site.

The reasons of change are shown below.

*The battery for this system adopted the sealed type and is not necessary to supply water, but the life of this type is generally shorter than ordinal type of batteries used for other households.

*The maintenancewill be complicate if the controller will happen to down in future, the system is better that they are consisted by same components.

The values in the table 7.1-2 mean as follows:

*The upper values are data gained at July 28 1993

*The lower values in ( ) are data gained at February 4 1994

*Each values were noted at atbthe time of checking (not an average value)

*The LED indication was also noted by checking at the survey time.

The monitoring results are shown in Table 7.1-2.

Table 7.1-2 The Monitoring Results from Evaluation Equipment

1)Makin Ngatau(A27)	After charge (Jul.28 evening)	Before charge (Jul.28 morning)	During charge (Jul.24 daytime)
Remain Capacity (Ah)	57.223	53.434 (78.419)	73.338
Charging or discharging Current Value (A)	- 0.3	+ 0.1 (+ 0.3)	+ 1.9
Battery Voltage (V)	13.1	13.0(13.1)	13.5
Battery temperature(°C)	29	26(28)	28
Expected Available Life (hour:minute)	26116:04	26125:02 (22136:04)	26208:12
LED Indication	60	60(80)	80

2)Bauro(Tika)	After charge (Jul.28 evening)	Before charge (Jul.28 morning)	During charge (Jul.24 daytime)
Remain Capacity (Ah)	75.413	59.582	79.564
Charging or discharging Current Value (A)	- 0.2	- 0	+ 3.59
Battery Voltage (V)	12.6	12.2	13.4
Battery temperature(°C)	30	26	30
Expected Available Life (hour:minute)	22332:56	22342:31	22427:25
LED Indication	80	60	80

(c)Terminal Voltage Measurement of Solar Module and Storage Battery

For the solar power generation systems in North Tarawa, measurement is made for the terminal voltage of the module and battery after 6 months, and an analysis is made to see if the system is operating properly.

1)Performance of Voltage Measurement

Voltage has been measured for the storage before, after and during charging.

- Voltage Measurement after Charging : PM 5:30 ~ 7:00
- Voltage Measurement before Charging : AM 7:00 ~ 9:00
- Voltage Measurement during Charging : AM 11:00 ~PM 3:00

2)Results of Measurement

On this system, battery terminal voltage is controlled by the charge/discharge controller within the voltage show on the following Table 7.1-3.

Table 7.1-3 Control Voltage of Charge/discharge Controller for General House (Unit:V)

Protection against Over-charge		Protection against Over-discharge	
Charge stop	15.6	Discharge stop	11.4
Charge restart	12.6	Discharge restart	12.6

Data from Abaokoro is used for this analysis. The example data is shown in Table 7.1-4.

Table 7.1-4. The Example of State of Operation in Abaokoro

			AFTER CHARGING (evening)		BEFORE CHARGING (morning)		DURING CHARGE (daytime)		
NO	CODE NO	CUSTOMER NAME	PV Voc (V)	BATTERY TERMINAL VOLTAGE (PV OFF) (V)	PV Voc (V)	BATTERY TERMINAL VOLTAGE (PV OFF) (V)	PV Voc (V)	PV CHARGE VOLT-AGE (V)	BATTERY TERMINAL VOLTAGE (PV ON) (V)
3	A 5	EKEIETA	19.5	13.6	21.6	12.9	23.0	12.7	15.4

The Example shows that the terminal voltage is controlled within the voltage range of Table 7.1-3. Note that during charge, the panel voltage is lower than the battery terminal voltage indicating that the parallel type controller has stopped charge from following to the battery.

Table 7.1-5 shows the results of measurements performed in July and here shows the results in Notoue village as example.

Table 7.1-5 System Voltage Data for Each Cuatomer

VILLAGE NAME : NOTOUE

NO	CODE NO	CUSTOMER NAME	MEASUREMENT RESULT OF SYSTEM VOLTAGE						
			AFTER CHARGING (evening)		BEFORE CHARGING (morning)		DURING CHARGE (daytime)		
			PV Voc (V)	BATTERY TERMINAL VOLTAGE (PV OFF) (V)	PV Voc (V)	BATTERY TERMINAL VOLTAGE (PV OFF) (V)	PV Voc (V)	PV CHARGE VOLT-AGE (V)	BATTERY TERMINAL VOLTAGE (PV ON) (V)
1	N 1	AREBONTO	20.0	13.4	23.9	13.5	22.9	15.9	14.3
2	N 3	BENTARA	20.0	13.8	23.2	13.8	22.7	15.0	14.3
3	N 10	KEETI	20.5	13.7	22.2	13.6	22.1	14.3	13.9
4	N 16	MIKAERE TIMAIA	20.9	13.9	23.7	14.1	23.5	15.6	14.5
5	N 30	TERINAKI	21.4	13.7	23.2	13.4	22.6	14.3	13.9
6	N 32	TIKANRO	21.3	14.1	22.5	13.3	22.4	15.5	14.4
7	N 35	UTIMAWA	20.8	13.4	23.0	13.2	22.8	14.9	14.0
8	N 36	WAIRE	UNDER ABSENCE						
9	N 37	IOTEBWA	19.8	13.5	21.8	12.9	23.4	14.0	13.5
10	N 38	AIRIN	21.1	13.9	23.0	13.3	22.3	15.7	14.3
11		RONIITI TETABO	21.7	13.7	23.0	13.2	22.7	14.6	14.0
12		TAUKABAN IOANE	21.3	13.7	22.6	13.1	22.9	14.7	14.2
13		TAMUERA KAREBANGA	20.3	13.7	23.6	13.6	23.3	14.5	14.1
14		TEBIKE NENEIA	21.5	13.8	22.4	13.2	22.4	14.7	14.1
15		TIIBAU	21.2	13.7	22.6	13.4	22.4	14.5	14.0

(3)State of Liquid in the Storage Battery

For the solar power system in North Tarawa, the level of liquid in each storage battery was surveyed to help extend the service-life of the system.

(a)Details of the Survey

·Solar power systems in 6 villages of North Tarawa:

General Users: 55 houses Maneaba : 1 house

·Period of Execution: July 24 to 30, 1993 and February 3 to 6, 1994

(b)Results of Survey in July 1993

The results show that there were many cases showing a decrease in liquid in the storage battery with about 80% showing a very low level.

It was necessary to ask the SEC for an improvement in their procedures for maintenance to insure that water levels did not fall too greatly in the future. Further, this will be again checked during the technical follow up by the JICA team. Table 7.1-6 shows data from the survey of House. Table 7.1-7 shows data from the survey of the Maneaba.

Table 7.1-6 Battery Liquid Survey of House

Phenomena	Taratai	Notoue	Abao koro	Marena nuka	Taboni bara	Kainaba	TOTAL
Detection of decrease in battery liquid		12	7				19
Water-supplied by SEC technician		1	10	2	6		19
Detection of decrease in battery liquid water-supplied by JICA team	1					3	4
Good condition in battery	1	2	5	1		1	10
No-check (absence)			1				1
Water-supply not necessary (seal type)			2				2
TOTAL	2	15	25	3	6	4	55

Table 7.1-7 Battery Liquid Survey of Maneaba

Phenomena	Taratai	Notoue	Abao koro	Marena nuka	Taboni bara	Kainaba	TOTAL
Detection of decrease in battery liquid water-supplied by JICA team						4	4
TOTAL						4	4

For 2 out of 4 batteries, SEC-technician supplied the water on June 3, but, the battery liquid was reduced at the time checked by the JICA-team on July 29.

(c)Probable reasons for the rapid decrease in battery liquid:

For the above phenomenon "decrease of battery-liquid", the following conditions are estimated.

- The solar modules provide much more energy than is used by the load leading to an excessive amount of charge.
- Users are absent and do not use the load, causing an excessive charge to the battery.

(d)Availability of Replacement Water

In Kiribati, the distilled water cost is 1A$/l, and is higher than gasoline at 70¢/l. Accordingly, rain water is to be tried with water quality tested for the distilled water, rain water and water from a well.

- Date of Analysis : Sept. 1993
- Place of Analysis : Furukawa Battery Inc.
- Result of Analysis:

The result of analysis is as follows. The analysis result of the water samples is shown in Table 7.1-8.

1)Result of Water Analysis

Table 7.1-8 Results of Water Analysis for Types of Water Available

Kind of Water / Item	Distilled Water	Rain Water (South Tarawa) Restaurant Roof of Otintaai	Rain Water (North Tarawa) On Plastic Bucket	Well Water (North Tarawa) Guest House	SBA4001 Standard Purified Water for Battery
PH	3.70	5.75	5.70	7.20	5.8~8.6
Cl-	Below 0.5	Below 0.5	Below 0.5	4.0	Below 1.0
Fe+	Below 0.1	Below 0.1	Below 0.1	Below 0.1	Below 0.1
Organic matter	1.42	2.84	1.89	2.85	Below 50

(Unit) PPM (Parts per Million)

2)Suggestion

In comparison with the SBA-specification of purified water for the storage battery, there was no problem with rain water on all items.

However, water from the well contained excess Cl and is unsuitable. Rain water should have no problem as a supply-water though it should be used after removing solid impurities.

(e) Survey results in February 1994

According to the survey results in July 1993 and the analytical result of rain water, the study team check the condition of batteries again.

The result shows that all batteries are well maintained and the water level in batteries were kept as proper as the team recommended and trained the field technician before.

The survey results are shown in Table 7.1-8 and table 7.1-9 shows the amount of water supplied from June 1993 to January 1994.

(3)Evaluation on the illuminance

Illumination by the solar systems varies due to the different structures of houses, thus the same level (20~100lux) as measured in existing installations was adopted.

Among the 6 villages, Abaokoro Village has the most houses, survey and was chosen as the site for illuminations measurements.

The measured result was as expected and the results shown in Table 7.1-9 [Measured Illuminance].

·Name of Village: Abaokoro

·Used Illuminometer

Maker Hioki Electric Inc.

Type Lux Hi Tester 3421(3000, 1000, 300 lux, 3 points range shifting system)

·Measured position : At each position, measurement was made in a horizontal position just under the light fixture. Based on that measurement, the values were then converted to illumination at a standard position of 1.5m.

Measured position illumination and converted position illumination is shown in Fig 7.1-1.

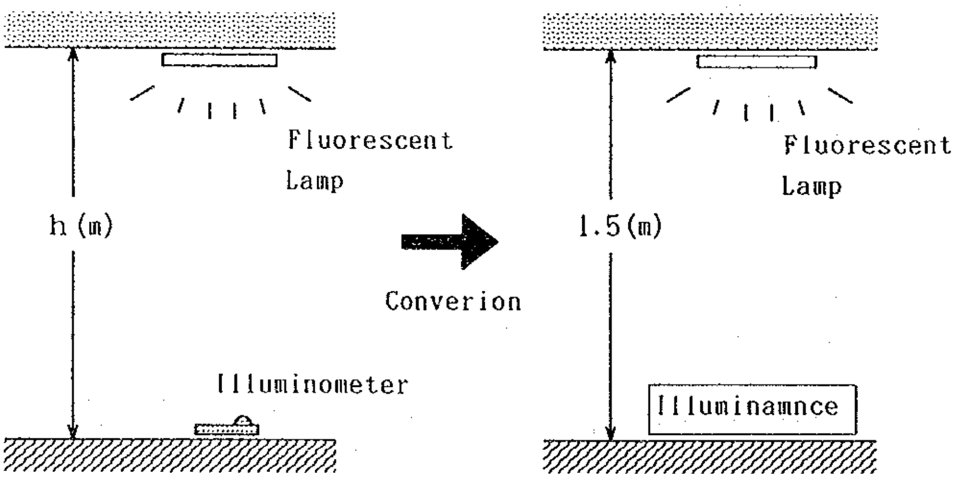


Fig 7.1-1. Illumination at the Measured position and converted position

Table 7.1-10 Illumination as Measured Unit:Lux

NO	CODE NO	CUSTOMER NAME	Illuminance in Each Room 11(W)	7(W) Sleeping Room	7(W) Dining Room
1	A 4	BEIA TOARA	88.0	21.0	45.0
2	A 9	LOUI NAMANE	49.0	26.0	16.0
3	A 10	NATIRIA TAMTON	54.0	40.0	22.0
4	A 11	OBETA	60.0	26.0	36.0
5	A 17	TEBUAKA	100.0	40.0	14.0
6	A 18	TEKAKIABO	58.0	23.0	25.0
7	A 21	TEMARAWA KAWITU	64.0	10.0	18.0
8	A 27	MAKIN NGATAU	50.0	14.0	24.0
9	A 29	TAUKABAN	56.0	24.0	19.0
10	A 32	RIBATI	33.0	24.0	25.0
* 11	A 33	TIOTI(BOUA TEKAAI)	77.0	32.0	23.0
12	A 35	ABAUA	60.0	24.0	26.0
13		BAURO		15.0	48.0
14		TEKATAU	68.0	35.0	32.0
15		TEKERAOI	56.0		21.0
16		TENAGIMAU	84.0		53.0 [11(W)lamp attached]
17		TETAKE	45.0	19.0	24.0
18		BIITA	44.0		12.0

·* mark:Householder was changed(Inside of( ) is Old householder's name)

·Open space means [no measurement] because persons were sleeping.

(4)Damage of Other Materials and Components:

A survey was made on the condition of each component and materials after 6 months of use of the solar power systems in North Tarawa, and service life of the system was estimated.

(a)Survey of The State of The System

The present survey revealed problems in the systems as follows:

- For Houses
  - 11W fluorescent lamp: 1 unit
  - 7W fluorescent lamp: 1 unit
- For Maneaba
  - 20W fluorescent lamp: 1 unit

(5)Measurement of Voltage and Current of System

Measurement shall be made on the voltage and current of the representative present solar power generation system and the system-operation state shall be evaluated.

(a)Measurement Item

- Charge/Discharge Current of Battery
- Terminal Voltage of Battery

(b)Equipment Specification and Measurement Circuit

1)Equipment Specification

*Charge/Discharge Current Measurement

- Current Data Recorder

  Type : KADEC-US 2sets

  Measurement Range : 0～10(A)/0～20(mV)

- Standard Shunt Resistance

  Type : 5204 2sets

  Resistance Value : 0.002(Ω)

*Terminal Voltage Measurement

- Voltage Data Recorder

  Type :KADEC-US 2sets

  Measurement Range :0～20(V)/0～20(mV)

- Voltage Divider

  Type :S-30

  Dividing Range :0～20(V)/0～20(mV)

2)Measurement Circuit

Measurement circuit connection for using equipment of item 1)is shown in Fig 7.1-2.

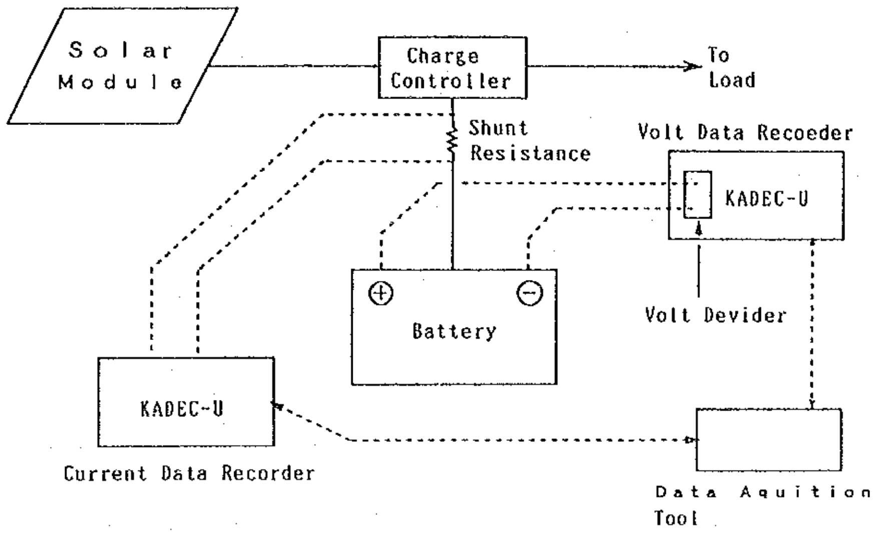


Fig 7.1-2 Measurement Circuit

(c)Selection of The Measurement Sites:

1)Structures of houses shall be strong.

- Structure of roof, posts etc shall not be easily broken.
- Submerging due to rain water shall not occur.
- The space housing the measuring instruments shall be easily accessed, and the survey team shall be able to easily access the space at the time of data collection to check the instruments.

2)Theft or damage of the measuring instruments is unlikely.

3)The site should be located near the Island Council Office in Abaokoro so it is convenient for checking and controlling the instruments and for data collection.

4)The difference shall be considered for the load in its using state.

5)Users shall cooperate for the evaluation and setting of the measuring instruments.

(d)Sites Selected

Based on the selecting standards in item (c), selection has been made of the users which will have the measuring instruments for evaluating system as follows:

1)Name of Village: Abaokoro

2)Name of User:

- Natiria Tamton (Code No: All)

  Feature: Used for illumination at general house and shops
- Beia Toara (Code No: A-4)

  Features: Used for illumination in general house (e)Survey result

The data logger removed at the study in February 1994, and data of through July 1993 to January 1994 were analyzed.

These data are making it clear the difference between customer's style of using light(s) and also strictly recorded the deviation of charge and discharge of batteries.

Fig 7.1-3 and 7.1-4 are each one week data, they show how customer used lights and how the batteries are charged and discharged.

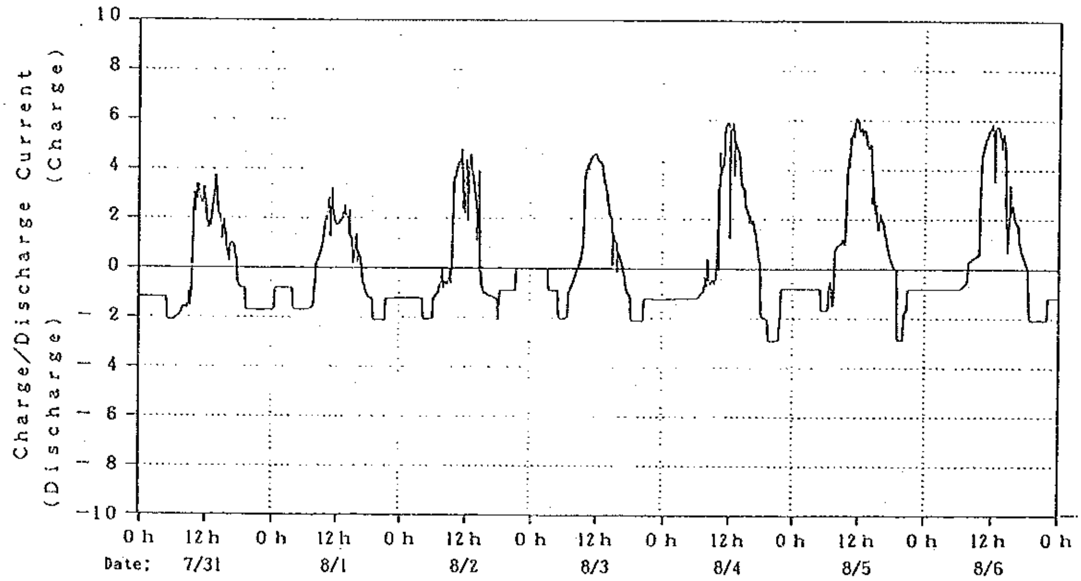


Fig 7.1-3 The load cycle of customer 'Natiria Tamton'

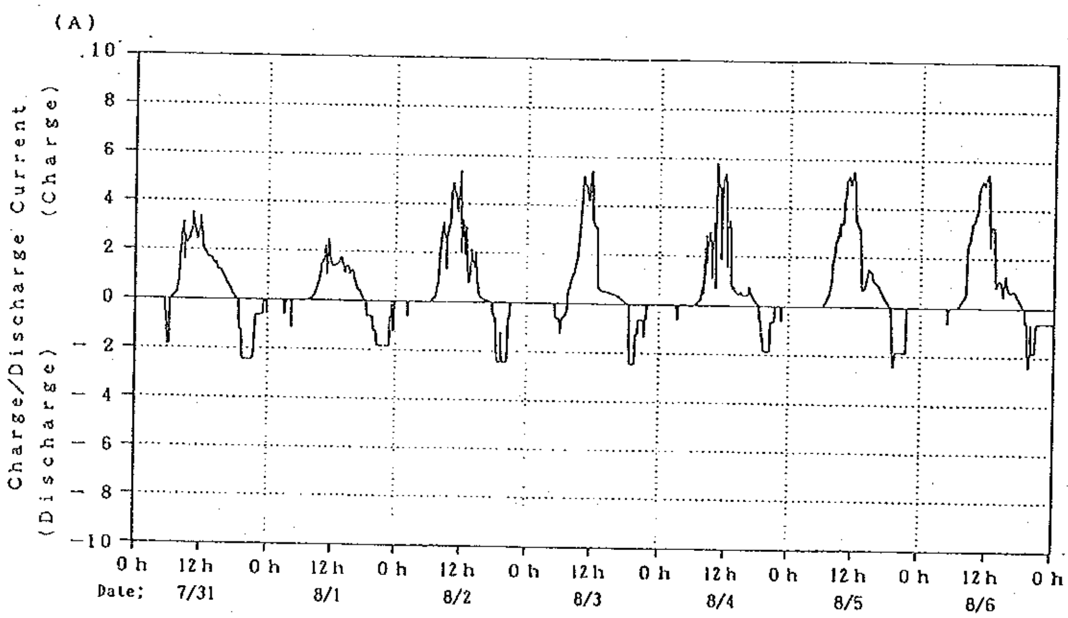


Fig 7.1-4 The load cycle of customer 'Beia Toara'

8. Evaluation of Solar Energy Company (SEC) Management

8.1 Organizational Analysis

Solar Energy Company was established in 1984 with USA assistance for the selling of solar systems and installation of government solar systems but it was trance formed as the utility company that supply electricity through the photovoltaic system to the customer, and their objectives are:

To promote and encourage the use of solar PV system in rural areas.
To design and install government PV projects.
Procurement and selling of PV equipment and appliances.
Responsible for the management of Rural PV Electrification Program.

The management of SEC is based on The Articles of Association which in conformity with The Companies Ordinance of the Republic of Kiribati.

(1) Stock holders of SEC

Minister of Works and Energy	495
Secretary of Works and Energy	1
Secretary of Home Affairs	1
Manager of Bank of Kiribati	1
Manager of Public Utility Board	1
Secretary of Finance	1

(2) Board of Directors

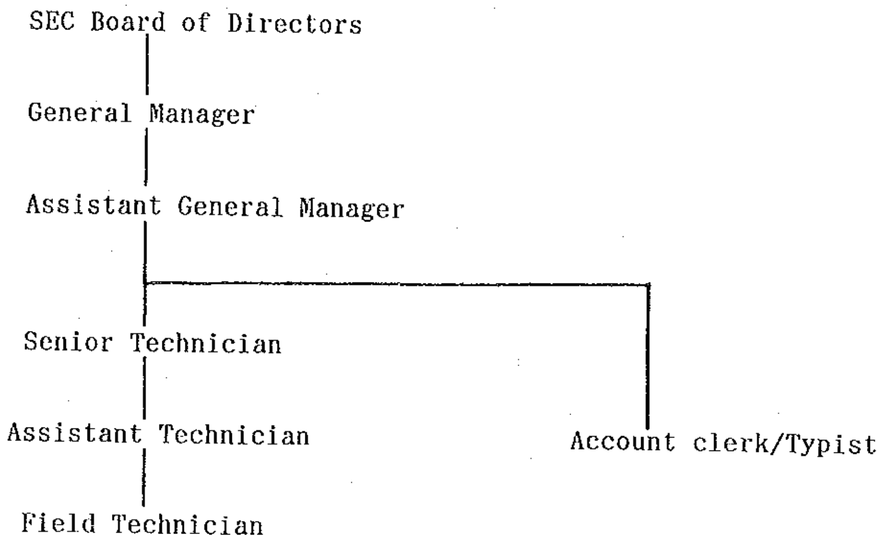
Chair person:	Mr. Abureti Takaio,	Senior Assistant Secretary for MWE
Directors:	Mr. Tebwe Ietaake,	Public Finance Economist,MFEP
	Mr. Buibui Tiweri,	Electrical Engineer, PUB
	Mr. Toawea Tiweri,	Private Businessman
Secretary:	Mr. Terubentau Akura,	Manager of SEC
Auditors:	Office of the directors of Audit	

Power and Duties of Directors

a. Appoint the manager of company
b. Pay all expenses properly incurred in promoting the company

c. Appoint all officers and servants of the company as they may think necessary, and determine their duties,salaries and wages.
d. Exercise the powers conferred by the Companies Ordinance in necessary.

(3) Organizational chart of SEC



(4) Duties/Responsibilities of SEC members

a. General Manager: Responsible for day to day total management of the SEC
b. Assistant General Manager: Support general manager in total management and especially responsible for the implementation of Rural Electrification
c. Senior Technician: Responsible for the technical work on installation and maintenance of PV system and guide the assistant technician and the field technician to improve their technology
d. Assistant Technician: Install and Maintain the PV systems under the supervision of senior technician and train the field technician to be able to maintain the PV system
e. Field Technician: Stay at the rural area and maintain the PV system installed near by his place with supervision of the Assistant technician and Senior Technician
f. Account clerk/Typist: Responsible for the daily receipts and disbursement of SEC and support managers as secretary

The assistant general manager(AGM) and the field technician were appointed to implement the rural electrification and to expand the operations of SEC in 1993.

8.2 Financial Analysis

(1) Profit and loss statement

Items (A$)	1992	1991	1990	1989
Operating revenue	229,183	103,768	108,073	77,398
Operating expenses	225,123	109,339	113,660	92,384
purchased	186,043	79,362	85,355	59,073
maintenance	1,127	188	614	1,249
depreciation	657	818	2,096	2,097
salaries & wages	16,056	15,552	14,134	20,402
others	21,236	13,419	11,461	9,563
(trip & per-diem	10,037	8,768	4,028	)
(communication	2,588	1,236	2,386	)
(audit fee	2,375	- 50	950	)
(rental fee	2,170	--	--	)
Operating income	4,060	- 5,571	- 5,587	-14,986
Other income	625	214	0	950
Net profit	4,685	- 5,357	- 5,587	-14,036

The operating revenue is improving rapidly and the yearly balance has turned from a loss to a profit and this improved profitability is expected to continue.

8.3 Medium-Term Estimation of SEC

The management system has been strengthened by recruiting an assistant general manager who is responsible especially for the Rural Electrification Project.

The system of accounting is being computerized with training by an external consultant and the computer with its software programs have been supplied by UNDP according to their Cooperation programme with the JICA project. The financial tables show that the financial situation of SEC is gradually improving and the trend is expected to confirm.

The JICA project and the succeeding EC project will provide the SEC about 300 new PV customers and their monthly payment (9 A$/month/user) will provide pretty amount of cash income to SEC.

A major concern of the SEC regarding PV electrification is the problem of collecting monthly fees from customers since a failure to collect will adversely affect the financial condition of the SEC.

8.4 Calculation when JICA and EC system have been installed

The simple calculation of financial effect for the SEC after JICA and EC PV systems have been installed shows that 9A$/month of maintenance fee covers the field technicians wages and a part of administration cost of SEC aside of exchange cost of battery and controller. The even point of collecting the monthly fee is about 80%.

Preconditions of calculation are:

(1) Life of component; PV panel 20y, battery 5y, controller 10y.
(2) Unit cost; PV panel 350A$, battery 150A$, controller 100A$.
(3) Number of household; 300, Number of field technician 4.
(4) Wage of field technician; 2,000A$/year 5% increase/year.
(5) Administration cost of SEC; 15% of field technician's wage.
(6) Discount rate 10%.

The result is showed in Table 8.4-1

Table 8.4-1 Case study of JICA and EC system had been installed

Profit & Loss Items		Cost		1	2	3	4	5	6	7	8	9	10	11	12--15	16	17--20
Policy & Environment	Unit cost of H.H	2000.0	A$														
	Unit cost of O.B	10000.0															
	Unit cost of panel	350.0															
	Unit cost of Battery	150.0															
	Unit cost of control	120.0															
	Wage of Field Tech.	2000.0															
	Inst. fee per Unit	50.0															
	Maint. fee per year	108.0															
Sales	No. of Inst. Unit H.H			300													
	No. of Inst. Unit O.B			5													
	accum H.H			300	300	300	300	300	300	300	300	300	300	300	300	300	300
	accum O.B			5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Sales of Install			15,250	0	0	0	0	0								
	Sales of Maintenance			32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940
	Total Income			48,190	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940	32,940
Variable cost	Number of panel	2.0	%		13	13	13	13	13	13	13	13	13	13	13	13	13
	Number of Battery	5years							320	0	0	0	0	320	0	320	0
	Number of controller	10years												310	0	0	
	Cost of panel			0	3,900	3,900	3,900	3,900	3,900	3,900	3,900	3,900	3,900	3,900	3,900	3,900	3,900
	Cost of battery			0	0	0	0	0	48,000	0	0	0	0	48,000	0	0	0
	Cost of controller			0	0	0	0	0						31,000	0	0	0
	Total Var. Cost			0	3,900	3,900	3,900	3,900	51,900	3,900	3,900	3,900	3,900	82,900	3,900	3,900	3,900
Fixed cost	Number of Field tech			5	5	5	5	5	5	5	5	5	5	5	5	5	5
	Wages of Field Tech.			10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000	10,000
	Administration	15.0	%	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
	Total Fixed Cost			11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500	11,500
	Total cost			11,500	15,400	15,400	15,400	15,400	63,400	15,400	15,400	15,400	15,400	94,400	15,400	15,400	15,400
	(Investment cost)			650,000	0	0	0	0	0	0	0	0	0	0	0	0	0
Income from Opn.				36,690	17,540	17,540	17,540	17,540	-30,460	17,540	17,540	17,540	17,540	-61,460	17,540	17,540	17,540
	Net Present Value	r=10%		102,457													

9. Social Impact Analysis

9.1 Background of requirement for PV systems

(1) Requirement of the people on PV systems

The main lighting equipment in North Tarawa are now the kerosene lamps, but the people in North Tarawa have problems getting kerosene for their lamps, because it is not only problems of transportation between South Tarawa and North Tarawa which depend on canoes, but also the oil supply system is not completely organized in the country. Also the maintenance of kerosene lamps is an annoyance to their daily lives.

Electric light is strongly desired in North Tarawa. 124 households in 167 in the survey want and they will pay for PV systems. When the number of the households desired PV systems is estimated for all ten villages in North Tarawa, we can take the number of the households surveyed in the six villages which is 167 and the number of households in the ten villages which is estimated at 430 households. Then the number of the households desiring PV systems in the ten villages in North Tarawa can be estimated to be 320 households(=430*124/167). Therefore it is appears that the requirement for PV systems from the people in North Tarawa is strong.

(2) Cost of kerosene lamp

Most of the households in North Tarawa use kerosene wick lamps or kerosene pressure lamps and kerosene is rarely used for anything else. Then the fuel cost for light is equal to the kerosene consumption value in North Tarawa. According to the survey, if the kerosene price would be 75 cent per liter, the kerosene consumption value per household would be A$10.58 per month. And the number of the households which pay more than A$6.0 per month is 85(=160*53%). Therefore it is reasonable that the maintenance fee of the PV systems is set the range of A$6~10 per month when considering a PV system is a substitute for kerosene lamps.

(3) Burden of the people for the cost of PV system

The annual average income per household is A$2,150 in the six villages. A$9 per month is required as the maintenance fee for the PV system, so the fee occupies 5.0% of the average income in North Tarawa. It is therefore not considered that the fee gives a heavy burden to the households getting income more than the average, particularly since expenditures for kerosene will be reduced.

The rate of the households having income more than the average is 37%, the number is 74(=200*37%) households. And the number of the households having income more than the average in the ten villages in North Tarawa is 160(=430*37%). According to the economic analysis of the mission, 50 households which desire PV systems require one maintenance technician in the field. Then 160 households which desire PV systems can distribute will require 3 maintenance technicians.

(4) Environmental impact and control

Having the PV systems include problems of disposing of failed batteries and electric lamps, it is not good for the environment to dispose them outside of their houses. A collection system of these wastes is required to protect the environment. At the same time, cooperation of the people is required too. The survey asked about this cooperation, and most of the respondents answered that they would cooperate in the collecting the wastes.

9.2 Evaluation of the PV systems after installed

(1) Evaluation of the PV systems

The PV system has the outstanding points that its lights are brighter than kerosene lamps and there is a constant fee without respect to hours used. It is clear that the PV systems are welcomed by the families and villages of North Tarawa.

For a modern life style, even in remote areas of a developing country, it is not enough for people to have only lighting. The people in North Tarawa also use radios and tape recorders and they want to get power for these appliances from the PV system. For the next stage of electrification, we should consider much more useful and convenient PV system for the people of Kiribati.

(2) Evaluation of the life of families having PV systems

a. Impact to housewives

In North Tarawa, housewives can cook without any light until 6:30 pm, but they need lights after 7:00 pm. Thus most of the housewives in North Tarawa wish to finish cooking by 7:00 pm. Generally they cook both inside and outside their houses. They sometimes do cooking in the house with torches after 6:00 pm, since after 6:00 pm there is not enough light to work in the house. The PV system is very useful for such housewives' works. By using the PV lights, they were able to work much later in the night.

Also the PV systems impact housewives' life styles after dinner. Before having the PV system, they usually went to the Maneaba to weave mats and sew clothes under kerosene pressure lamp or electric lights powered by a generator. But they could not use kerosene pressure lamps and diesel powered lights in their houses since they were too expensive.

To meet in the Maneaba at night and work while talking with one another is one of their pleasures. Therefore installation of the PV system to the Maneaba is more effective than installing PV systems for each household in the impact on village life styles for women.

b. Impact to men

Men in Households having a PV system were able to prepare for fishing even at night. This is a great improvement for the men. Before having a PV system, They could not have work at night and spent their time listening to radio or watching video. Without having a PV system, they had to been work under a kerosene lamp or a torch at night. As the PV light is brighter than these lights and it does not have any additional cost for longer use, they can increase their production activity and need not worry about any additional cost for their lights.

c. Impact to children

Most of children in North Tarawa do not do their homework in their homes though there are some children who study their homework in the Maneaba, but it is rare. Most of them are watching a video in their neighborhood or playing with each other around the Maneaba at night. The children having a PV system were able to study their homework in their homes at night. That is a great advance in their life.

Also the children in the six villages desire electric lights in their schools even in the daytime when it rains. This is a very serious problem. Rain in North Tarawa can be very heavy and the sky become very dark. So at this time the children can not read their books or study. Therefore, it would be best the future PV systems installed in Kiribati can be lit both in daytime and at night.

As a result, the housewives having PV systems received the most advantages from the PV systems, the next are the men, third are the children.

(3) Social problems caused by PV system and measures

a.Difference of income between households having a PV system and those not having

Initially the Difference in individual income was assumed to divide households in North Tarawa into a group having the capability to install the PV system and another group not having that capability. Since households to receive the PV systems were selected through a drawing held in the Maneaba at Abaokoro, there are households having a PV system and households not having a PV system with the same income.

The PV systems installed in North Tarawa do not have any power outlet for radio, tape recorder and refrigerator. The difference in household income has not caused a difference in their life style. But as the PV lights are liked by the households having the PV system, It is supposed that if only 55 households have the PV system for a long time, there will be a bad effect upon the villages. Then it is desired that in the near future additional PV systems are installed in households not presently having them.

There are 200 households in the targeted six villages of North Tarawa. Only 55 PV systems are now installed in the households and it was shown by the april 1992 survey that there exists about more 70 households desiring to have PV system. Therefore after the feasibility study survey finishes, the Kiribati government and the SEC need to make plan for installing additional PV systems to the households desiring them. Otherwise, it is feared that in the near future trouble will occur between households having a PV system and households not having a PV system.

b. Impact of the PV system to the Maneaba

By the social impact survey, it appears that installation of the PV system for the Maneaba gives the greatest impact on village life. Therefore installation of PV systems should be carried out in Maneaba immediately after discussing with councilors of villages in North Tarawa.

c. Electric appliances powered by PV systems

Refrigerators and water pumps are desired by some people in North Tarawa as equipment for economic activity. This equipment can be used for fish storage and is useful to improve the villager's storage of food. At the same time the people can store and sell fresh fishes by using this equipment. By doing so they will be able to increase their income as a result. It is believed that an improvement of village life and complete electrification of the villages will be realized after installation of such equipment.

d. Accomplishing maintenance of the PV systems and adopting a flexible payment system for the PV system fee

It is expected that the people will become used to having electricity and will be very angry when their systems stop operating. It will be important that the SEC provide prompt repairs and maintenance ,otherwise people will be unwilling to pay the fee.

As there is a money economy in North Tarawa only at the primitive level, the households having the PV system are not yet accustomed to periodically pay for the fee for the PV system every month. Then it is appropriate that the SEC prepare some kind of the fee collecting system such as a prepayment system or deferred payment system for the households having the PV system.

9.3 Measures for maximizing to the effectiveness of the PV systems

There are positive impact and negative impacts of the PV systems to family life and social life. The details are as follows:

Table9.3-1 Impact of the PV systems for family life and social life

	Positive impact	Negative impact
Family life	・Increase in productivity	・To desire to buy electric appliances
	・No additional fee for the PV system	・To pay constantly fee of the PV system
Social life	・To keep younger generation in the villages and increased vigor in villages	・The contrast between a Maneaba having lights and other Maneabas not having lights may cause friction
	・Increased literacy rate and security	

(1) Increased positive impacts for family life in North Tarawa

Positive impacts for family life are increasing their productivity and their children's studying time and so on. These are primary impact and the main effectiveness of the PV systems. As the PV systems are achieving these purposes, the Kiribati government and SEC are advised to install as many PV systems in North tarawa as the people desire.

(2) Increased positive impact for social life in North Tarawa

Positive impacts on social life include increased retaining of the young generation in villages and revitalizing the villages in North Tarawa. For keeping the phenomenon, it is needed to have more occupations for the young generation to be able to get income in the villages. If this can not be realized in the villages, the families in North Tarawa need to get more income through sending family members overseas or to South Tarawa to work for money for their homes. To achieve this purpose of increasing retention of young people by using the PV systems, they need to have outlets for radios and other small electric appliances. Also there will be social improvement in villages where the PV lighting systems are installed in their Maneabas, PV water pump systems are added, PV telecommunication systems are used and PV refrigeration systems are available for food storage.

(3) Decrease of the negative impact against family life in North Tarawa

It is a fear that the people will expend much money to buy electric appliances causing a negative impact in family life when they have PV systems. Additionally every month they have to pay the fee of A$9. It is supposed that the payment is a heavy load for households having the PV system, because their income is not constant. To decrease the negative impact, it may be necessary to stabilize their income. At the same time, the SEC needs to arrange some kind of payment systems such as prepayment or deferred payment systems for collecting the fee of the PV systems.

(4) Decrease of negative impact against social life in North Tarawa

There are often several Maneabas in a village. A Maneaba having a PV system will be used every night, but Maneabas not having PV systems are hardly used at night. As ceremonies of the villages are almost always held in daytime, then it is no problem to the leaders of the villages whether a Maneaba has a PV system or not.

But meetings for discussing improvements in their lives and improving their skills are frequently held in the Maneaba at night. Therefore it is considered to give a top priority to installing future PV systems in Maneabas which women use frequently.

10. Rural Electrification of KIRIBATI

10.1 Existing status of Kiribati

(1) ENERGY RESOURCES:

(a) Biomass, primarily in the form of coconut fronds, husk, spathe, sheathe and nut are historically the principal source of energy within Kiribati both in rural and the densely populated urban area of South Tarawa. Other tree species such as casuarina, te uri, iron wood, te mao, pandanus and breadfruit are also utilized.

(b) Coconut oil may provide a viable alternative as long term fuel supply for power generation and ground transport needs. However, there has been no work done or planned to determine its potential viability.

(c) Solar energy on South Tarawa is conservatively estimated to have an average of 5 KWh/m2/day available for utilization using various conversion technologies. On Kiritimati island average solar insolation is estimated at 5.6 KWh/m2/day.

(d) Wind, potential in the Gilbert group appears to be low and non-persistent averaging in the range of 4.0-6.0 m/s. However, on Kiritimati island it reported to average 6.6 m/s and is consistent over much of the year.

(e) Ocean energy may have a long term future potential for the utilization of sea water temperature differences and seawave energy but no assessment has been done or planned.

(2)Electricity in Kiribati

The commercial electricity supply in Kiribati is provided by a state-own organization, the PUB(Public Utility Board). The PUB covers only South Tarawa(and a small part of North Tarawa plus Kiritimati Island).

Table 10.1-1 Electricity produced

	1989/90	1990/91	
Residential	1,638MWh	1,679MWh	
Commercial	1,500	1,536	
Industrial	3,500	3,773	
Total	6,638	6,988	(+350)

(3) Photovoltaic systems in Kiribati

In kiribati, it is estimated that about 300 PV systems have been installed since the early 1980's but poor design combined with a low quality of system components, a lack of the proper installation technology and insufficient maintenance has left few systems working properly.

A partial survey of PV systems was conducted by the Solar Energy Company in 1990 on several villages and comprehensive survey was done in 1992. The preliminary summary is shown on Table 10.1-2.

Table 10.1-2 Comprehensive Survey Result of PV system in Kiribati

Name of Island	Number of PV systems	Utilization of PV system for: Lighting	Lighting+ Radio/Tape	Lighting+ CB Radio	Lighting+ Pumping	Refrige- rator	Communi- cation	Pumping	Others
①BANABA									
②MAKIN	8	6				1	1		
③BUTARITARI	12	7		3					2
④MARAKEI	22	15		1	1	1	2		2
⑤ABAIANG	22	13				1	4		4
⑥NORTH TARAWA	11	6		2		1	2		
⑦SOUTH TARAWA	--								
⑧MAIANA	33	16	6	4		1	2		4
⑨ABEMAMA	51	41		3	1	1	2		3
⑩KURIA	15	7		3		1	3		1
⑪ARANUKA	11	4		2		1	1		3
⑫NONOUTI	12	6		4		1	1		
⑬TABITEUA NORTH	14	6		2		1	3	2	
⑭TABITEUA SOUTH	8	7		1					
⑮BERU	7	2		3		1	1		
⑯NIKUNAU	14	4				1	2	7	
⑰ONOTOA	13	11					2		
⑱TAMANA	10	6				1	2	1	
⑲ARORAE	12	7	1			1	1	1	1
⑳WASHINGTON	unsurveyed								
㉑FANNING	unsurveyed								
㉒CHRISTMAS	unsurveyed								
㉓CANTON(KANTON)	unsurveyed								
TOTAL	275	164	7	28	2	14	29	11	20

10.2 Proposal of Rural Electrification Program

10.2.1 Procedure for PV rural electrification

(1) The first step target is to electrify about 20% of households on each Island plus the Maneabas, schools, clinics, churches and Island Council buildings that want and are able to pay the maintenance fee.

(2) Field technicians should be trained on each Island to maintain the PV systems to be installed and their fees should be met by the monthly payment of users.

(3) Field technicians will initially cover about 75 systems per person within the area they can easily visit on foot or bicycle.

After they become to used to their job, the number of customer covered by them will increase to about 100.

(4) SEC is to be responsible for the installation of the systems, supply of spare parts, training of field technicians and the fund for replacing the battery and other failed parts.

(5) The basic concept of this rural electrification is as follows:

- (a) Users are supplied electricity generated by a PV system installed close to their house.
- (b) The systems belong to SEC and SEC is responsible to maintain these systems.
- (c) Users pay the monthly fee for the service of supply of electricity.
- (d) SEC installs the PV systems for which the investment will covered by the Government or funded from overseas Aid or Grants.

(6) After the first stage electrification is finished, PV systems will have been introduced on each Islands and there will be field technicians for the maintenance of systems. Then new or additional installation of PV systems in Kiribati will be easily supported by the SEC and existing field technicians.

The estimated number of PV systems and field technician in the first stage of PV rural electrification is shown in Table 10.2-1.

Table 10.2-1 Estimated number of PV systems at first stage.

Name of Island	Household	20% of HH	Maneaba	Clinic	School	Number of Systems	F.Tech
① Banaba	62	12	0	1	1	14	0*
② Makin	295	59	2	2	3	66	1
③ Butaritai	633	127	6	5	7	145	2
④ Marakei	443	89	7	3	5	104	2
⑤ Abaiang	743	149	15	6	7	177	3
⑥ N.Tarawa	551	110	10	3	9	132	2
⑧ Maiana	378	76	9	3	3	91	2
⑨ Abemama	534	107	6	4	4	121	2
⑩ Kuria	187	37	3	2	1	43	1
⑪ Aranuka	169	34	2	2	2	40	1
⑫ Nonouti	539	108	6	4	7	125	2
⑬ N.Tabiteua	586	125	10	5	8	148	2
⑭ S.Tabiteua	250	50	4	3	4	61	1
⑮ Beru	539	108	6	3	3	120	2
⑯ Nikunau	369	74	4	3	3	84	2
⑰ Onotoa	431	86	7	3	5	101	2
⑱ Tamana	263	53	2	1	1	57	1
⑲ Arorae	276	55	2	1	1	59	1
⑳ Washington	163	33	2	2	1	38	1
㉑ Fanning	244	49	4	2	3	58	1
㉓ Canton	8	2	1	1	1	5	0*
Total	7,663	1,543	108	59	79	1,789	31

* User maintained with annual visit by the SEC technician

The number of household to be electrified is about 1,550 and in 1993/94, JICA and EC has installed or is going to install about 300 systems, then, the number to be installed is 1,250 household and 250 other buildings.

10.2.2 Systems to be installed

The PV systems for rural electrification will be designed assuming the main purpose of electricity for households is for lighting while for other buildings is lighting, communication(CB radio) and radio/VCR use.

Table 10.2-2 Main component of PV system

	Household	Other buildings
PV array	50W x 2	50W x 10
Battery	100Ah x 1	100Ah x 4
Controller	1	2

Systems should be designed after the user's needs are surveyed thoroughly

Table 10.2-3 Materials to be required for the first stage electrification

	Household	Other building	Total
PV panel(50W)	1250 x 2 = 2500	250 x 10 = 2500	5000
Battery(100Ah)	1250 x 1 = 1250	250 x 4 = 1000	2250
Controller	1250	250 x 2 = 500	1750

Table 10.2-4 Installation schedule

year	First	Second	Third	Fourth	Fifth	Total
Training of F.T*	6	6	6	6	6	30**
Installation of household system	250	250	250	250	250	1250
Installation of other building	50	50	50	50	50	250

* Field Technician ** including each one of Banaba and Canton

In the JICA's study experiences, it seems practical for the SEC to install 300 to 400 PV systems in each year with assistance from local labor.

If we suppose the cost of PV system as 20A$/W for PV array output, the installation fund for the first stage electrification is estimated as follows:

Table 10.2-5 Installation cost (1,000A$)

year	First	Second	Third	Fourth	Fifth	Total
Installation of household system	500	500	500	500	500	2500
Installation of other building	500	500	500	500	500	2500
Total	1000	1000	1000	1000	1000	5000

The total project cost will come to roughly five million Australian dollars including the labor cost for installation.

10.2.3 The case study of rural electrification

Under the several preconditions, the simulation results shows the first stage of electrification by PV systems is viable.

The preconditions are:

(a) Initial investment is provided by government or foreign Aid.

(b) Users pay installation fee(50A$) and monthly maintenance fee(9A$/M).

(c) Degradation of system components is PV panel(2%/Y), battery(life time 5years) controller(life time 10years).

(d) Exchange cost of system components is PV panel(350A$), battery(150 A$), controller(120A$).

Through the first stage, neglecting depreciation, the income will cover the cost. (see the Table 10.2-6).

10.2.4 Recommendation for rural electrification by Photovoltaics

(1) The turn of Islands to be electrified

It seems reasonable to implement the electrification by the nearest Island such as Abaian, as SEC will be possible to maintain and control the system and their field technicians.

(2) The fund collection

The calculation of Table 10.2-6, the maintenance fee for a large system such as Maneaba is same as a household but if the fee for a large system will be higher than a household then, the rough profit of the SEC becomes more preferable.

(3) The field technician

The field technician is very important to implement and succeed the rural electrification that the SEC should be care to engage the field technician.

(4) Fund management

The excess of maintenance fee from rural electrification should be kept in separate account from SEC ordinal account and it will be applied to increase the fund for an exchange of batteries and controllers.

(5) Support from the Government

The support from the government is necessary such as to exempt the profit in appearance like the fund described above from the true profit of the activity of the SEC.

(6) Exchange of information

There are many organizations to concern the PV electrification such as: SPFS(South Pacific Forum Secretariat, Fiji), SPIRE(South Pacific Institute for Renewable Energy, French Polynesia), TSECS(Tuvalu Solar Electricity Cooperative Society, Tuvalu), USP(University of South Pacific), etc. it is also better to exchange their Knowledge and experience to each other.

(7) Education of people

It is necessary to educate people not only installed the PV system but also people who can touch the PV system what is good or not good for PV system.

Table 10.2-6 Case study of rural electrification A$

Profit & Loss Items		Cost		1	2	3	4	5	6	7--10	11	12	13--15	16	17	18	19	20
Policy & Environment	Unit cost of H.H	2000.0	A$															
	Unit cost of O.B	10000.0																
	Unit cost of panel	350.0																
	Unit cost of Battery	150.0																
	Unit cost of control	120.0																
	Wage of Field Tech.	2000.0																
	Inst. fee per Unit	50.0																
	Maint. fee per year	108.0																
Sales	No. of Inst. Unit H.H			300	250	250	250	250	250									
	No. of Inst. Unit O.B			5	50	50	50	50	50									
	accum H.H			300	550	800	1050	1300	1550	1550	1550	1550	1550	1550	1550	1550	1550	1550
	accum O.B			5	55	105	155	205	255	255	255	255	255	255	255	255	255	255
	Sales of Install			15,250	15,000	15,000	15,000	15,000	15,000									
	Sales of Maintenance			32,940	65,340	97,740	130,140	162,540	194,940	194,940	194,940	194,940	194,940	194,940	194,940	194,940	194,940	194,940
	Total Income			48,190	80,340	112,740	145,140	177,540	209,940	194,940	194,940	194,940	194,940	194,940	194,940	194,940	194,940	194,940
Variable cost	Number of panel	2.0	%		13	33	53	73	93	113	113	113	113	113	113	113	113	113
	Number of Battery	5years							320	450	770	450	450	770	450	450	450	450
	Number of controller	10years									310	350	350	350				
	Cost of panel			0	3,900	9,900	15,900	21,900	27,900	33,900	33,900	33,900	33,900	33,900	33,900	33,900	33,900	33,900
	Cost of battery			0	0	0	0	0	48,000	67,500	115,500	67,500	67,500	115,500	67,500	67,500	67,500	67,500
	Cost of controller			0	0	0	0	0	0	0	31,000	35,000	35,000	35,000	0	0	0	0
	Total Var. Cost			0	3,900	9,900	15,900	21,900	75,900	101,400	180,400	136,400	136,400	184,400	101,400	101,400	101,400	101,400
Fixed cost	Number of Field tech			5	11	17	23	29	35	35	35	35	35	35	35	35	35	35
	Wages of Field Tech.			10,000	22,000	34,000	46,000	58,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000	70,000
	Administration	15.0	%	1,500	3,300	5,100	6,900	8,700	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500	10,500
	Total Fixed Cost			11,500	25,300	39,100	52,900	66,700	80,500	80,500	80,500	80,500	80,500	80,500	80,500	80,500	80,500	80,500
	Total cost			11,500	29,200	49,000	68,800	88,600	156,400	181,900	260,900	216,900	216,900	264,900	181,900	181,900	181,900	181,900
	(Investment cost)			650,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	0	0	0	0	0	0	0	0	0
Income from Opn.				36,690	51,140	63,740	76,340	88,940	53,540	13,040	-65,960	-21,960	-21,960	-69,960	13,040	13,040	13,040	13,040
	Net Present Value	r=10%		230,682														

JICA