Attachment C Technical Transfer and Counterpart Trainings

Attachment C-1 Counterpart Training in Japan (1st Year)

Table C-1.1 Schedule of Counterpart Training in Japan (1st Year)

Day	Date	Site	Activity/Theme	Lecturer/Researcher/Facility
1	27/08	Nairobi	Departure	-
2	28/08	Tokyo	Arrival	-
3	29/08	Tokyo	Orientation and Program Briefing	JICA Tokyo
4	30/08	Tokyo	Case Study - Rural Electrification Project	Nippon Koei Company, JICA Tokyo
5	31/08	Tokyo	Case Study- Renewable Energy Project	Nippon Koei Company, JICA Tokyo
Weekend Break				
8	03/09	Tochigi Prefecture	Lecture- Renewable Energy Technology Site Visit- Research Facility	Ashikaga Institute of Technology Collaborative Research Center
9	04/09	Nagano Prefecture	Lecture and Site Visit- Small hydropower plant	Department of Environmental Science and Technology Shinshu University
10	05/09	Chiba Prefecture	Lecture and Site Visit- Solar PV testing facility	Sakura Testing Facility Kyocera Corporation
11	06/09	Kanagawa Prefecture	Solar PV technology Environmental education	Kawasaki Eco-life Museum for Future
12	07/09	Ibaraki Prefecture	Biomass Resources Large Scale wind power (semi-offshore)	Wind Power Ibaraki Ltd.
Weekend Break				
15	10/09	Tochigi Prefecture	Site Visits: Biogas power generation system Micro-hydro power station	Nasunogahara Land Improvement Districts Livestock Dairy Research Center
16	11/09	Tokyo	Lecture and Site Visit- Small Wind Turbine	Zephyr Corporation
17	12/09	Yamanashi Prefecture	Site Visit- Solar PV pilot testing facility	Yamanashi Prefecture Hokuto City
18	13/09	Tokyo	Documentation, Wrap-up Meeting- Nippon Koei Company	JICA Tokyo
19	14/09	Tokyo	Evaluation	JICA Tokyo

Attachment C-2 Counterpart Training in India (2nd Year)

Table C-2.1 Schedule of Counterpart Training in India (2nd Year)

SCHEDULE OF THE COUNTERPART TRAINING IN INDIA

11/9 Sat	11/10 Sun	11/11 Mon	11/12 Tue	11/13 Wed	11/14 Thu	11/15 Fri	11/16 Sat
New Delhi				Bhubaneswar		Kolkata	
(PM) Depart from Nairobi (PM) Arrival in New Delhi			(AM) 10.00 AM: Start-up meeting for the officials at TERI head quarter, New Delhi followed by three lectures **Lecture 1**: Use of Renewable Energy in enhancing access – Technology used and Business Models in India **Lecture 2**: Experiences of solar PV projects implementation and management including tariff collection strategies and financial mechanism followed in India **Lecture 3**: Jawarlal Nehru National Solar Mission in India – Status and Experiences 02.00 PM **Site 1:** Visit to TERI's Smart-Mini-Grid facility at Guwalpahari (1 hours journey from TERI head quarter)	07.00 AM Travel from Delhi to Bhubaneswar, Odisha (early Morning) Check-in at the hotel in Bhubaneswar 11.00 AM **Site 2:** Visit to Solar Charging Station implemented by TERI at Khurda	8.00 AM - 6.00 PM **Site 3:** Travel from Bhubaneswar to Chaudwar and visit to Solar Multi Utility facility implemented by TERI **Site 4:** Travel from Chaudwar to Dhenkanal and visit to Micro-Grid implemented by TERI	8.00 AM Travel from Bhubaneswar to Kolkata, West Bengal and check-in in the hotel in Kolkata 2.00 PM **Site 5:** Interactive Meeting with senior officials of West Bengal Renewable Energy Development Agency (WBREDA)	7.00 AM - 8.00 PM Travel to Sagar Island in Sundarbans, West Bengal **Site 6:** Visit off-grid Solar PV and small Wind Turbine systems at sagar Island
Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Contact no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Contact no. +91 11 4683 3333	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Contact no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Contact no. +91 11 4683 3333	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Contact no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Contact no. +91 11 4683 3333	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Contact no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Contact no. +91 11 4683 3333	Accomodation in Bhubaneswar : Hotel Swosti Premium P-1, Jaydev Vihar, Bhubaneswar, Odisha - 751013 Contact no. +91 674 301 7000	Accomodation in Bhubaneswar : Hotel Swosti Premium P-1, Jaydev Vihar, Bhubaneswar, Odisha - 751013 Contact no. +91 674 301 7000	Accomodation in Kolkata : Indismart Hotel X-1, 8/3, Block- EP, Sector- V, Salt Lake Electronics Complex, Kolkata - 700091, Contact no. +91 33 4010 1350 E-mail id. reservation@indismart.in	Accomodation in Kolkata : Indismart Hotel X-1, 8/3, Block- EP, Sector- V, Salt Lake Electronics Complex, Kolkata - 700091, Contact no. +91 33 4010 1350 E-mail id. reservation@indismart.in

11/17 Sun	11/18 Mon	11/19 Tue	11/20 Wed	11/21 Thu	11/22 Fri
Kolkata	New Delhi				Nairobi
8.00 AM - 7.00 PM Travel to Asansol, West Bengal **Site 7:** Visit grid connected solar PV (1MW) power plant at Asansol	7.00 AM Travel from Kolkata to New Delhi 10.00 AM Check-in at the hotel in New Delhi 12.00 PM **Site 7:** Visit to poultry litter based biogas power plant site in Jhajjar, Haryana	7.00 AM to 8.00 PM Travel to Roorkee in early morning Site 8: Visit to Alternate Hydro Energy Center (AHEC) at IIT Roorkee	10.00 AM - 12 PM Wrap-up meeting at TERI head quarter, New Delhi Experience sharing by participants from the visit and clarifications, if any Lessons Learnt and follow up discussion/Addressing any queries		(AM) Depart from New Delhi (PM) Arrival in Nairobi
Accomodation in Kolkata : Indismart Hotel X-1, 8/3, Block- EP, Sector- V, Salt Lake Electronics Complex, Kolkata - 700091, Contact no. +91 33 4010 1350 E-mail id. reservation@indismart.in	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Phone no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Phone no. +91 11 4683 3333	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Phone no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Phone no. +91 11 4683 3333	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Phone no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Phone no. +91 11 4683 3333	Accomodation in New Delhi : Hotel Parkland E-19, Defence Colony, New Delhi, Delhi - 110024 Phone no. +91 11 4227 7777 OR The Ashtan Sarovar Portico, C-2, Sri Aurobindo Marg, Green Park Extension, New Delhi, Delhi - 110016 Phone no. +91 11 4683 3334	

Contact Person from TERI during the visit:
Sudhakar Sundaray
Research Associate
The Energy and Resources Institute
India Habitat Centre, Lodi Road, New Delhi - 110003 | India
T: +91 11 2468 2100 / 4150 4900 (extn. 2168) | F: +91 11 2468 2144
M: +91 9990 4567 62 E-mail id. sudhakar.sundaray@teri.res.in

Attachment C-3 Counterpart Training in Thailand (3rd Year)

Table C-3.1 Schedule of Counterpart Training in Thailand (3rd Year)

SCHEDULE OF THE COUNTERPART TRAINING IN THAILAND

8/2	8/3	8/4	8/5	8/6	8/7	8/8	8/9
Sat	Sun	Mon	Tue	Wed	Thu	Fri	Sat
Kenya-Thailand		**Phitsanulok, Thailand**					
Departure from Nairobi (KQ886): 11:10 PM	Arrival in Bangkok: 12:50 PM (Thailand time) Bangkok to Phitsanulok: 1:15 PM to 6:15 PM. (transport by road)	(AM) 09.00 AM: Start-up meeting for the officials at SERT followed by two lectures **Lecture 1**: Photovoltaic System (PM) **Lecture 2**: Photovoltaic System (continue)	(AM) 09.00 AM: Hands on training (technical O&M) (PM) Hands on training (technical O&M) (continue)	(AM) 09.00 AM **Lecture 1:** Small/ Micro Hydro (PM) **Lecture 2:** Wind power	(AM) 09.00 AM **Lecture 1:** Biomass/ Biogas (PM) **Lecture 2:** Biomass/ Biogas (continue)	(AM) 09.00 AM **Lecture 1:** Rural Electrification (off-grid, mini-grid) (PM) **Lecture 2:** Rural Electrification (off-grid, mini-grid) (continue)	(AM) 09.00 AM **Lecture 1**: Solar Energy (PM) **Lecture 2**: Solar Thermal Energy (continue)
	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555

8/10	8/11	8/12	8/13	8/14	8/15	8/16
Sun	Mon	Tue	Wed	Thu	Fri	Sat
Phitsanulok, Thailand			**Field Trip, Thailand**		**Thailand-Kenya**	
Day-off	(AM) 09.00 AM **Lecture 1:** Sustainable Rural Energy Development (PM) Wrap-up meeting and follow up discussion/Addressing any queries	(AM) 09.00 AM **Lecture 1:** Economic & Financial analysis (PM) **Lecture 2:** Economic & Financial analysis (continue)	8.00 AM Travel from Phitsanulok to Pichit 10.00 AM Visit Biomass power plant PM Visit Biogas power plant	8.00 AM Travel from Phitsanulok to Pichit 10.00 AM Visit PV power plant (PM) Wrap-up meeting and follow up discussion/Addressing any queries	Domestic flight from Phitsanulok to Bangkok: 8:00 AM to 8:50 AM	Departure from Bangkok (KQ887): 0:35 AM Arrival in Nairobi: 6:05 AM (Kenya time)
Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555	Accomodation in Phitsanulok: Wangchan River view Hotel Phitsanulok 65000, Thailand Contact no. +66 5525 2555		

Contact Person from SERT during the visit:
Assist. Prof. Dr.-Ing.Nipon Ketjoy
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The Project for Establhishment of Rural Electrification Model Using Renewable Energy

Objective & Achievement Sheet

Date:

Name: Alex M. Makori

Position: Technician.

Objectives of the concerned project activities:

1. Lighting up the rural areas to aid in activities such as phone charging etc.

2. to be familiar with the JICA project design of the solar installation model.

3. creation of job opportunities using the project for people living in rural areas.

Individual achievement goal in the OJT

1. Was able to get more technical ideas from the project. Use of the wooden box to cover the facilities proved useful.

2. l was able to compare the JICA design with others like it, and concluded in the same.

3. Interaction with the government officials of the area and the locals was of utmost help. This included sharing of project information and helping the participants understand the advantages of the project.

4. the main aim of the project being to help light up the rural areas and assist in other activities like phone charging was successful.

Achievements corresponding to the abovementioned individual goal (self evaluation):

1. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
   4

Comment: Use of the box covers elevated the idea of protection. The facilities lifespan thus increased.

2. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
   4

Comment: The JICA Design helped in designing for other solar installation in other parts where its needed.

3. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

   4

Comment:

The meetings held among the JICA members, M.O.E, REA officials and the locals was outstanding and informative.

4. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

   5

   Comment: Phone charging in the specific areas escalated to an outstanding level. It proved that the project really aided the locals ie they now had options in their locality when it came to use of power.

Other opinions

1. Proposed alternative measures to boost the workers commitment eg occasional gifts for best worker. Educational small visits from the engineers who installed the solar power etc
2. Official payable day offs for the system alternating workers would boost workers commitment to the job.
3. Other ideas like the ones in the pictorial diagram provided should be emulated.

The Project for Establishment of Rural Electrification Model Using Renewable Energy
Objective & Achievement Sheet

Date: 11/12/2014
Name: Antony Wanjara
Position: Technician Renewable Energy

Objectives of the concerned project activities:
1. Design of a solar PV system and a MHP system

2. Pre feasibility study for a MHP project
3. Monitoring and evaluation of a solar PV system
4. Making a solar PV system sustainable.

Individual achievement goal in the OJT
1. Ability to design a solar PV and a MHP system.
2. Ability to conduct feasibility study and prepare a report
3. Ability to monitor the performance of a solar PV system
4. Ability to make installed solar PV system sustainable by generating self sustaining finances.

Achievements corresponding to the abovementioned individual goal (self evaluation):
1. Achieved level (Achieved ← 5 4 3 2 1 →Not Achieved)
Comment:

2. Achieved level (Achieved ← 5 4 3 2 1 →Not Achieved)
Comment:

3. Achieved level (Achieved ← 5 4 3 2 1 →Not Achieved)
Comment:

Other opinions
The aspect of collecting revenue from the pilot projects could not be achieved due to extensive grid extension on the identified site. However the same can be replicated in other remote areas that are far from the grid.

The Project for Establishment of Rural Electrification Model Using Renewable Energy

Objective & Achievement Sheet

Date: 19/12/2014
Name: Judith Kimeu
Position: Assistant Engineer Renewable Energy

Objectives of the concerned project activities:
1. Design of a MHP system
2. Pre feasibility study for a MHP project

Individual achievement goal in the OJT
1. Ability to design a MHP system.
2. Ability to conduct feasibility study and prepare a report

Achievements corresponding to the abovementioned individual goal (self evaluation):
1. Achieved level (Achieved ← 5 4 3 2 1 →Not Achieved)
Comment:

2. Achieved level (Achieved ← 5 4 3 2 1 →Not Achieved)
Comment:

3. Achieved level (Achieved ← 5 4 3 2 1 →Not Achieved)
Comment:

Other opinions
The technical transfer focused on the project objectives and has aimed to achieving them. This has been done very effectively

The Project for Establishment of Rural Electrification Model Using Renewable Energy
Objective & Achievement Sheet

Date: 17th January 2015
Name: Semekiah Ongong'a
Position: Assistant Engineer-Renewable Energy

Objectives of the concerned project activities:

1. To understand the theoretical knowledge in planning and developing a mini hydro power project

2. To understand environmental issues associated with the development of mini hydro power projects and mitigation measures

3. Establishment of rural electrification models using mini hydro power schemes

4. To understand prefeasibility processes in establishing mini hydro power projects

Individual achievement goal in the OJT

1. Learnt hydrological analysis processes and tools for evaluating potential of a mini hydro project and estimation of an area power demand for demand for establishing sustainability of exploiting a mini hydro power.

2. Understood the necessary data for evaluating the hydro power potential

3. Understood the operation of equipments necessary for determination of hydro potential. Example is the current flow meter

Achievements corresponding to the abovementioned individual goal (self evaluation):

1. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

Comment: 4 I can collect data draw necessary flow graghs and determine to a higher accuracy using demand models to establish the power demand necessary for knowing sustainability of developing a mini hydro.

2. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

Comment: 4 I can collect data draw necessary flow graghs and apply necessary equations for determining catchment area potentials

3. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

Comment:　5 I can effectively operate the various equipment necessary for determining the flow rates and altitude measurement for determining river gross power potential

Other opinions

The exercise is very interesting however in future it would have been more knowledgeable to incorporate practical development of one of the schemes and also carry a full feasibility study. That way a learner could be able to understand the challenges in the development of a mini hydro scheme.

The Project for Establishment of Rural Electrification Model Using Renewable Energy

Objective & Achievement Sheet

Date: 26/011/2014

Name: Caroline Kelly

Position: Assistant Officer Renewable Energy

Objectives of the concerned project activities:

1. Design of a biogas system for establishment of a biogas system
2. Pre feasibility study for a new project site
3. Preparation of bidding document with technical specification for a new site
4. Monitoring of existing biogas system using monitoring tools

Individual achievement goal in the OJT

1. Ability to design to a biogas system with or without a generator system
2. Ability to conduct feasibility study and prepare a report
3. Ability to prepare a bidding document including technical specification
4. Ability to monitor existing system and conducting analysis of the biogas obtained and conditions of the digester

Achievements corresponding to the above mentioned individual goal (self evaluation):

1. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

Comment:

2. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

Comment:

3. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)

Comment:

Other opinions

The technical focused on the project objective and has aimed to achieving them. This has been done very effectively.

The Project for Establishment of Rural Electrification Model Using Renewable Energy
Objective & Achievement Sheet

Date: 16/01/2015
Name: Gilbert Gichunge
Position: Assistant Engineer Renewable Energy

Objectives of the concerned project activities:
1. Design of a biogas system for establishment of a biogas system
2. Pre feasibility study for a new project site
3. Preparation of bidding document with technical specification for a new site
4. Monitoring of existing biogas system using monitoring tools

Individual achievement goal in the OJT
1. Ability to design to a biogas system with or without a generator system
2. Ability to conduct feasibility study and prepare a report
3. Ability to prepare a bidding document including technical specification
4. Ability to monitor existing system and conducting analysis of the biogas obtained and conditions of the digester

Achievements corresponding to the above mentioned individual goal (self evaluation):
1. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
Comment:

2. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
Comment:

3. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
Comment:

Other opinions
The technical focused on the project objective and has aimed to achieving them. This has been done very effectively.
M &E was successively carried out

The Project for Establishment of Rural Electrification Model Using Renewable Energy
Objective & Achievement Sheet

Date: 11-12-2014
Name: HANNINGTON GOCHI
Position: SENIOR TECHNICIAN

Objectives of the concerned project activities:
1. Carry out pre-feasibility study on wind power technology
2. Carry out wind data analysis
3. Acquire skills for designing a wind/diesel hybrid system

Individual achievement goal in the OJT
1. SKILLS IN WIND DATA ANALYSIS
2. SIZING OF HYBRID SYSTEMS (WIND/SOLAR/DIESEL)
3.

Achievements corresponding to the abovementioned individual goal (self evaluation):
1. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
Comment:

2. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
Comment:

3. Achieved level (Achieved ← 5 4 3 2 1 → Not Achieved)
Comment:

Other opinions
The project has been helpful in furthering our knowledge on wind power technology
That will go a long way in tapping into wind power potential in the country.

Attachment D Features of Pilot Projects

D Facility Information

D-1 Lot 1 site

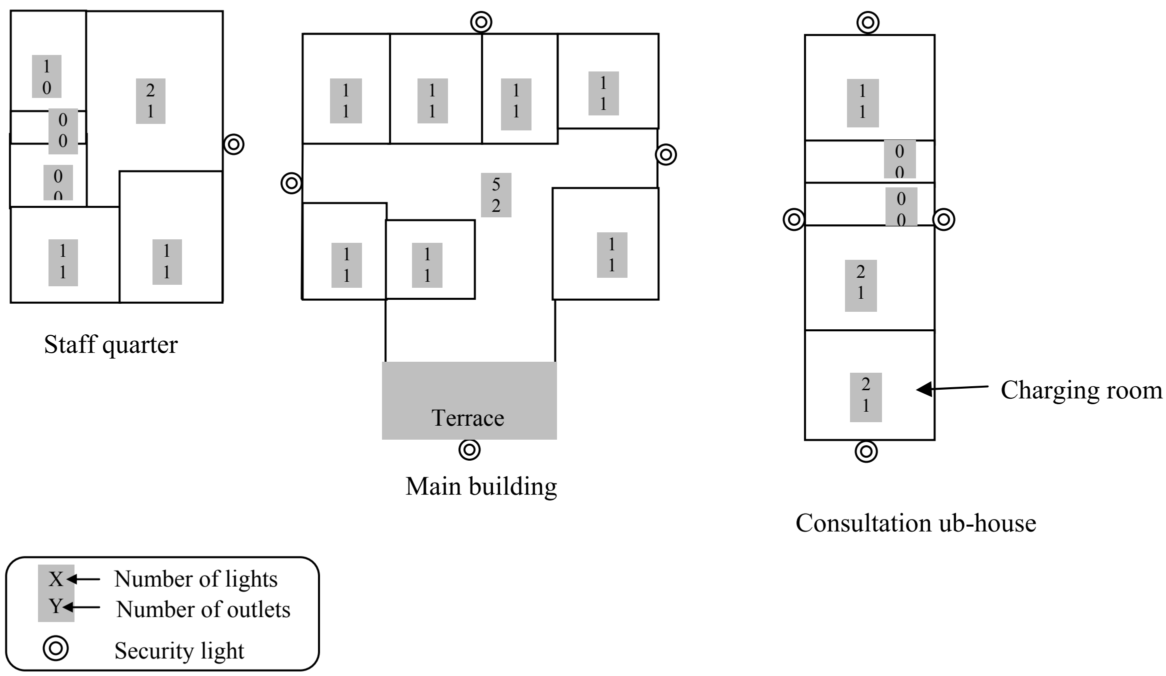
(1) Ilkilnyeti Dispensary			
General		Technical	
Facility type	dispensary	System Voltages (V)	12, 24
Sub-county	Kajiado East	Total capacity (Watts)	1680
County	Kajiado	Watts X Qty	120 X 14
Location	Latitude: S 2.29268 Longitude: E37.61312 Altitude: 1,035 m	Battery (Ah X Qty)	100 X 1 225 X 8
Facility staff members	2	Charge Controller (Amps X Qty)	10 X 1, 20 X 1, 30X 1, 60 X 1
Nos of pupils (boarding pupils)	-	Inverter (VA X Qty)	350 X 2, 800 X 2
		Vaccine Refrigerator	Solar Drive fridge (Vestfrost MKS 044S) X 1
	-		

Photo

Left: Consultation sub house. Right: Main building

Staff quarter

Drawing



(2) Iltumtum Primary School

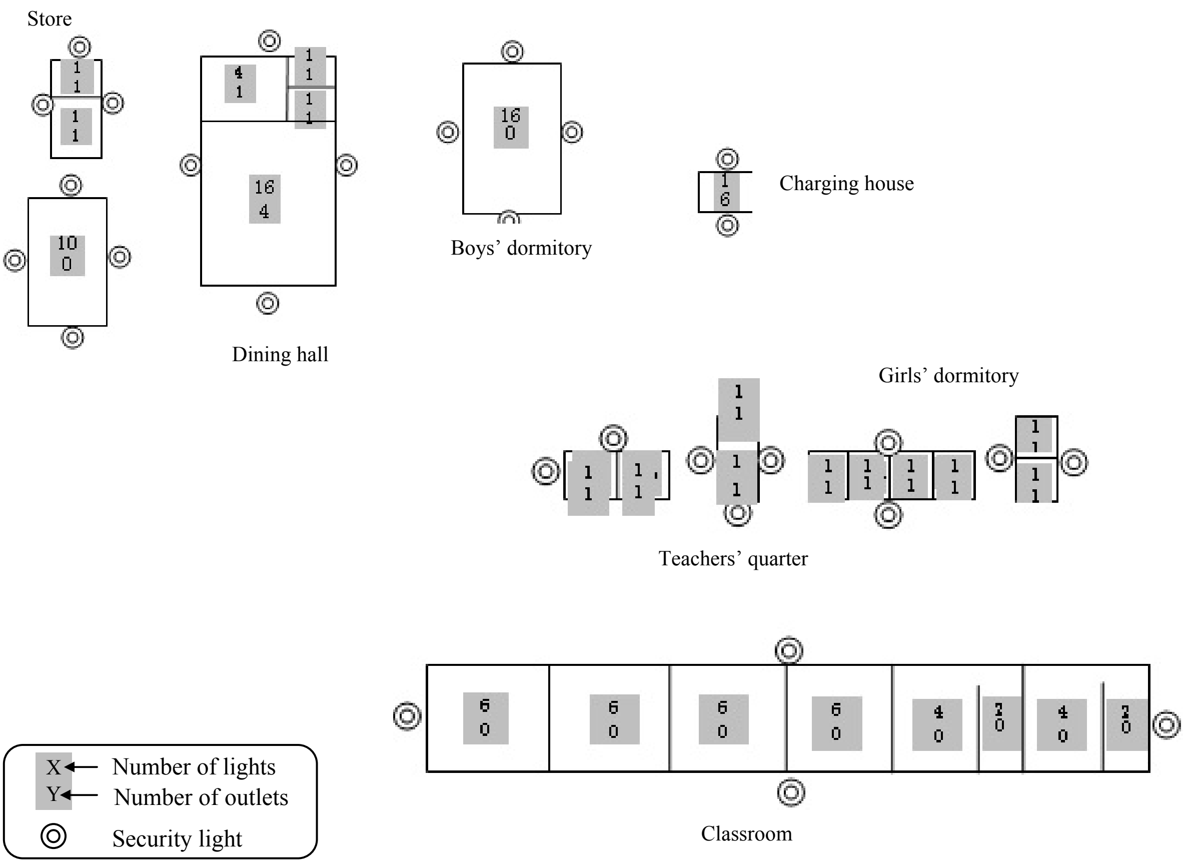
General			Technical	
Facility type	School		System Voltages (V)	12, 24
Sub-county	Narok North		Total capacity (Watts)	3360
County	Narok		Watts X Qty	120 X 28
Location	Latitude:	S1.2451	Battery (Ah X Qty)	200 X 4 225 X 9
	Longitude:	E35.95778		
	Altitude:	1,855 m		
Facility staff members	9		Charge Controller (Amps X Qty)	10 X 1, 20 X 1, 30X 1, 60 X 1
Nos of pupils (boarding pupils)	351 (106)		Inverter (VA X Qty)	350 X 3, 800 X 4

Photo

Charging house

Classroom (before installation)

Drawing



(3) Olkinyei Dispensary

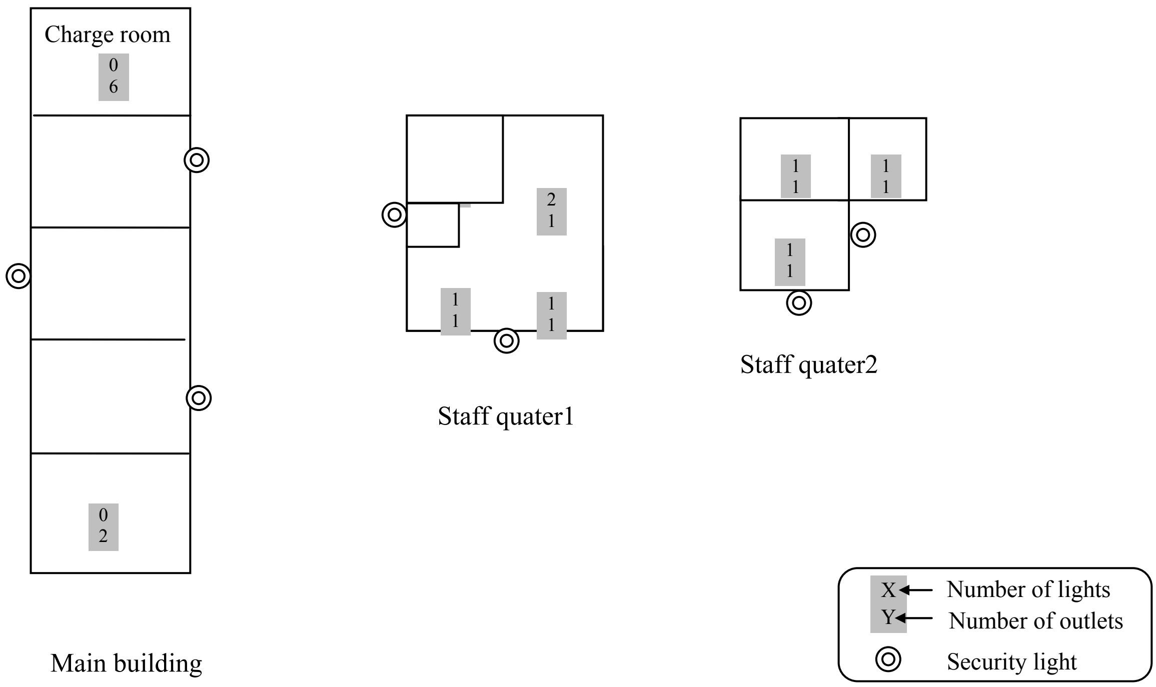
General			Technical	
Facility type	dispensary		System Voltages (V)	12
Sub-county	Narok South		Total capacity (Watts)	800
County	Narok		Watts X Qty	80 X 4, 120 X 4
Location	Latitude:	S1.18395	Battery (Ah X Qty)	100 X 1 225 X 4
	Longitude:	E34.40691		
	Altitude:	1,973 m		
Facility staff members	4		Charge Controller (Amps X Qty)	10 X 1, 20 X 2, 30X 1
Nos of pupils (boarding pupils)	-		Inverter (VA X Qty)	350 X 3, 800 X 1

Photo

Main building (during installation)

Staff quarter 1

Drawing



(4) Olemoncho Primary School

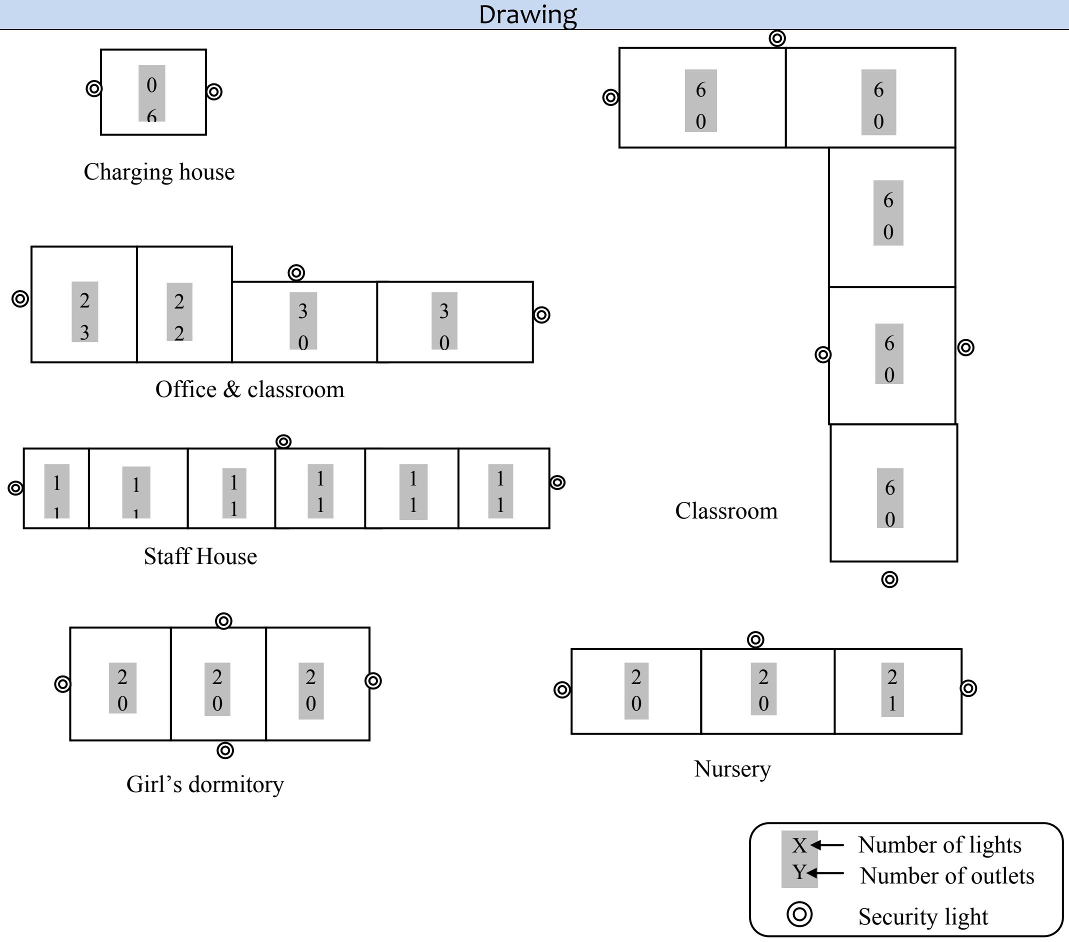
General			Technical	
Facility type	School		System Voltages (V)	12, 24
Sub-county	Narok South		Total capacity (Watts)	2640
County	Narok		Watts X Qty	120 X 22
Location	Latitude:	S1.19849	Battery (Ah X Qty)	225 X 11
	Longitude:	E35.28584		
	Altitude:	1,799 m		
Facility staff members	10		Charge Controller (Amps X Qty)	20 X 3, 60X 4
Nos of pupils (boarding pupils)	347 (62)		Inverter (VA X Qty)	350 X 3, 800 X 4

Photo


Office & classroom


Nursery

Drawing



D-2 Lot 2 site

(5) Tuum Primary School

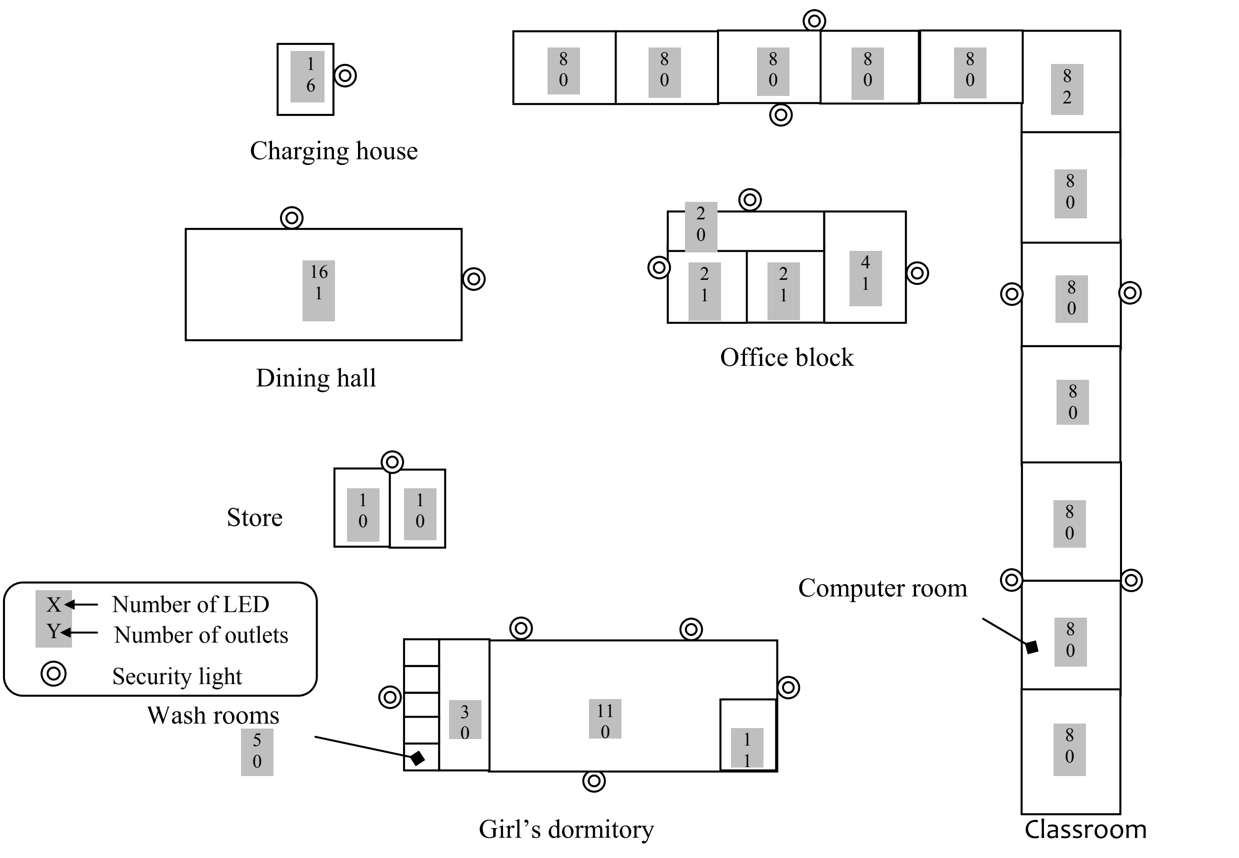
General			Technical	
Facility type	School		System Voltages (V)	12, 24, 48
Sub-county	Samburu North		Total capacity (Watts)	5,250
County	Samburu		Watts X Qty	125 X 42
Location	Latitude:	N 2.14533	Battery (Ah X Qty)	100 X 1 200 X 16
	Longitude:	E 36.77296		
	Altitude:	1,426m		
Facility staff members	Teacher	9	Charge Controller (Amps X Qty)	15X 1, 30 X 6, 45X 1
	Staff	2		
Nos of pupils (boarding pupils)	174 (0)		Inverter (VA X Qty)	350 X 1, 800 X 6, 3000X 1

Photo

Classroom (during installation)

Classroom (after installation)

Drawing



(6) Illaut Primary School

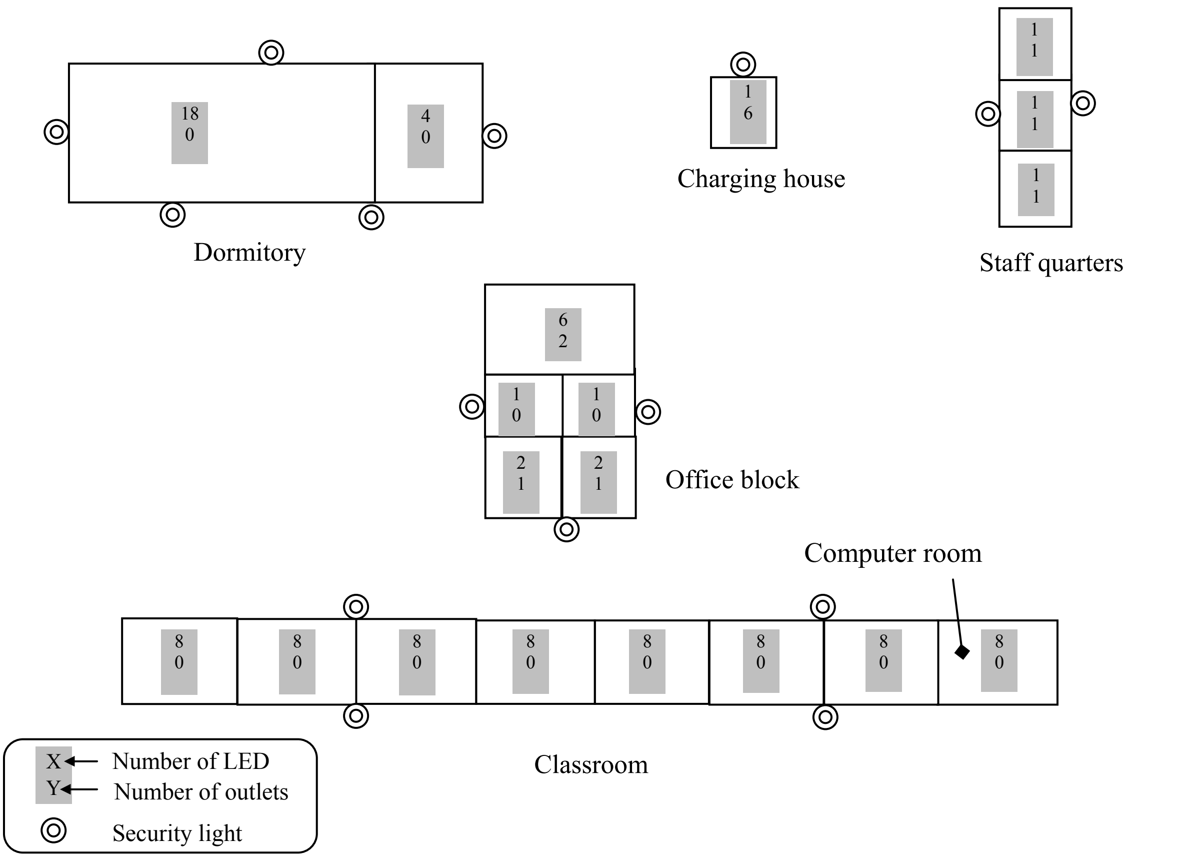
General			Technical	
Facility type	School		System Voltages (V)	12, 24, 48
Sub-county	Samburu North		Total capacity (Watts)	5,000
County	Samburu		Watts X Qty	125 X 40
Location	Latitude:	N 1.86749	Battery (Ah X Qty)	100 X 3 200 X 14
	Longitude:	E 37.24077		
	Altitude:	785 m		
Facility staff members	Teacher	8	Charge Controller (Amps X Qty)	15X 2, 30 X 5, 45X 1
	Staff	2		
Nos of pupils (boarding pupils)	275 (80)		Inverter (VA X Qty)	350 X 2, 800 X 5, 3000X 1

Photo


Classroom


Charging house

Drawing



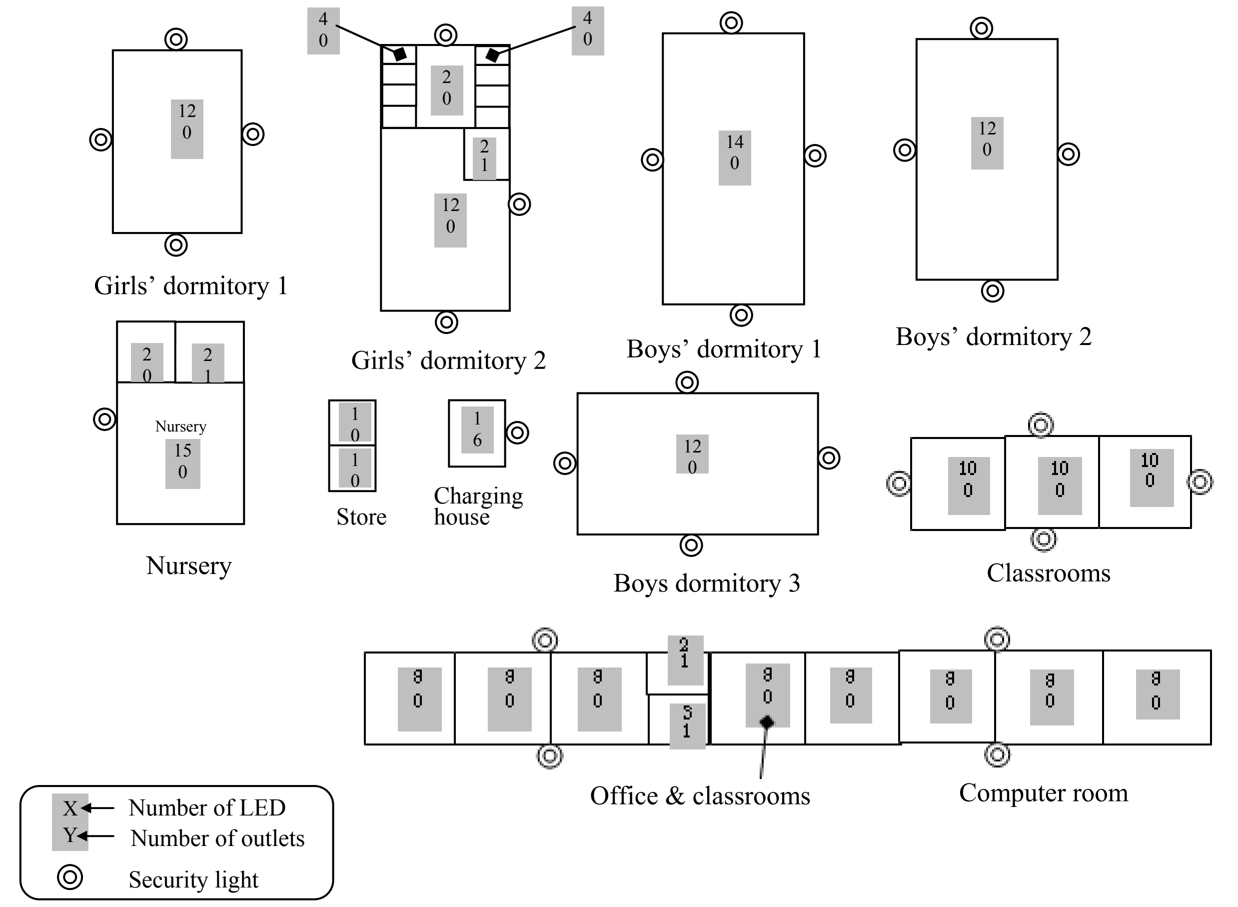
(7) Marti Primary School					
General			Technical		
Facility type	School		System Voltages (V)	12, 24, 48	
Sub-county	Samburu North		Total capacity (Watts)	6,750	
County	Samburu		Watts X Qty	125 X 54	
Location	Latitude:	N 1.47290	Battery (Ah X Qty)	100 X 1 200 X 22	
	Longitude:	E 36.71998			
	Altitude:	1,642 m			
Facility staff members	Teacher	8	Charge Controller (Amps X Qty)	15X 1, 30 X 9, 45X 1	
	Staff	5			
Nos of pupils (boarding pupils)	437 (150)		Inverter (VA X Qty)	350 X 1, 800 X 9, 3000X 1	

Photo

Classroom (after installation)

Girls dormitory

Drawing



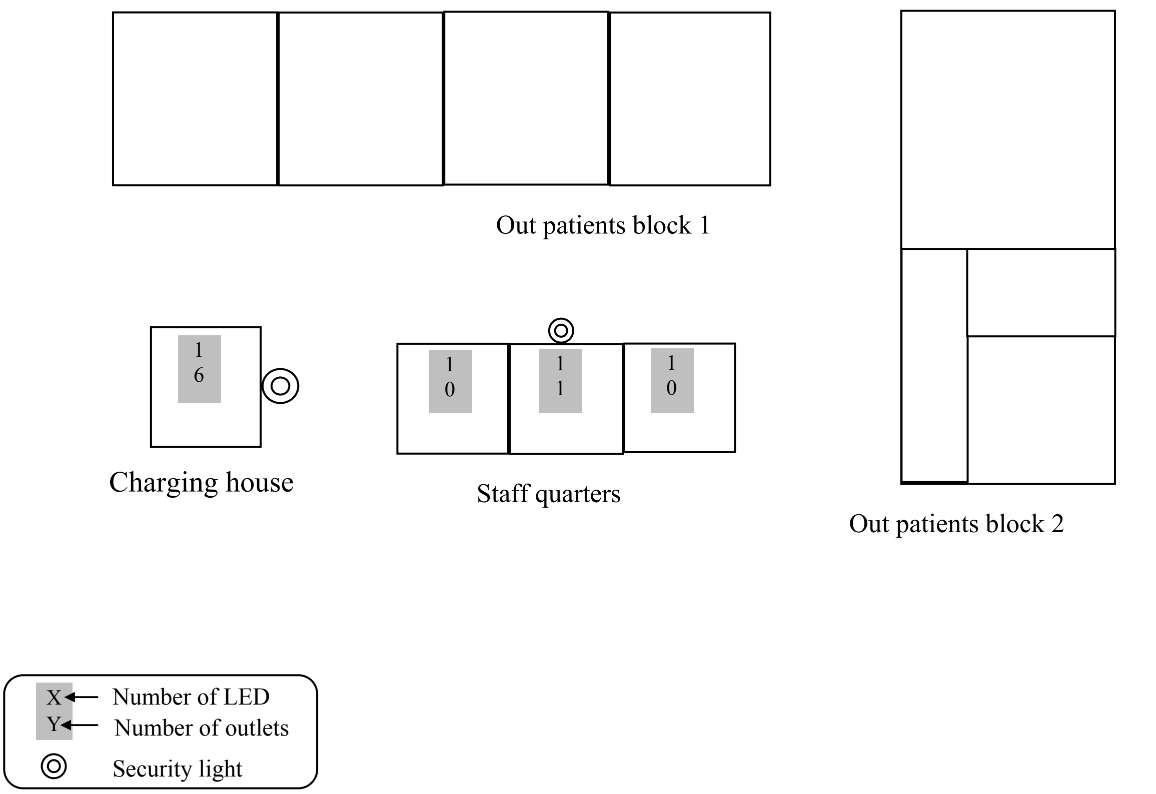
(8) South Horr Dispensary					
General			Technical		
Facility type	Dispensary			New Installation	Rehabilitation
Sub-county	Samburu North		System Voltages (V)	12, 24	12
County	Samburu		Total capacity (Watts)	500	-
Location	Latitude:	N 2.09171	Watts X Qty	125 X 4	-
	Longitude:	E 36.92031			
	Altitude:	1,015 m			
Facility staff members	Medical staff	4	Battery (Ah X Qty)	100 X 3	200 X 6
	Non-Medical	3			
Nos of pupils (boarding pupils)	-		Charge Controller (Amps X Qty)	15X 2	30X 2, 60X 1
			Inverter (VA X Qty)	350 X 2	-

Photo

Out patients block 1 and 2

Staff quarters (before installation)

Drawing



(9) Latakweny Dispensary

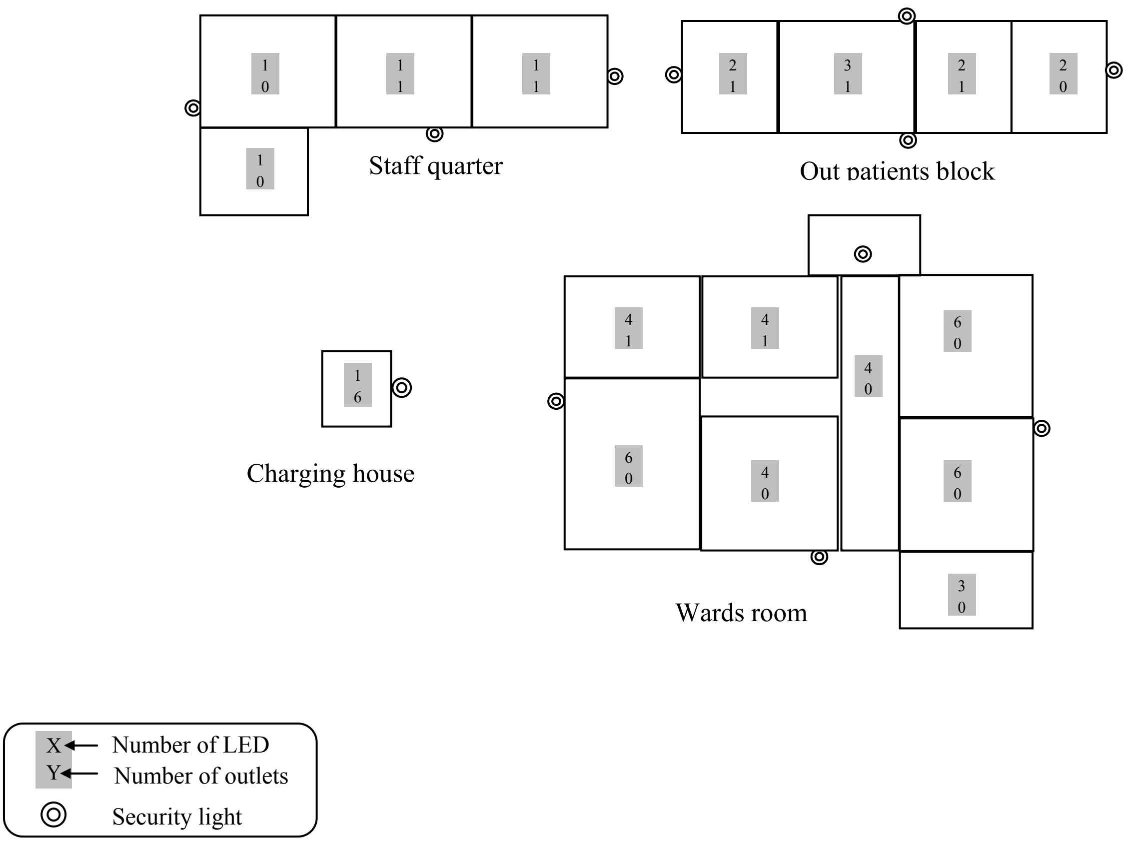
General			Technical	
Facility type	Dispensary		System Voltages (V)	12, 24
Sub-county	Samburu North		Total capacity (Watts)	2,500
County	Samburu		Watts X Qty	125 X 20
Location	Latitude	N 1.54728	Battery (Ah X Qty)	100 X 1 200 X 8
	Longitude:	E 37.10295		
	Altitude:	906 m		
Facility staff members	Medical staff	2	Charge Controller (Amps X Qty)	15X 1 30X 4
	Non-Medical	3		
Nos of pupils (boarding pupils)	-		Inverter (VA X Qty)	350 X 2, 800 X 2

Photo

Wards room

Staff quarter

Drawing



(10) Angata Nanyokei Dispensary

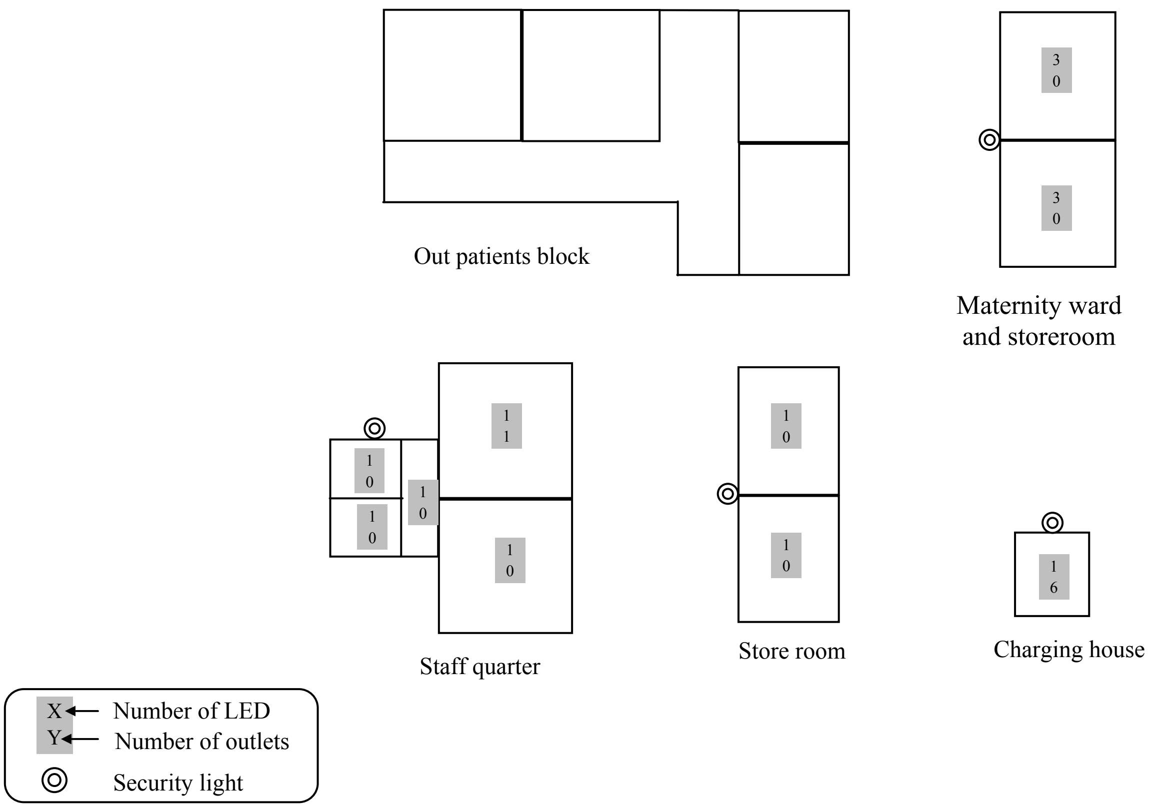
General			Technical		
Facility type	Dispensary			New Installation	Rehabilitation
Sub-county	Samburu North		System Voltages (V)	12, 24	12
County	Samburu		Total capacity (Watts)	750	-
Location	Latitude:	N 1.31809	Watts X Qty	125 X 6	-
	Longitude:	E 36.67377			
	Altitude:	2,155 m			
Facility staff members	Medical staff	1	Battery (Ah X Qty)	100 X 5	200 X 5
	Non-Medical	3			
Nos of pupils (boarding pupils)	-		Charge Controller (Amps X Qty)	15X 3	30X 1, 60X 1
			Inverter (VA X Qty)	350 X 3	-

Photo


Out patients block


Staff quarter

Drawing



Attachment E

Draft MOU of REA and MoH for Financial Support of O&M

MEMORANDUM OF UNDERSTANDING (MOU)

BETWEEN

RURAL ELECTRIFICATION AUTHORITY

AND

MINISTRY OF HEALTH

(DRAFT)

NAIROBI, KENYA

THIS Memorandum of Understanding, (hereinafter referred to as "the MOU") is entered into this _______________ day of ____________________ 2014;

BETWEEN:

a. The Rural Electrification Authority, a state corporation established under Section 66 of the Energy Act, having its registered offices at The Chancery Building, 8th Floor, Valley Road of P. O. Box 34585 – 00100 Nairobi (hereinafter referred to as "**REA**")

b. Ministry of Health, Afya House of P.O. Box _______________ Nairobi (hereinafter referred to as "**MoH**") of the other part

REA and MoH are hereinafter referred to individually as "Party" and referred to collectively as "Parties."

WHEREAS

A. MoH is interested to install solar PV systems in all the public health institutions countrywide.

B. REA has the capacity to design, procure, supply, install and commission solar PV system to be installed in public health institutions.

C. REA has the capacity to operate and maintain all the solar PV systems to be installed in the public health institutions countrywide.

D. REA and MoH have agreed to enter into this MOU for the proposes of designing, procuring, supplying, installing and commissioning of solar PV system in all the public health institutions countrywide.

E. This MoU shall only apply to specific projects funded by MoH

NOW THIS MEMORANDUM OF UNDERSTANDING (MOU) WITNESSETH AS FOLLOWS:

1. Objective of the MOU

The objective of this MOU is to state the terms and conditions under which REA in conjunction with MoH has implemented and will implement the execution of the solar PV projects to the extent of designing, supplying, installing and commissioning of the solar PV systems in the health institutions including the operations, maintenance and replacement of the systems' components.

2. Undertakings by each Party

The Parties agree to undertake the following:

2.1. REA's Undertakings:

- To identify in consultation with MoH priority public health institutions to be electrified.
- REA shall provide the budgetary estimate for all the design, procurement, supply, installation and commissioning of all the solar PV system to be installed in public health institutions.
- To update the list of un-electrified public health institutions in entire country.
- To design, procure, supply, install and commission all the solar PV system in public health institutions.
- To monitor the operations and maintenance of the solar PV systems installed in all public health institutions countrywide.
- To provide technical assistance including training of staff in respective public health institutions to enable them operate solar PV systems.
- REA shall on a quarterly basis account for all the funds remitted by MoH for the design, procurement, supply, installation and commissioning of all the solar PV systems to be installed in public health institutions.
- To share any training information on the solar PV systems with MoH.

2.2. MoH's Undertakings:

- To provide and transfer funds to REA on an annual basis for the design, procurement, supply, installation and commissioning of all the solar PV systems to be installed in public health institutions.
- To identify in consultation with REA all the un-electrified public institutions to be electrified.
- To compile information on un-electrified health institutions in Kenya and provide to REA on a regular basis to promote electrification of institutions.
- To facilitate the preparation and signing of any arrangement agreed between REA and the County Health Offices delineating the responsibilities of each Party during O&M of the solar PV systems.
- To support the County Health Offices in proper operation and maintenance of the solar PV systems, including facilitation of budget allocation for any O&M or replacement costs.
- To distribute REA's "Guideline of Solar PV System for Health Institutions" any additionally necessary manuals to the County Health Offices.
- To share information and facilitate the participation of County Health Officers in training opportunities provided by REA on the O&M of solar PV systems to ensure continuous use of the institutions.

3. Effective Date and Duration of the MOU

This MOU shall come into force and take effect on the date of signing by the Parties, and shall be effective during the operational and maintenance of the solar PV systems.

4. Assignment

No assignment will occur without a prior written consent from the Parties being obtained.

5. Amendment and modification

This MOU shall be modified, supplemented or amended by consent of the Parties.

6. Confidential Information

Each party undertakes to ensure that its employees, officers and Directors, shall hold in confidence this MOU and information, documentation, data and know-how disclosed to it by the other Party and designated in writing as 'confidential' both before and after the Signature Date ("Confidential Information"), and shall not disclose to any third party or use Confidential Information other than in connection with the performance of this MOU or any part thereof without the other Party's prior written approval.

7. Notifications

All notifications given under this MOU shall be addressed in writing and shall be delivered, faxed and/or by registered mail to the following addresses:

FOR MoH
Name: -------------------------
Address: Afya House
P.O. Box ------------------------------ – 00100, Nairobi.

FOR REA
Chief Executive Officer
Rural Electrification Authority
Address: 8^{th} Floor, The Chancery, Valley Road,
P. O. Box 34585 -00100
Nairobi, Kenya
Telephone: +254-20-4953000, 4953600
Fax: + 254- 20 – 2710944

Each Party referred to above could change its information indicated above by notifying it beforehand to the other party.

IN WITNESS WHEREOF, the Parties hereto have caused this MOU to be signed in their respective names as of the day and year first herein above written.

SIGNED FOR AND ON BEHALF OF
RURAL ELECTRIFICATION AUTHORITY

____

NG'ANG'A MUNYU
AG. CHIEF EXECUTIVE OFFICER

In the Presence of

____

ROSE N. MKALAMA
AUTHORITY SECRETARY

SIGNED FOR AND ON BEHALF OF
MoH

____

CABINET SECRETARY,
MINISTRY OF HEALTH

In the Presence of

____

PRINCIPAL SECRETARY,
MINISTRY OF HEALTH

Attachment F

Guidelines, Manual and Seminar/Workshop Materials for Solar PV System

Attachment F-1	Guideline for Solar PV System in Health Service Institutions (The main body of contents available in PDF format in the data CD-ROM)
Attachment F-2	Guideline for Solar PV System in Schools (The main body of contents available in PDF format in the data CD-ROM)
Attachment F-3	User Manual and Accounting Manual for Solar PV System (Annex 1 of Attachment F-1 and F-2)
Attachment F-4	PV Seminar Material (for Solar PV Suppliers)

Guideline for Solar PV in Health Institutions

February 2015

Ministry of Energy and Petroleum

Table of Contents

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All figures and tables are prepared by Working Group of Solar PV Guideline, consists of Rural Electrification Authority and JICA Expert Team, otherwise specified.

Working Group of Solar PV Guideline
Rural Electrification Authority (REA)
Eng. Ephantus Kamweru
Eng. James Muriithi
Mr. Hannington Gochi
Ms. Colleta Koech
and JICA Expert Team

List of Terms and Abbreviations

Abbreviation	Description
AC	Alternating Current
CC	Charge Controller
CRT	Cathode Ray Tube
DC	Direct Current
DECs	District Environmental Committee
EIA/EA	Environmental Impact Assessment/ Environmental Audit
EIA-TAC	Environmental Impact Assessment Technical Advisory Committee
EMCA	Environmental Management and Coordination Act
HH	Household
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
KSh.	Kenya Shilling
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MC	Management Committee
MOE&P	Ministry of Energy and Petroleum
MoH	Ministry of Health
NASA	National Aeronautics and Space Administration, USA
NEMA	National Environment Management Authority
O&M	Operation and Maintenance
OPD	Out Patient Department
PbCb	Lead Calcium
PbSb	Lead Antimony
PCS	Power Conditioners
PECs	Provincial Environmental Committee
PP	Power Package
PV	Photovoltaic
PVC	Polyvinyl Chloride
REA	Rural Electrification Authority
SEA	Strategic Environmental Assessment
TOR	Terms of Reference
WHO	World Health Organization
USEPA	United States Environmental Protection Agency

List of Electrical Terminology

Unit	Description
Ah (Ampere-hour)	Unit of electric charge
V (Volt)	Unit of voltage
kV (kilovolt)	1,000 volts
W (Watt)	Unit of electric power
kW (kilowatt)	1,000 W
Wh (Watt-hour)	Unit of energy
kWh (kilowatt-hour)	1,000 Wh
MWh (Megawatt-hour)	1,000 kWh
Wp (Watt-peak)	Unit of PV output
kWp (kilowatt-peak)	1,000 Wp
MWp (Megawatt-peak)	1,000 kWp

EXECUTIVE SUMMARY

1. Background

Japan International Cooperation Agency (JICA) implemented the "Project for Establishment of Rural Electrification Model using Renewable Energy in Kenya" in 2012-2015. The project has two main components; (i) pilot projects for solar PV systems, and (ii) technical assistance for wind, small hydro, and biomass/biogas. This Guideline for Solar PV Generation is prepared within the scope of the project by a Working Group (WG) of JICA Expert Team of Nippon Koei Co., Ltd /KRI in cooperation with Rural Electrification Authority (REA) in Kenya.

2. Objective of the Guideline

The pilot projects for solar PV systems consist of four sites of Lot 1 installed in Narok and Kajiado County and six sites of Lot 2 conducted in Samburu County. On the basis of the lessons learnt from the installation of Lot 1 and Lot 2 solar PV systems, and also of the inspection of existing PV systems, necessities for appropriate design procedure of solar PV system were found. Therefore, the WG prepared "Guideline for Solar PV System for Public Institutions (Health Institutions and Schools)".

3. Structure of the Guideline

The main subjects included in the Guideline of Solar PV system are as follows.

(1) Main Text

"CHAPTER 1 INTRODUCTION" summarizes objectives and contents of each Chapter.
"CHAPTER 2 SOLAR PV SYSTEM" is designed as a technical resource for people interested in learning how to design stand - alone PV systems. The main objective of this chapter is to impart the ability to successfully deal with the many aspects of PV system design. It is also designed to integrate a range of skills required to specify the appropriate electrical components for the system, and select them from a wide variety of products and manufacturers.

The purpose of the "CHAPTER 3 O&M AND MANAGEMENT" is that REA, MoH and MoEST enhance their knowledge on the appropriate and effective action of sustainable PV system, strengthen their attitude towards action and give detail elements of practice. This section of the guideline can be used to ensure that all stakeholders make up an effective management system, in terms of physical and O&M matters, for electrification of dispensaries and primary schools in the non-electrified areas using solar PV systems. It also can be used to ensure that the facility users can enjoy the power generated by installed PV systems for as long as the lifetime of solar panels (20 years). The section covers all solar PV systems that REA installed and will install.

The purpose of the "CHAPTER 4 FINANCIAL SYSTEM" is to facilitate all the executing agencies, facility owners, concerned ministries and stakeholders to prepare and provide the necessary funding for O&M and replacement of equipment for the solar PV systems for the long run. This chapter includes the introduction of the financial model to provide methodology to estimate the required public funding from the government budget as well as the commercial revenue of each facility.

"CHAPTER 5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS" describes the systems of environmental managements, reviews of relevant EIA reports and issuances of environmental licenses. Environmental and social impacts caused by solar PV projects on small scales are limited because solar PV is an inherently silent technology.

(2) Solar PV Operation Manual

The Solar PV manual is prepared for distribution to end users, to make them understand about the installed solar PV system. In addition, the manual can be referred whenever O&M is required.

The manual contains basics of standalone PV system technology, installed systems at public facilities and information of charging system. The manual was developed with many illustrations for easier understanding by local system operators. The developed manual is attached at Annex 1.

For the operation of charging services, an operator needs to understand not only the technical part of the system but also the method of management and financial recording of the system. For this, the management and financial parts are also developed and included in the same manual.

CHAPTER 1 INTRODUCTION

1.1 Objective

(1) Background

Japan International Cooperation Agency is implementing the "Project for Establishment of Rural Electrification Model using Renewable Energy in Kenya" in 2012-2015. The project has two main components; establishment of electrification model for public facilities, dispensaries and public primary (boarding) schools, using solar PV system and implementation of pilot projects, and technical assistance for wind, small hydro, and biomass/biogas. This guideline for electrification of public facilities by solar PV system is prepared within the scope of the aforementioned Project, and includes the lessons learnt from the pilot projects.

Strategic Plan 2013/2014-2017/2018 of Rural Electrification Authority (REA), Third Draft, stipulates the new electrification strategy of Kenya is to electrify public facilities of second priority such as primary schools.

Solar PV system is a common method of electrification in remote, non electrified areas where abundant sunshine is available. It does not need construction of power plant, extension of electric line, and purchase of fuel. It consumes only sunshine for power generation. These are reason why not only Kenya but many countries with low electrification rate apply it for rural electrification.

On the other hand, solar PV system needs constant maintenance as same as other types of power plant and needs certain amount of O&M cost including replacement of equipments. It is not easy for users of the system to respond to all requirements to use the system till the end of life time of solar panels.

The problem is that the requirements for sustainable system use are not widely shared among system users in Kenya. In Kenya, REA, MOE&P and other organizations installed solar PV system at a lot of schools and dispensaries, but many of them have already lost their power generation capacity or stopped mainly due to lack of appropriate system management. This comprehensive guideline is therefore prepared in order that the users of all strata to use the solar PV system sustainably.

(2) Objective of the Guideline

The guideline is prepared for the sustainable implementation and O&M of solar PV system at public facilities: such as, dispensaries and public (boarding) primary schools. The intended readers of this guideline are government offices and facility staff members who will implement the solar PV system and use it. REA and Ministry of Energy and Petroleum (MOE&P) are principal government implementers while Ministry of Health (MoH) (both headquarters and county offices, are owners of public facilities having solar PV system. This guideline can be utilized for entire stages of electrification covering technical, managerial and financial fields: site survey, planning, basic design, preparation of specifications, procurement, construction supervision, O&M support, monitoring, and preparation of necessary budget.

(3) Components of the Guideline

The guideline consists of the following four sections:

Chapter 2	Technical Section
Chapter 3	O&M and Management Section
Chapter 4	Financial Section
Chapter 5	Section of Environmental and Social Considerations

1.2 Introduction to the Technical Section of the Guideline

The technical section of the guideline is designed as a technical resource for people interested in learning how to design stand - alone PV systems. This section is intended for use as a self – teaching aid and although it focuses on professionals who will be designing systems for clients; individuals interested in designing their own systems will also benefit from it.

The main objective of this section is to impart the ability to successfully deal with the many aspects of PV system design. The technical section seeks to develop skills not only in computation, but also in making the necessary judgments of when and where PV can be a viable solution to power needs. It is therefore also designed to integrate a range of skills required to specify the appropriate electrical components for the system, and select them from a wide variety of products and manufacturers.

Most of the time, system design involves some degree of compromise between competing and desirable qualities. There are many choices that have to be made including the types and sizes of equipment, and related components and accessories.

Many people assume that PV system design involves the use of sophisticated machines such as computers. However, the actual truth is that designing a solar power system involves a great deal of judgment before and after every calculation is made.

1.3 Introduction to the O&M and Management Section of the Guideline

The purpose of the management section of the guideline is that REA and MoH enhance their knowledge on the appropriate and effective action of sustainable PV system, strengthen their attitude towards action and give detail elements of practice. This section of the guideline can be used to ensure that all stakeholders make up an effective management system, in terms of physical and O&M matters, for electrification of dispensaries and primary schools in the un-electrified areas using solar PV systems. It also can be used to ensure that the facility users can enjoy the power generated by installed PV systems for as long as the lifetime of solar panels (20 years). The section covers all solar PV systems that REA installed and will install.

1.4 Introduction to the Financial Section of the Guideline

The purpose of the financial section of the guideline is to facilitate all the executing agencies, facility owners, concerned ministries and stakeholders to prepare and provide the necessary funding for O&M and replacement of equipment for the solar PV systems for the long run.

This section includes the introduction of the financial model to provide methodology to estimate the required public funding from the government budget as well as the commercial revenue of each facility.

Besides REA and MOE&P, this financial section is expected to provide necessary information to other stakeholders, i.e. MoH as well as their county offices, as owners of solar PV systems in dispensaries and primary schools. The section is also useful for those who are at dispensaries as beneficiaries and local managers of the solar PV system in the rural areas.

1.5 Introduction to the Environmental and Social Considerations Section of the Guideline

The National Environment Management Authority (NEMA) is a practical official body responsible for managing environment, reviewing “EIA Project Reports” and “EIA Study Reports” and issuing Environment Licenses for development projects in Kenya. These systems of environmental managements, reviews of relevant EIA reports and issuances of environmental licenses are regulated by the most principal regulations as shown below.

- Environmental Management and Coordination Act of 1999 (EMCA)
- EIA/EA Regulations (Amendment) 2009.

Renewable energy projects including PV systems fall under “No. 10 Electrical Infrastructure” in the “Second Schedule” of EMCA. Therefore, all solar PV projects are naturally subject to the EIA procedures in Kenya.

Environmental and social impacts caused by solar PV projects on small scales (excluding mega solar PV projects) are limited because solar PV is an inherently silent technology. With regard to environmental and social considerations, therefore, general countermeasures including noise and vibration, solid waste, construction vehicle managements and so on are taken for such solar PV projects during construction stage.

During the operation stage, however, replacement of each component of the solar PV system will cause environmental issues which shall be managed by each solar PV project facility. Namely, the issues of “e-waste management” are prominent. Especially e-waste components such as used batteries, used fluorescent lamps and other used electrical appliances including solar PV panels, inverters, etc. are the core issues.

In Kenya, solid waste management issues shall be addressed in compliance with the following regulations and Guidelines

- EMCA 1999
- Environmental Management and Coordination (Waste Management) Regulations 2006
- Guidelines for E-Waste Management in Kenya 2010.

In order to make sure the solid waste management of such e-wastes from solar PV systems, an E-waste Manifest structure can be applied to the facilities and communities operating such systems.

As points to keep in mind, the act and regulations noted above are subject to some modification in accordance with the new constitution enactment 2010.

CHAPTER 2 SOLAR PV SYSTEM

2.1 Solar Irradiation

Solar irradiation data for the installation site is essential for the design of an adequate solar PV system. If there is ground measurement solar irradiation data, then it is recommended that this data is used as a reference in system design. Even if the measured data is for a very short period it will still be helpful for comparison with other data source. If the ground measurement data is not available then satellite data can also be used as reference data for system design. In order to understand the irradiation level at the site, satellite data can be downloaded from NASA website. The solar irradiation levels for Kenya are summarized below.

Kenya receives a large amount of solar irradiation over the year, in almost every part of the country. Even though the country lies on the equator, there is very little difference between the level of solar irradiation received in the Northern part of the country, and that received in the Southern part. If data is considered separately then the annual average solar irradiation is 5.89 kWh/day and 5.61 kWh/day for Northern and Southern hemisphere respectively, and the country's annual average is 5.7 kWh/day. The graphs below summarize the monthly and annual minimum, maximum, and average solar irradiation for the Northern and Southern hemispheres, and the country.

Monthly Minimum, Maximum and Average Solar Irradiation on Horizontal Surface of the Country that lies at Northern Hemisphere (kWh/day)

Data : 1983 to 2005 (22-year Average)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average	6.26	6.69	6.39	5.76	5.69	5.38	5.39	5.79	6.37	5.84	5.43	5.79	5.89
Minimum	5.27	5.76	5.75	5.18	5.19	4.63	4.79	5.27	5.71	5.27	4.63	5.08	5.21
Maximum	6.94	7.51	7.04	6.25	6.16	5.87	5.96	6.30	6.90	6.33	5.90	6.41	6.46

Source : NASA (http://eosweb.larc.nasa.gov/)

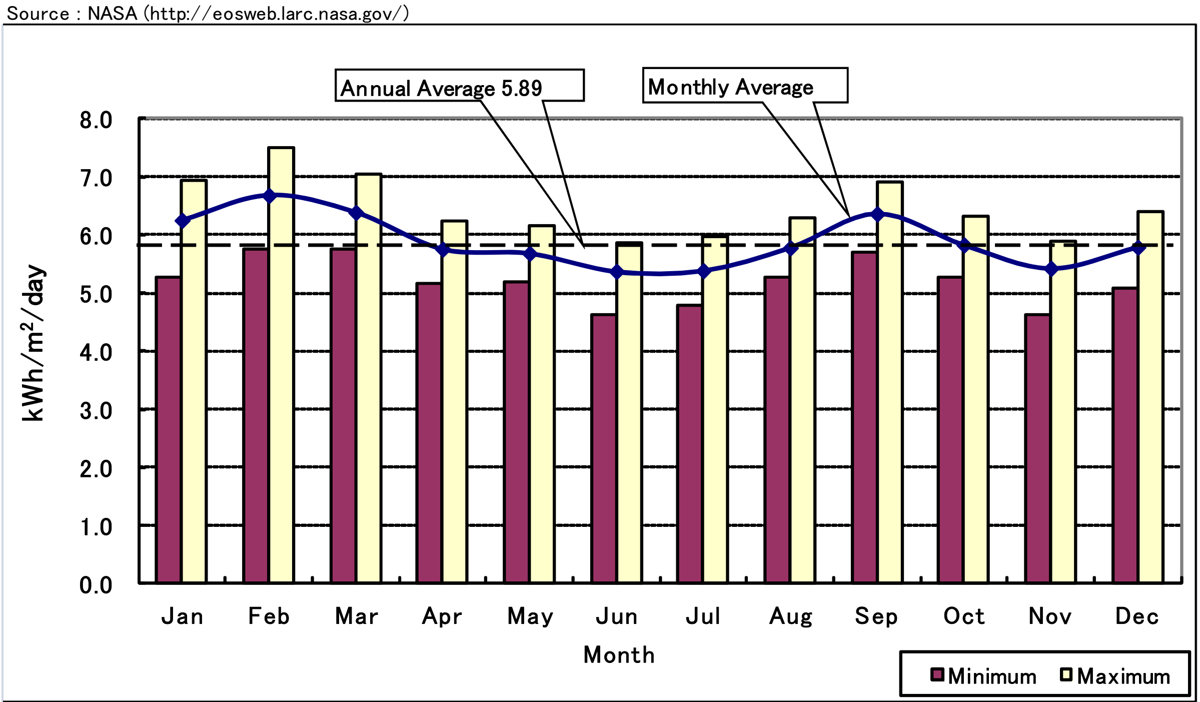

Figure 2.1.1 Solar Irradiation for Northern Hemisphere

The above figure shows that the monthly average is lower than the annual average of irradiation, for the months of May, June, July and November. However, for the months of April, August, October and December, the monthly averages are almost equal to the annual average. Further, for the months of January, February, March and September, the monthly averages are higher than the annual average.

Monthly Minimum Maximum and Averege Solar Irradiation on Horizontal Surface of the Country that lies at Southern Hemisphere (kWh/day)

Data : 1983 to 2005 (22-year Average)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average	5.98	6.44	6.20	5.63	5.13	4.83	4.89	5.24	5.93	5.92	5.51	5.67	5.61
Minimum	5.03	5.51	5.67	5.07	4.54	4.29	4.46	4.66	5.31	5.24	4.81	5.09	4.97
Maximum	6.67	7.25	6.70	6.11	5.69	5.36	5.48	5.84	6.49	6.48	6.02	6.22	6.19

Source : NASA (http://eosweb.larc.nasa.gov/)

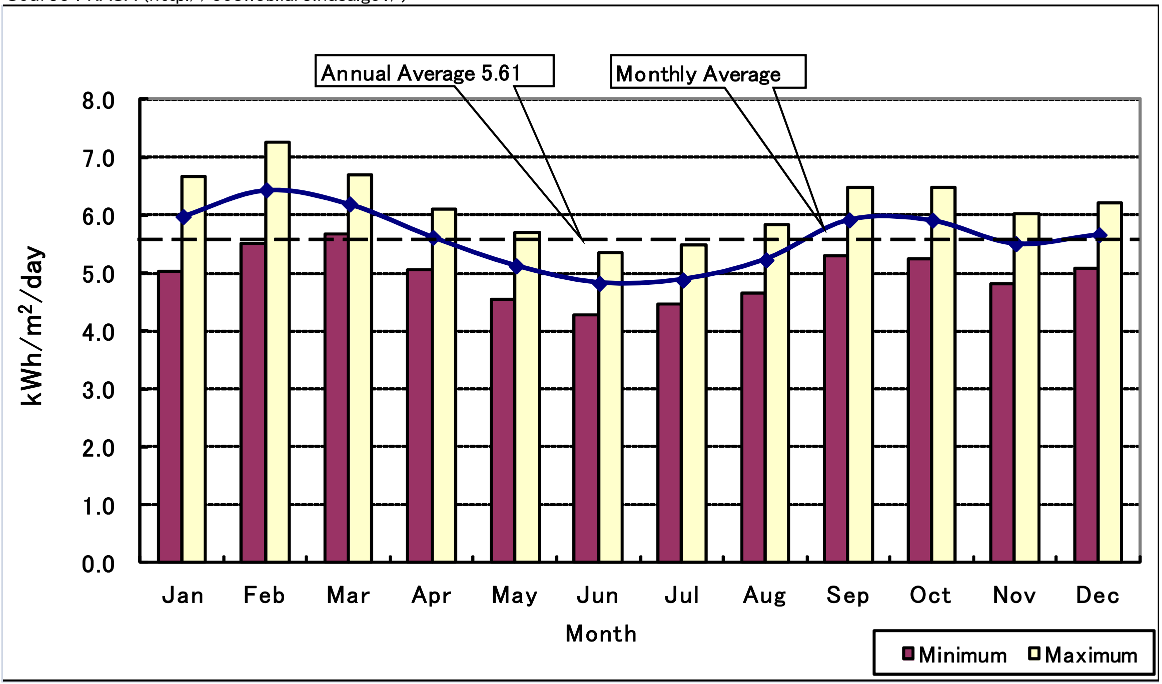

Figure 2.1.2 Solar Irradiation for Southern Hemisphere

The above figure shows that the monthly average is lower than the annual average irradiation for the months of May, June, July and August. However, for the months of April, November and December, the monthly averages are almost equal to the annual average. Further, for the months of January, February, March, September and October, the monthly averages are higher than the annual average.

A comparison of the above data for the Northern and Southern hemispheres shows that the Southern part of the country receives lower solar irradiation than the Northern part for the months of April to August. In the month of November, the Northern hemisphere receives slightly higher solar irradiation than the Southern hemisphere. However, for the remaining months the Southern hemisphere receives slightly higher solar irradiation. There is some variation in the average monthly solar irradiation between the Northern and Southern parts of the country, mainly for the months of April to August. The largest variations in solar irradiation between the Northern and Southern hemispheres are in the months of May and August, at around 0.56 kWh/day and 0.55 kWh/day respectively.

Country Monthly Minimum, Maximum and Average Solar Irradiation on Horizontal Surface (kWh/day)

Data : 1983 to 2005 (22-year Average)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average	6.1	6.6	6.3	5.7	5.4	5.1	5.1	5.5	6.1	5.9	5.5	5.7	5.7
Minimum	5.1	5.6	5.7	5.1	4.9	4.5	4.6	5.0	5.5	5.3	4.7	5.1	5.1
Maximum	6.8	7.4	6.9	6.2	5.9	5.6	5.7	6.1	6.7	6.4	6.0	6.3	6.3

Source : NASA (http://eosweb.larc.nasa.gov/)

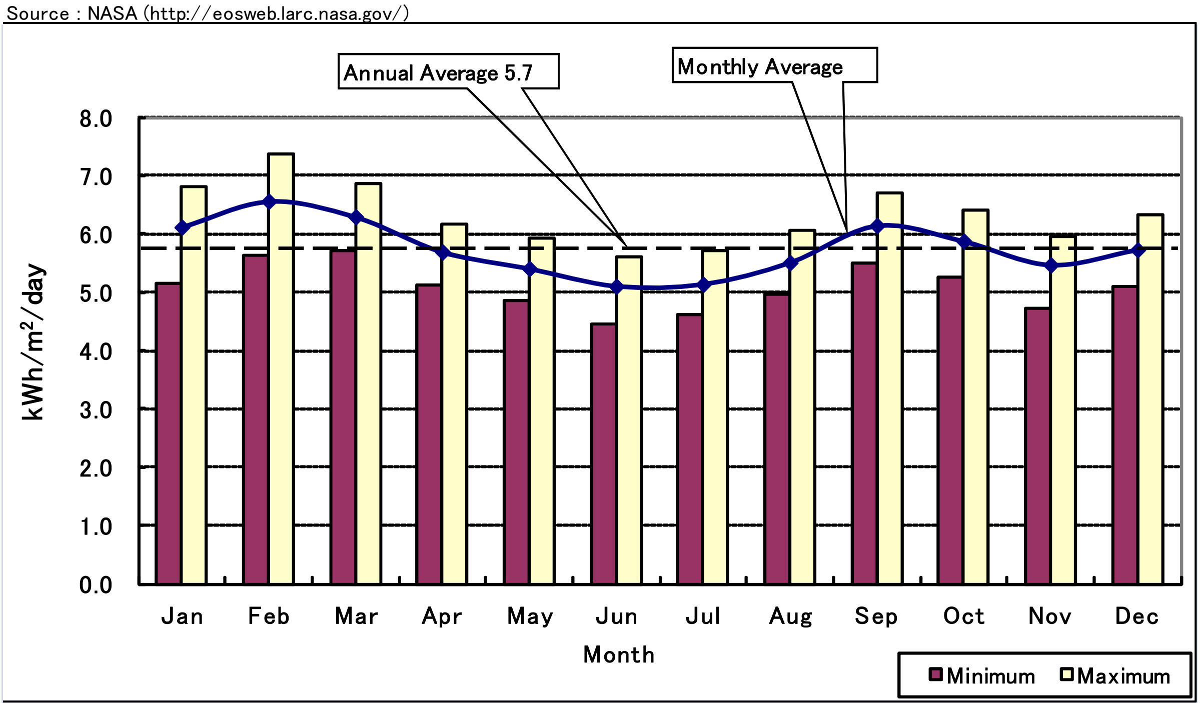

Figure 2.1.3 Solar Irradiation for Kenya

The above graph shows that the monthly average irradiation level is lower than the annual average for the months of May to August and November. However, their monthly and annual averages are almost equal for April, October and December. Further, for the months of January to March and September, the monthly averages are higher than the annual average for the whole country.

The detailed solar irradiation data for the country is attached in Annex 4 of this guideline. The data has been downloaded from NASA website http://eosweb.larc.nasa.gov/. The data provided is based on specific values of latitude and longitude.

2.2 System Components

It is important to understand the fundamental concepts of each component in order to design the solar Photovoltaic (PV) system. Each key word described below includes the basic points that need to be understood and applied as best practices for system design to ensure the system is adequate.

2.2.1 Solar PV cell/module

(1) Characteristics of PV module

The generation of voltage from light is referred to as “Photovoltaic” and often abbreviated as “PV”. The common term for a PV cell/module is “solar cell/module”.

A solar cell is just a converter which receives light energy and changes it into electrical energy. Therefore, sun light acts as a fuel to generate electricity from PV cell/module. A number of solar cells arranged in a closed circuit (series and parallel) for the purpose of securing a defined output is called a PV module. These products (PV modules) are available to users, from the commercial market. A number of PV modules arranged and installed (series and parallel) for the purpose of generating electrical output is called a PV array.

The PV module produces but does not store any energy. Therefore, when the light source is not available or is removed, there is no electrical output from the PV module. If electricity is required when there is no light source (typically the sun), some form of energy storage is necessary. To meet this requirement, a storage unit (commonly battery) is included in the system.

1) PV module I-V Curve terminology

Solar PV power generation is influenced by natural conditions, namely solar intensity and ambient temperature at that instance. Therefore, it is very essential to understand the effect of these conditions on the system design and performance. Figure 2.2.1 summarizes the output current and voltage of the PV module respective to the solar irradiance.

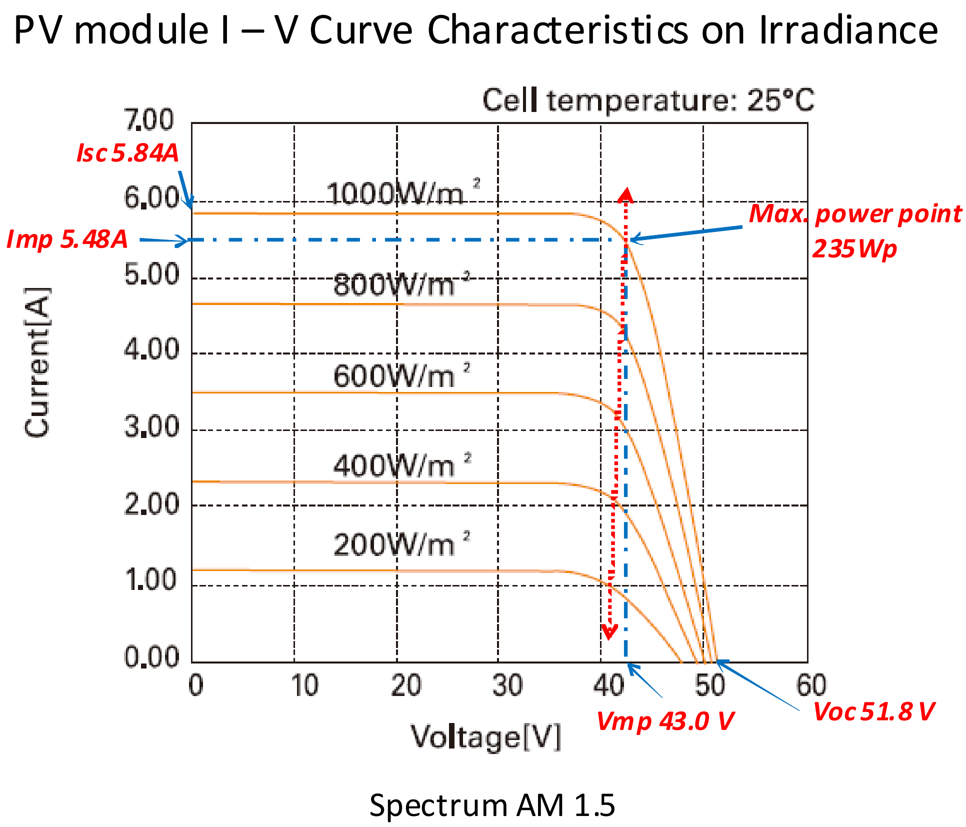

Figure 2.2.1 Example of PV Module I-V Curve – Effect of Irradiance on PV Module Characteristics

The above figure (I-V curve) shows that as the irradiance level increases, the output current of the PV module increases, while the output voltage remains almost the same (very little increase). Although the output voltage increases only slightly, the output power (voltage x current) increases significantly due to the increase in current generation. It can therefore be considered that the output current of the PV module is directly influenced by solar intensity, and output power varies according to the solar intensity mainly due to change in output current.

Figure 2.2.2 summarizes the output voltage of the PV module respective to the module temperature.

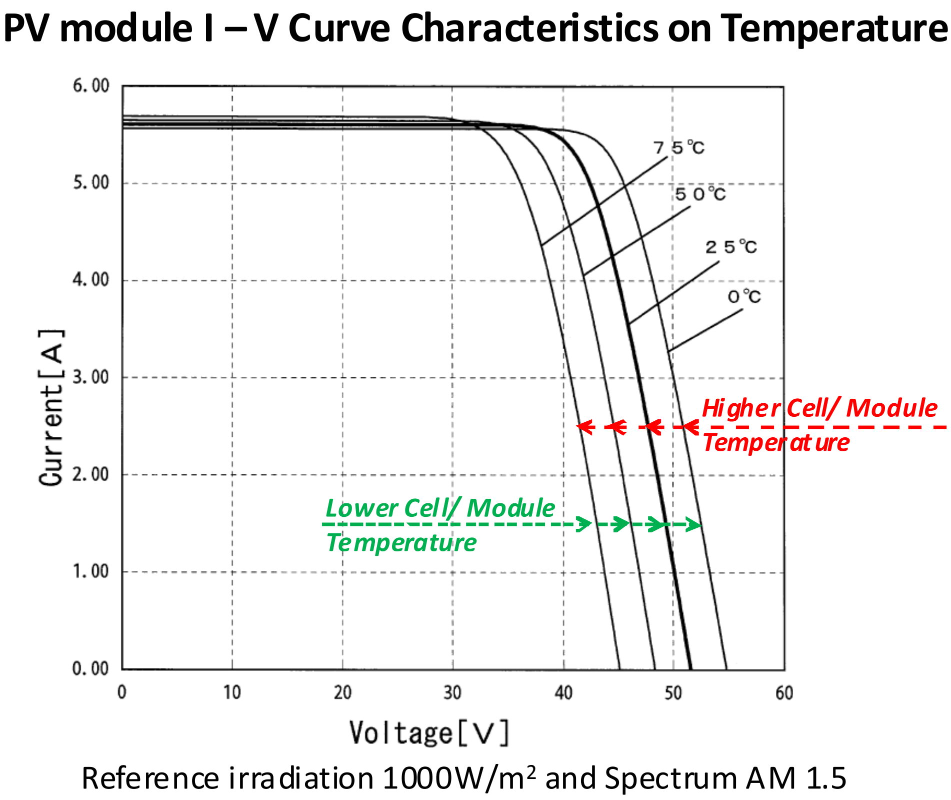

Figure 2.2.2 Example of PV Module I-V Curve – Effect of Temperature on PV Module Characteristics

The above figure (I-V Curve) shows that as PV cell/module temperature increases, the output voltage decreases, while there is very little increase in output current which is almost negligible. It can therefore be considered that the output voltage of the PV module is directly influenced by the operating temperature of PV module, and the output power varies accordingly mainly due to change in output voltage. Therefore, it is very essential to consider this factor at the time of system design.

It is clear that increase in temperature greatly influences the output voltage, which subsequently directly affects the output power (voltage x current). Different types of PV modules assembled from different types of PV cells are available in the commercial market. The response of each type of PV module to temperature therefore varies, depending on the material selected to manufacture it.

Table 2.2.1 summarizes the range of reduction in current and voltage due to increase in the operating temperature of the PV cell/module.

Table 2.2.1 Power Reduction Range of PV Cell/module due to Temperature Rise

PV Cell/module Type	% /°C reduction
Crystal silicon	-0.3 ~ -0.5
CIS	-0.2 ~ -0.4
a-Si	Almost to "0"

Note: Even though a PV cell is crystal silicon, various manufactures may use different technologies in the same crystal silicon cell and controls/reduces voltage drops even when PV cell/module temperature rises. For details refer to manufacturers' literature.

The calculation method to determine the power generation by the installed PV module/array considering the influence of temperature is summarized in section 2.3, and a detailed example of an actual installation is described in section 2.4.

2) PV module connections

There are many types of PV modules available to end users, from the commercial market. Amongst the various types, crystalline PV modules are the most common.

The capacity of the system is totally dependent on load demand and solar intensity at the particular site. To get the design output voltage (e.g. 12 V, 24 V, 48 V or higher) and required energy from an installed solar PV system; PV modules are either wired together or connected individually from the installation area to the installed control units and storage batteries.

Depending on the required system voltage and power, PV modules are connected in series and parallel. Therefore, if more than one PV module is used in the system then they are connected either in series or in parallel. The PV modules connected in series or in parallel have the same characteristics as connected dry cell batteries. It's possible to connect a number of PV modules in series and/or parallel to get the desired design voltage and current.

(i) Series connection

When two PV modules are connected in series, the output voltage doubles. When three PV modules are connected in series, the output voltage triples. Hence, whenever the number of series connections is increased, the output voltage increases proportionally with respect to the number of connected PV modules. It is possible to connect PV modules in a number of series connections to get the required voltage output while current output remains unchanged.

The figure below summarizes series connection of PV modules.

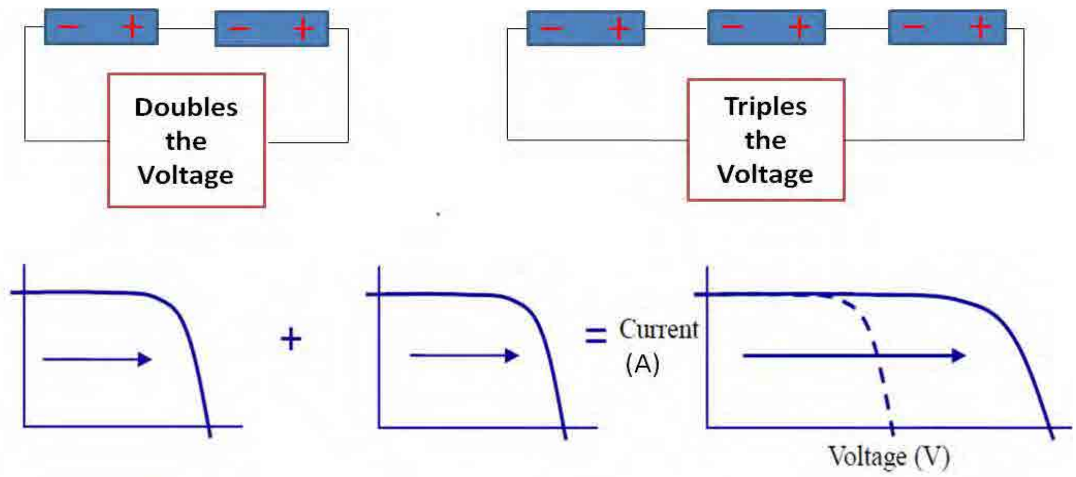

Figure 2.2.3 Example of PV Modules connected in Series

(ii) Parallel connection

When two PV modules are connected in parallel, the current output doubles. When three PV modules are connected in parallel, the current output triples. Hence, whenever the number of parallel connections of PV modules is increased, the current output will increase proportionally with respect to the number of connected PV modules. It is possible to connect PV modules in a number of parallel connections to get the required current output, while voltage output remains unchanged.

Figure 2.2.4 summarizes parallel connection of PV modules.

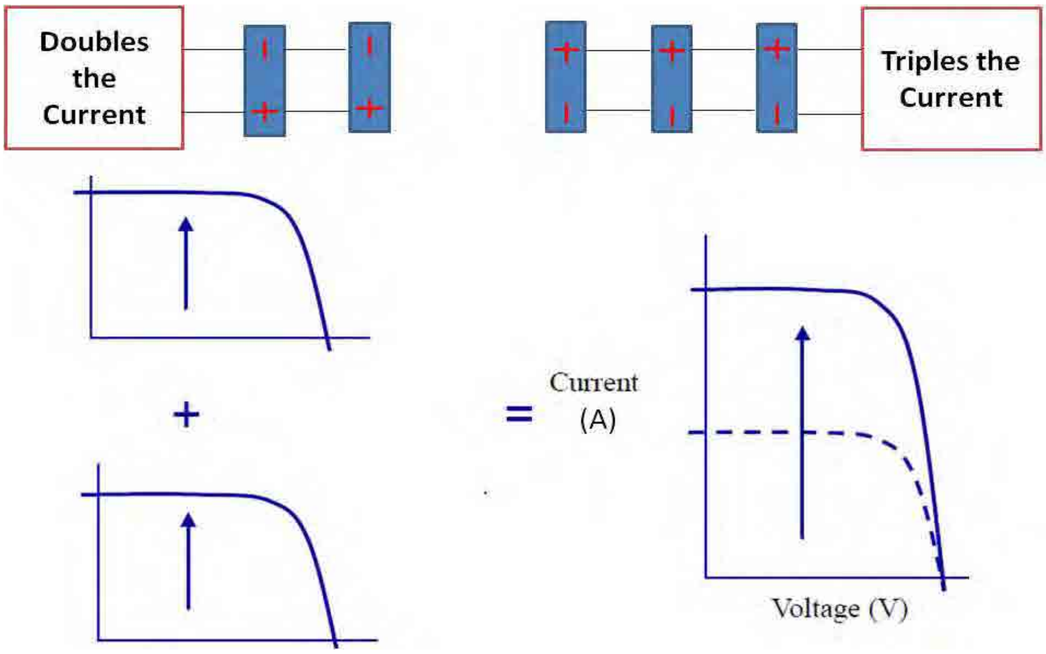

Figure 2.2.4 Example of PV Modules connected in Parallel

In the system, the number of series and parallel connections is determined by the design system voltage and required power for the loads. In some cases, input ratings of selected equipment for the system also restrict the total capacity and number of PV modules connected in series and parallel.

To decide the number of series and parallel connections of PV modules in a system, it is also necessary to consider technical specifications, such as the availability of components/equipment as per design, voltage and current bearing capacity of the equipment, workability, O&M, financial support and so on.

In the actual installation, the designed PV system capacity may need to be adjusted due to the availability of equipment, space for installation, demand and so on.

2.2.2 Batteries

Most PV systems use batteries to store the energy converted by the solar modules during the daylight hours. The converted energy is stored in the battery as chemical energy for use during the night or on bad weather days. The system's battery works like a water storage tank and as an intermediate between the power that might be available at any moment from the PV array and the power that the load might need to draw at any time. If the loads need more power than the installed PV array can produce at that time, then the storage battery discharges to supply the difference. During the night or on bad weather days when the PV array does not produce power, the batteries must discharge and fully supply the power that is required by the loads. During the daylight hours, if the loads do not consume all possible generation from the installed PV array, then the unused generation goes into recharging the installed storage battery.

(1) Purpose of Batteries in PV systems

In PV systems, the most important yet most poorly understood component is the battery. It is very difficult to have a perfect type of battery for all remote PV systems. There are many factors that influence the choice and performance of batteries in a PV system.

- The most important function of the batteries in a PV system is to allow the loads to be operated even when there is no generation of power. This occurs each night, on cloudy day and during bad weather days. To cover these instances of low or no power generation, a PV system is described as having "Autonomy". This is the ability of the system to operate by itself without any energy input from the PV array.

- The purpose of the batteries in a PV system is to level the wide fluctuations in voltage that can be produced by the installed PV array. A load may operate only during the day, and days of autonomy may be needed, or it may not be necessary to cover any surge current. However, direct coupling to the load may expose the system to voltages that might be too high or too low for proper operation. Ultimately the equipment may break due to the wide range of voltage fluctuation. Batteries operate within a smaller range of voltage than the PV array and can hold the voltage point of the system within a more acceptable range.
- Another important function of batteries in PV systems is to supply the level of current that may be demanded by the load, which is higher than the installed PV array can produce. The current output of the PV array is limited and directly influenced by solar intensity. The designed capacity of the PV array may be large enough to meet the total energy demand over the day, but may not be large enough to meet a large momentary demand at any particular time of the day. Hence, the battery can act as a buffer, supplying large currents to the load for short periods and being slowly charged by the installed PV array during daylight.

(2) Typical Construction of lead acid batteries

A variety of batteries are available in the market, for the choice of users. For PV systems, lead acid batteries are the most commonly used because they are cheaper compared to others on an ampere-hour basis, and are available in a wide range of capacities.

One of the main parameters to distinguish batteries is their ability to "cycle". The cycle involves discharge and then charge of the battery. The type of batteries used in a PV system can be cycled, but it is important to understand how deeply and how many times the battery can cycle before permanent loss of capacity occurs.

There are also many different types of batteries, even for the general classification of batteries commonly used in PV systems. Some important components of battery construction are mentioned below. Here, the types of batteries commonly used for PV systems are considered.

In lead acid batteries, the grid is made of lead or alloys such as lead-antimony (PbSb) or lead-calcium (PbCa). The lead-calcium grid alloy is used in shallow cycling or flat type batteries, as this chemistry reduces gassing and requires less water maintenance. Lead-antimony is typically used in deep cycle batteries as this chemistry can efficiently recover from deep discharge on a regular basis.

The thickness of the grid also affects the cycle depth of the battery. In automotive starting type batteries, many thin plates are used, which provide more surface area for contact. A larger surface area means that it is possible for large current to flow in an instance, which is required for starting engines. However, the thin plate means that the discharge cannot be sustained for a long time.

Thick plates are used for more deep cycling applications such as power for forklifts, golf carts, electric vehicles and in PV systems. The thick plate allows deep discharge for a long period of time, while still preventing transmission to the grid. For this reason, good adhesion is maintained and the battery has a long lifespan as a result. Due to the thick plates, thick plate batteries are heavier than thin plate type for the same ampere-hours.

(3) Battery Trade-off

When deciding on the batteries for the PV system, either shallow cycle or deep cycle batteries are selected. Designers and system owners are forced to deal with the financial decision to "pay now or pay later" which means to either;

i) Pay less initially for shallow cycle type batteries and get a short lifespan (1-2 years).
ii) Pay more initially for deep cycle type batteries and get a longer lifespan (4 - 7 years).

(4) Series and Parallel Connection of Batteries

Most of the time, questions arise on how many batteries can be connected in series and parallel. If the requirement is a large in capacity, 2 V batteries are normally used in the system. For example, in telecommunication systems, the number of days of autonomy is higher and large capacity batteries are required to ensure reliable power supply without interruption. In this case, if the battery capacity is designed with normal 12 V batteries, then series connection of batteries may be reduced to adopt the design system voltage. However, to secure the required Ampere-hours, a large number of batteries are connected in parallel. This means that a number of batteries are connected in parallel to secure the required capacity for reliable power supply. However, in parallel connection the batteries are connected externally, and charging and discharging of all the batteries may not work equally. This may affect reliability of power supply to the equipment, which will directly hamper services to the public. Hence, in telecommunication systems or other systems where a large battery capacity is required, 2 V batteries are used. To make 12 V systems, 6 nos. of 2 V batteries are connected in series, 12 nos. to make 24 V and 24 nos. to make 48 V. This means that every battery needs to react to charge or discharge.

From the above, it is clear that when 12 volt batteries are used in parallel connection, the batteries are connected externally to have a large capacity (Amp-hour). This means that when connected externally, if the number of parallel connections becomes large, then some of the batteries may not be charged or discharge properly, and they may finally collapse. Therefore, when a large battery capacity is required, it is recommended to increase the DC system voltage in order to decrease the parallel connections and required battery capacity (Amp-hour). If batteries are connected in series, then they are connected internally and all batteries need to charge and discharge in order to run the system. Hence, it is not recommended to have more than 4 or 5 batteries (12 V mono block type) in series connection too, because the internal resistance increases and heat will be generated, ultimately affecting the battery life. If a large battery capacity (Amp-hour) is required in the system, then 2 V batteries are the best option.

2.2.3 Charge Controller (Regulator)

In a PV system, modules are highly reliable and virtually maintenance free. But in most cases, PV module/array alone does not solve the customer's demand. Therefore, PV modules are connected with batteries to supply power 24 hours a day. When batteries are included in the system, additional equipment are required to protect the system and control against overcharge and over-discharge.

(1) Purpose of using Charge Controller (CC)

The Charge Controller (CC) is an important component of a PV system with storage battery. The most important function of the CC is;

i) To prevent Overcharge

When there is sunlight, current from PV array will flow into the battery. This current is proportional to the irradiance at that time, whether the battery needs to be charged or not. If the battery is almost full, it will overcharge. The voltage will rise and gassing will begin, causing the electrolyte to be lost, internal heating to occur and battery life to be reduced. If left uncontrolled, the battery could lose almost all its electrolyte and be permanently damaged, which means that supply to the load will fail and it will not be possible to use appliances.

The charge controller prevents excessive charging of the battery by interrupting the current flow from the PV array into the battery. If the loads drive the battery voltage down, then the charge controller will sense this shift and reconnect the PV array to the circuit to supply power.

ii) To prevent Over-discharge

If the loads are left in ON position for too long, the battery can be over discharged. The reaction of lead and lead dioxide will continue and approach the lead grid material, weakening the bond. This can result in greater resistance and heat generation, and accelerate the loss of lifetime. Some shallow cycle type batteries are very difficult to recharge once they have been severely discharged, especially with slow charge rates typical of remote PV systems. If batteries are too deeply discharged, the voltage falls below the operating range of the loads, and it is not possible to use the appliances.

Over-discharge protection is built into the charge controller. If the battery voltage falls to a low level, the built in protection unit will disconnect the load, preventing further battery discharge. The PV array can gradually recharge the battery to some intermediate value, and the protection unit will reconnect automatically to the circuit. This process also gives feedback to the users as to the limits of their system use.

iii) To provide information to users

PV systems operate quietly and without much intrusion on the users. Some form of feedback of the system status is essential to users, so that they can understand the operation status of the system and specifically the battery status. The information can be communicated via LED light that can show the status of the battery at different stage, or a digital readout of battery voltage. Users must also be given guidelines to interpret the information received from the system, such as the color of LED lamp changing at each stage or the voltage reading. From this information, the users should be able to begin demand side management of energy uses to prevent the battery from over-discharge which may lead to system failure.

2.2.4 Inverter (DC/AC)

The PV array generates DC current and voltage. The battery also works on DC current and voltage. If AC power is required for the loads then an inverter is required to convert DC to AC. Commonly available inverters can convert DC power to single or three phases, 50/60 Hz and AC voltage. The main characteristics of the inverter is output power and surge power.

(1) Output power and Surge power

Output power

An inverter is capable of providing output power depending on its ability to dissipate the heat generated within the inverter. Its rated output power is generally the power level it can maintain for a long period of time. An inverter can supply larger output power than its nominal rating for a short period of time, before it overheats and shuts off. Good inverters can supply output power above their nominal ratings for a few minutes, allowing large loads such as large power tools and pump motors to operate.

However, there is no standard period of time acceptable by all manufactures for inverter output rating. There is a trend for manufacturers to rate their inverters on a continuous basis indicating the power that the inverter could supply for many hours. This is a conservative and safe rating method. In most cases, inverters do not operate at their full rated output level for 24 hours a day, but rather for a few hours or minutes as required.

Some manufactures rate their product output for 30 minutes while others rate for 15 minutes. The problem in this situation is that the system designer will have the burden of establishing the exact method of output rating to make a fair comparison. Therefore, instead of reading a single power value, it is better to find a chart or graph that describes the output as time increases.

Surge Power

In actual practice the output power of the inverter can exceed the nominal rating for a few minutes. This is often referred to as the “surge capability” of the inverter. The surge power may be defined as the power that the inverter can output for less than a second to start a large inductive (motor) loads. Therefore, if there is an inductive load in the system, then it is necessary to consider and select an inverter that is capable of coping with the surge power of the inductive load in addition to other non-inductive loads that may run at the same time.

The surge power of an inverter is not a single fixed value, but varies with the amount of time. A good inverter can typically output more than 200% of its nominal power for a few seconds. Some low cost inverters cannot output more than 130% of their output for a short time. These would have limited surge capability and would not be useful for systems where an inductive load exists.

i) Inverter efficiency

An Inverter consumes some power itself. This adds to the load that the PV array must operate, and the inverter should therefore be as efficient as possible. The efficiency may depend on the nature of the load. Pure resistive loads may operate the inverter at a higher efficiency than inductive loads that absorb the power differently.

The inverter efficiency is not a fixed value, but varies depending on the amount of power being generated by the inverter. A curve of efficiency versus output power is the best way to determine how the inverter will perform under different conditions. It is very difficult or almost impossible to predetermine exactly what the power demand on the inverter will be at any moment. It is therefore necessary to estimate the power levels at which the system will operate and determine the average inverter efficiency from a curve.

ii) Output waveform

The waveform of the inverter output is an important factor in matching with loads. The waveform describes the way the current and voltage vary over time. There are three general classes of waveforms:

Square wave

Generally, the most inexpensive inverters are square wave types. In this technology the input DC power is chopped and boosted in voltage, with little filtering or modulation of output. The resulting output contains many unwanted harmonics, or waves of various frequencies that fight each other. The effect of these unwanted waveforms is harmonic distortion. The square wave inverters cannot surge significantly. Their efficiencies can be as low as 50 to 60% and they have little output voltage regulation. However, these inverters may be useful for small inductive loads or resistive loads.

Modified square wave or modified sine wave

Another type of inverter produces a modified square wave output. This type of inverter is also referred to as modified sine wave. The waveform more closely resembles a square wave, with delay through zero. The total harmonic distortion is significantly lower than that of a square wave type inverter. This type of inverter can surge over 200% above the continuous power, and has good voltage regulation. Efficiencies greater than 90% are common. This type of inverter is quite popular in remote home systems and can operate a wide variety of common appliances and electronic loads. However, there are reported problems with operating specific loads such as laser printers, microwave ovens, small electronic clocks and so on. It is necessary to check with the manufacturer whether any incompatibility with planned loads for installation has been reported.

Sine wave

This kind of inverter produces nearly sine wave output, and may involve extensive and carefully tuned filtering of digital synthesis. The efficiency of this type of inverter is more than 90%. In general, it is best to choose a sine wave inverter and supply a sine wave output to the AC loads. By choosing this type, very little or no problems will occur with respect to harmonic distortions or inadequate peak voltages.

2.3 System Designing (Sizing)

The purpose of PV system sizing is to calculate the capacity of PV array and batteries needed to reliably operate the load throughout the year. Here, a simple method for calculating PV array capacity and batteries are presented. It is necessary to keep in mind that there are decisions that require judgments on the part of designing.

To install a solar PV system which serves its purpose, the base parameters for system design need to be defined and established. Parameters are very critical points for design and it is very important to choose the correct values to get reliable output, not only to get required capacity but also to select the most suitable components/equipment for smooth operation and long lifespan of the system.

2.3.1 PV Array Capacity Sizing

The PV array is sized to meet the load on a daily basis, based on the site, area or regional weather conditions. The PV array will replenish the battery during subsequent days of country average irradiation. The PV array and battery are NOT sized based on how quickly the battery be recharged after a few days of bad weather conditions in which the irradiation level is lower than the average. If sizing is based on this, then the result will be a large PV array, most of which is not needed or used during most of the year. To determine the minimum size of PV array required for the installation, the following equation is applied.

PV Array capacity (Acap) = Total load (demand) / H_A x K' ……………….. (i)

Where,

H_A: Country minimum annual average Solar Irradiation (kWh/day) = 5.1 kWh/day

Depending on the type of system and importance, the selected value of solar irradiation may vary. Some may choose the minimum solar irradiation value while others may chose the maximum. However, in most cases, either the country average or minimum average is taken into account. Here, minimum average solar irradiation is used because:

a) The minimum average value is not very different from the average value
b) For basic design, the site is not specified and the system may be installed in any part of the country.

For higher accuracy, it is recommended to use site data if it is available. If it is not available, it is recommended to measure and collect data for the area where the installation is planned.

K' : Design coefficient factors (K_{HD} x K_{PD} x K_{PM} x K_{PA} x K_{PIX} x η_{INV} x η_{BA} x η_{CC} x K_{PT})

K_{HD}: Annual irradiation deviation = 0.97 (universal constant)

K_{PD}: PV module degrading = 0.9 (Range 0.9 to 0.95)
This depends on the manufacturer, and it is necessary to get the actual value from the specification sheet or to confirm with the manufacturer.

K_{PM}: PV array load matching = 0.97 (Range 0.9 to 0.98)
This depends on the design and load type.

K_{PA}: PV array circuit correction = 0.98 (Range 0.95 to 0.98)
The larger the PV array capacity or the higher the number of PV strings, the higher the loss.

K_{PIX}: PV array inclined angle and axis correction = 0.96 (Range 0.9 to 1.0)
If the installation is as per designed orientation and inclination angle, then this can be neglected (can be 1).

η_{INV}: Inverter efficiency = 0.9 (Range 0.9 to .95)
Depends on the manufacturer and type

η_{BA}: Battery charging loss = 0.95 (Range 0.9 to 0.95)
The charging loss is taken to PV array side because this will occur only during charging, and to avoid adding power to the battery.

η_{CC}: Charge Controller consumption = 0.99 (Range 0.97 to 0.99)

Depending on the type of CC and PV array capacity, it may not be necessary to consider this factor.

In case of crystalline silicon type PV cell/module there is a reduction in power generation when PV cell/module operating temperature rises. The loss of power may be critical in a system supplying power for demand load. Therefore, it is very important to consider the effect of temperature when designing solar PV systems. The equation below is used to calculate power losses as the cell/module operating temperature increases.

K_{PT} (Reduction due to the temperature rise) = $1 + \alpha_{Pmax} \times (T_m - 25)/100$ --------(ii)

Where,

α_{Pmax}: [PV Cell/Module Temperature coefficient (- %/°C)]

T_m (PV Cell/Module temperature °C) = $T_{av} + \Delta T$

T_{av}: (Ambient temperature °C)

Δ T: (Temperature rise on PV cell/module °C)

Temperature rise (ΔT) depends on the specific position of the installation. For example, the temperatures at various locations are:

a) Ground installation with some height for wind flow: 18°C
b) Installation on roof with some gap between module and roof for wind flow: 22°C
c) Roof integrated installation: 28°C

A roof integrated installation is where the PV module/array is installed on the roof itself without establishing an air gap underneath between the module/array and the roof for wind flow.

The value of ΔT is provided to understand how the distance between the installation surface and PV array affects the temperature rise of PV cell/module in different types of installations, to facilitate system design. This may vary from site to site and by country. To find the exact value; system installation, experiments, and data recording and analysis are required.

For example, if an installation on the roof with some space for wind to flow is considered, then from the above 'Equation (ii)' and value of reduction of power generation ($\alpha_{Pmax} = -0.4$), the actual power generation when ambient temperature rises to 32°C will be,

$K_{PT} = 1 + \alpha_{Pmax} \times (T_m - 25)/100 = 1 + (-0.4) \times \{(32+22)-25\}/100 = 0.89$ (89%)

Note: To determine the accurate value of temperature coefficient (α_{Pmax}) of each PV module type, it's recommended to refer to the specification sheet or confirm with the manufacturer.

Therefore if a 120 W PV module is selected for installation, then generation at 32°C ambient temperature will be 106.8 W (PV rating 120 x Reduction 0.89).

Hence, in the above 'Equation (i)', by adding reduction value of power generation from 'Equation (ii)' the total design coefficient (K') correction factor to determining PV installation capacity will be 0.6.

Now, by inputting the values of demand load and solar irradiation in the equation, the required PV array capacity can be determined.

'Equation (i)' can be used to determine the size of the PV array with storage battery, supplying power. In the case of a DC system there is no need to include inverter efficiency correction factor. However, in an AC system it is necessary to include inverter efficiency correction factor irrespective of the DC system voltage.

2.3.2 Battery Designing (Sizing)

The job of the battery is to supply energy to the loads when the solar irradiation is lower than designed and installed PV array cannot generate enough power to meet the demand. Batteries therefore also need to supply power when there is no sun, such as during the night. It's necessary to size the battery bank to operate the loads during a long sequence of low solar irradiation days. During a low solar irradiation day, the PV array cannot supply all the required power to charge and to replace what the load draws from battery. Therefore, the battery ends up being discharged at the end of the day. If the following day does not have enough solar irradiation, then the battery will continue discharging to operate the system. This process can continue until the battery is discharged to a point where it may become damaged. Therefore, in design, it is necessary to build battery capacity for an adequate number of days of charge, so that the battery operates the loads autonomously, meaning without any energy input from PV array. These days of reserve are referred to as “days of autonomy". The importance of reliable power to the facility and the economic situation greatly influence the days of autonomy of the system.

As in PV capacity sizing, the coefficients (correction factors) are very important for sizing battery capacity. The size of the battery bank can be determined using the following equation:

Battery Capacity (B_{CAP}) = A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC} ---------------- (iii)

Where,

A_{DY}: Days of Autonomy (Number of Days of reserved energy) = 3 (3 to 7) days

The value is highly influenced by the importance of reliable power supply requirements and the weather pattern at the installation site. If the weather conditions at the site/area are bad or a high degree of reliability is required, then it is necessary to have more days of autonomy.

D_{LD}: Daily load (kWh/day) = As per requirement

In some cases, the load may only be available in AC (kWh/day). In order to get the necessary battery capacity (Amp-hour), the required capacity (kWh) at DC side is first calculated and sized for the design days of autonomy, and this value is divided by the adopted DC system voltage.

B_{DD}: Battery Maximum ‘Depth Of Discharge (DOD)’ = 80%

In the case of a deep cycle tubular type battery, it's possible to discharge up to 80% in maximum by the end of the days of autonomy. If a shallow cycle type is used, then it shall not be discharged by more than 50% by the end of the days of autonomy. For a sealed type deep cycle battery, it is recommended to maintain a maximum of only 70%, by the end of the days of autonomy.

η_{INV}: Inverter efficiency = 0.9 (Range 0.9 to 0.95)

This depends on the type and manufacturer. If the product has already been decided, it is recommended to use the product value, considering the average operating load demand.

η_{CE}: Battery discharging efficiency = 0.95 (Range 0.9 to 0.95)

The battery has self - discharge, and a low self - discharge type of battery should be selected. The battery needs to supply power even when solar irradiation is low or the sun is not there during the night. When reserved energy is discharged from the battery, there is some internal heat generation which leads to some power loss. This should be considered when sizing the battery capacity.

η_{CC}: Charge Controller consumption = 0.99 (Range 0.97 to 0.99)

Depending on the type of CC and size of the PV array, it may not be necessary to consider this factor. If the battery is connected directly to the inverter, or there are no DC loads in the system, then this value can be neglected (can be 1). If the type of CC to be used has already been decided, then it's recommended to use the value that is provided by the manufacturer.

From the above ‘Equation (iii)’, it can calculate the required battery capacity for the decided days of autonomy.

If three days of autonomy are decided, then the calculated capacity is for 72 hours (3 days x 24 hours). Another factor that needs to be considered when sizing the battery is that battery capacity increases as discharge rate decreases. Typically manufacturers list the battery capacity at a standard rate of 8, 10 or 20 hours of discharge. But in PV systems, depending on the days of autonomy decided, the discharge rate becomes slower than standard rate. That is, 72 hours of discharge for three days of autonomy.

The average rate of discharge for a PV system can be determined using the equation provided below.

Avg. Rate of Discharge (hour) = Days of autonomy x 24 hours

After determining the average rate of discharge for the PV system, compare that rate with battery capacity at standard rate, for the same battery. The capacity at the standard rate will be less because the battery is being discharged much faster than at PV system discharge rate. To compare and decide the required battery capacity, it is recommended to refer to the specification sheet or confirm with the manufacturer.

The equation for the Rate factor is the ratio of the two rates of discharge, and indicates how much more capacity will be gained at calculated average slow rate.

Rate factor = Capacity at PV system rate/Capacity at manufacturer's standard rate

If it is not possible to get detailed information from the manufacturer when sizing the battery, a rough "rule of thumb" can be used for the initial stage. The rough Rate factor is 1.20 (for shorter days of autonomy) to 1.3 (for more than 3days autonomy). In other words, it can be considered that about 20% to 30% additional capacity may be gained at an expected discharge rate lower than the manufacturer's standard rating. This is just a rough method of calculating capacity on low discharge rate.

To determine the number of storage batteries to be connected in parallel and series for the system:

a) The basic method of calculation to determine the number of batteries to be connected in parallel is to divide the required capacity (Amp-hour) by the selected battery capacity (Amp-hour).
b) To determine the number of batteries to be connected in series, the DC system voltage should be divided by the nominal battery voltage.

2.3.3 Voltage Drop

The voltage drop is a critical point in the system to supply power or charge the battery to bring it to full charge state. There are two types of voltage drops in solar PV systems.

These are:

(1) The voltage drop at generation point due to the temperature rise of PV cell/module

When there is temperature rise in PV cell/module (especially in crystal silicon type) there is decrease in power generation mainly due to the voltage drop as explained in section 2.3.3, PV cell/module I-V curve, effect of temperature on PV characteristics. To calculate the possible voltage drop due to temperature rise in PV cell/module, hence power generation output at different temperatures, 'Equation (ii)' is used.

That is,

K_{PT} (Reduction due to the temperature rise) = $1 + \alpha_{Vmax} \times (Tm - 25)/100$ --------(ii)

Where,

α_{Vmax}: [PV Cell/Module Temperature coefficient for voltage (– %/°C)] = – 0.3 to – 0.4

For the actual value, refer to the specification sheet or confirm with the manufacturer. The multi-crystalline silicon type of PV cell/module has higher voltage drop than single-crystalline silicon type.

T_m (PV Cell/Module temperature °C) = $T_{av} + \Delta T$

T_{av}: (Ambient temperature °C)

ΔT: (Temperature rise on PV cell/module °C)

The value of ΔT is as explained in the section on PV array capacity sizing.

From the above equation, if α_{Vmp} is – 0.4, then the correction factor for the voltage generation when ambient temperature is 32°C is 0.89.

(2) Voltage drop along the cable section

In actual system operation, the charging voltage of charge controller (CC) is influenced by battery voltage at that time. Charging current gradually decreases as charging voltage gradually increases up to full charge state. However, even when there is some drop in voltage across the cable, it is necessary to understand the correct size of cable to supply voltage to the loads and to charge the batteries.

To calculate the voltage drops across the cable of each section, the following equation is applied:

e = 35.6 x L x I / 1,000 x A --------------- (iv)

Where,

e: Voltage drop across the cable (V)

A: Cross section area of the cable (mm^2)

L: Length of the cable (m)

I: Rated Current (A) flow

The above equation holds for copper conductors, when phase conductors of the circuit are in equilibrium and cable conductance is 97%.

2.3.4 Inverter

To select the inverter it is necessary to understand the peak demand. If an inductive load is in the system, it is recommended to choose a type of inverter which can withstand higher surge power for a long time. It is also necessary to understand that if peak demand supply is longer, then the inverter may become heated. Further, if the ambient temperate is high then it will negatively affect the operating efficiency of the inverter. If the inverter is highly heated during operation, its efficiency decreases drastically and could be as low as 50%. To avoid this, if the loads are non-inductive, it is recommended to select an inverter by multiplying required inverter capacity by 1.3 (minimum). Further, if inductive loads (depending on size) are included in the system, then it is recommended to multiply the required inverter capacity by 1.5 (minimum) if the inductive load is considered to be small in capacity.

Inverter Capacity (W) = Peak load demand (W) x 1.5

2.3.5 Charge Controller (CC)

To establish the system, one of the main points is to select the correct size of CC for the system. This requires that the DC system voltage and current flow from the installed PV array are understood correctly. Having determined the installation capacity of the PV array, the rated current (Imp) of PV array at reference solar radiation (1,000 Wh/m^2) should be multiplied by 1.5 to get the installation size of the CC for the system.

CC size (Amp) = Current rating (Imp) of PV array x 1.5

To decide the DC system voltage, it is necessary to consider not only the battery capacity with series and parallel connections, but also the required cable size, viability of required components/equipment, reliability, durability and workability, etc.

2.4 Determining PV System Capacity for Public Institutions

To decide the capacity of the PV system for facilities in the public institutions, it is necessary to understand the power demand of each facility. Hence, by using the equations described in section 2.3, the required capacity of the PV system and storage battery can be determined.

For the calculation of required power supply in health institutions, the demand is divided into three categories as described below.

- PV system for lighting
- PV system for charging services
- PV system for vaccination refrigerator

2.4.1 PV System for Lighting

For lighting, it is assumed that a PV system is installed in each building separately. To determine the capacity of each system, the points mentioned below are considered.

- In general, health institutions consist of a number of buildings constructed separately to serve the various requirements and there is some distance between these buildings.
- The load patterns are different for each building.
- With security reasons, PV modules are considered to be installed on the buildings' roofs.
- The existing roof structure may not be strong enough to hold a large PV array on the roof. In addition, it is necessary to consider the appropriate location of the installation on the roof to avoid shadows throughout the year.
- Avoiding complicated house wirings in an attempt to connect all buildings to one system.
- Avoiding concurrent blackouts in all facilities/buildings caused by system failure, by installing a separate system for each building,
- To optimize the replacement cost of equipment, especially storage battery, install a small scale PV system in each building.

From the demand load pattern of each facility in the institution such as staff quarters, Outpatient Department (OPD), pharmacy, delivery room, maternity ward and so on, the model for lighting is divided into three different Power Packages (PPs). If demand is rather high compared to the summarized demand range, then it is recommended to separate loads and install more than one system to serve the purpose. In addition, it is necessary to conduct demand side management by each facility whenever required. The table below shows the designed Power Package (PP) for lighting systems for public schools.

Table 2.4.1 Assumed PPs for Lighting Purpose according to the Demand

Power Package (PP) Type	PP0	PP1	PP2
Daily load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Days of autonomy (days)	3	3	3

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If demand matches an assumed PP as shown in the above table, then PV array capacity is calculated using the equation described in section 2.3.

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'

From the above equation, the required PV array capacity for each type of PP can be determined as shown below.

i) In case of power demand up to 350 Wh/day (PP0),

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 0.35 /5.1 x 0.6 = 0.114 kW = 114 W

As a 114 W PV module is not available, the nearest capacity which may be a 120 W PV module. In this case, the actual PV installation capacity will be 120 W.

ii) In case of power demand up to 700 Wh/day (PP1),

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 0.7 /5.1 x 0.6 = 0.228 kW = 228 W

If 120 W PV modules are used, then actual PV installation capacity will be 240 W.

iii) In case of power demand up to 1,400 Wh/day (PP2),

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 1.4 /5.1 x 0.6 = 0.458 kW = 458 W

If 120 W PV modules are used, then actual installation capacity will be 480 W.

The table below summarizes the results of above calculations of PV capacity based on designed Power Packages (PPs).

Table 2.4.2 Summarized Results of PV Capacity according to the PPs

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
County min. average solar irradiation (kWh/day)	5.1	5.1	5.1
Total system design factor	0.6	0.6	0.6
Calculated min. required PV array capacity (W)	114	228	458
Actual/Adjusted PV array installation capacity (W)	120	240	480

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2.4.2 Battery Designing (Sizing)

As in the PV capacity sizing, the coefficients (correction factors) are very important for battery sizing. To determine the size of battery for the aforementioned power packages, the following equation that is described in section 2.3 is used.

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / DC System voltage

Where,

A_{DY}: Days of Autonomy (Number of Days of reservation) = 3 days

D_{LD}: Daily load (AC) = Total demand (Wh/day)

B_{DD}: Battery Maximum 'Depth Of Discharge (DOD)' = 80%

η_{INV}: Inverter efficiency = 0.9

η_{CE}: Battery discharging efficiency = 0.95

η_{CC}: Charge Controller consumption = 1

(Here, it is assumed that battery is connected directly to inverter.)

Now,

i) In case of daily load demand up to 350 Wh/day (PP0)

When,

DC system voltage: DC 12 V
Load demand: 350 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 12
= (3 x 350 / 0.8 x 0.9 x 0.95 x 1) /12
= (1,050 / 0.684) / 12 = 127.9 Ah

If Rate factor is 1.3, then minimum required battery capacity is 98.4 Ah (127.9 / 1.3). As this capacity is not available, it requires upward adjustment. If 100 Ah at 20°C (charging rate) is used then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / Battery voltage
= 12/12 = 1 nos.

ii) In case of daily load demand up to 700 Wh/day (PP1)

When,

a) DC system voltage: DC 12 V

Load demand: 700 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 12
= (3 x 700 / 0.8 x 0.9 x 0.95 x 1) / 12 = (2,100 / 0.684)/12
= 255.9 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 196.8 Ah. As this size is not available, it requires upward adjustment. If 200 Ah at 20°C is used, then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / Battery voltage
= 12 / 12 = 1 nos.

b) DC system voltage: DC 24 V

Load demand: 700 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 24
= (3 x 700 / 0.8 x 0.9 x 0.95 x 1) / 24
= (2,100 / 0.684) / 24 = 127.9 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 98.4 Ah. As this size is not available, it requires upward adjustment. If 100 Ah at 20°C is used then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / Battery voltage
= 24 / 12 = 2 nos.

iii) In case of daily load demand up to 1,400 Wh/day (PP2)

When,

a) DC system voltage: DC 12 V

Load demand: 1,400 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 12
= (3 x 1,400 / 0.8 x 0.9 x 0.95 x 1) / 12
= (4,200 / 0.684) / 12 = 511.7 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 393.6 Ah. As this size is not available, it requires upward adjustment. If 400 Ah (100 Ah x 4 nos. or 200 Ah x 2 nos.) at 20°C is used, then days of autonomy will be slightly more than 3 days.

As mentioned in section 2.3 above, if a large number of batteries are connected in parallel, then charge/discharge and equalizing charge may not be effective. Over the time of operation, some of the batteries may not charge and discharge well.

If 100 Ah battery is used in the system,

Batteries in parallel = Required battery capacity / Ah of each battery
= 400 Ah / 100 Ah = 4 nos.

If 200 Ah battery is used in the system,

Batteries in parallel = Required battery capacity / Ah of each battery
= 400 Ah / 200 Ah = 2 nos.

The required number of batteries in series = DC system voltage / Battery voltage
= 12 / 12 = 1 nos.

b) DC system voltage: DC 24 V

Load demand: 1,400 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) $= (A_{DY} \times D_{LD} / B_{DD} \times \eta_{INV} \times \eta_{CE} \times \eta_{CC}) / 24$
$= (3 \times 1{,}400 / 0.8 \times 0.9 \times 0.95 \times 1) / 24$
$= (4{,}200 / 0.684) = 255.8$ Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 196.8 Ah. As this size is not available, it requires upward adjustment. If 200 Ah at 20°C is used, then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / battery voltage
= 24 / 12 = 2 nos.

The recommended capacities of PV array and batteries are summarized in the table below.

Table 2.4.3 Recommended PV Array and Battery Capacities for Installation

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Country min. average solar irradiation (kWh/day)	5.1	5.1	5.1
Total system design factor	0.6	0.6	0.6
Calculated min. required PV array capacity (W)	114	228	458
Recommended PV capacity (W) for installation	120	240	480
Recommended DC system voltage (V)	12	24	24
Days of autonomy (days) taken for calculation	3	3	3
Recommended Storage battery capacity (Ah)	100	100	200
Required Battery Quantity (Nos.)	1	2	2

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2.4.3 Voltage Drop

The Voltage drop is a critical point in the system, to supply power or charge the battery. In the system, there are two types of voltage drops as described in section 2.3.

These are:

(1) The voltage drop at generation due to temperature rise of PV cell/module.

For calculation, the following equation described in section 2.3 is applied.

K_{PT} (Reduction in voltage generation) = $1 + \alpha_{Vmax} \times (T_m - 25)/100 = 0.89$
Where,
α_{Vmp} [PV Cell/Module Temp coefficient for voltage (– %/°C)] = – 0.4
T_m (PV Cell/Module temperature °C) = $T_{av} + \Delta T$ = 52°C
T_{av} (Ambient temperature °C) = 32°C
ΔT (Temperature rise on PV cell/module °C) = 22°C

If 120 W module is used in the system, then the output is as follows:

Voltage at maximum power point (V_{mp}) = 17.49 V
Current at maximum power point (I_{mp}) = 6.86 V

Therefore, voltage generation at 52°C = $V_{mp} \times K_{PT}$ = 17.49 x 0.89 = 15.6 V

(2) Voltage drop along the cable section.

To calculate the voltage drop at each cable section, the following equation described in section 2.3 is applied.

e = 35.6 x L x I / 1,000 x A
Where,
e: Voltage drop across the cable (V)
A: Cross section area of the cable (mm^2)
L: Length of the cable (m)
I: Rated Current (A) flow

The equation shown above holds when the cable conductor is copper, phase conductors of the circuit are in equilibrium and cable conductance is 97%.

When selecting the cable size for the system, in addition to the voltage drops mentioned above in (1) and (2), it is necessary to consider required minimum voltage for equalizing charge. Most Charge Controllers (CCs) need minimum 15 V input from PV array for equalizing charge. Depending on the manufacturer, some may need more or less than 15 V, and this also depends on the type of battery (flooded, sealed or gel). Considering this, even with voltage drops in generation and cable sections, there should be at minimum 15 V supply to the CC.

In the case of 24 or 48 volt systems, the required minimum voltage up to the input terminal of CC is 30 and 60 (15 x 2 and 15 x 4) volts respectively.

Furthermore, most PV modules come with attached cable of 4 mm^2 in size and around 1 meter in length. This also needs to be considered when calculating voltage drops.

For the voltage drop calculation here, a 120 W module is used for reference. Therefore, voltage drop in the system up to the end of the attached cable to the PV module will be:

e = 35.6 x L x I / 1,000 x A = 35.6 x 1 x 6.86 / 1,000 x 4 = 0.06 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 4 mm^2
L (Length of the cable) = 1 meter
I (Rated Current flow) = 6.86 Amp

Hence, if operating temperature of PV module is 52°C, then voltage up to the end of attached cable (4 mm^2) will be 15.54 V.

That is,

Voltage generation by PV array at 52°C (a) – Voltage drop up to the end of attached cable of PV module (0.06 V).
15.6 V – 0.06 V = 15.54 V

Now, from the end of attached cable to CC input terminal, the cable size should be such that the voltage drop shall not be more than 0.5 V irrespective of the cable length, in order to ensure input voltage is over 15 V.

To calculate voltage drop of the cable, it is assumed that current flow is maximum at that time. If the above values are applied to the Power Packages (PPs) mentioned in preceding sections, then the results are as follows:

(1) In case of PP0 (Demand load up to 350 Wh/day)

System voltage (V) = 12 V DC
Generated voltage by PV up to the end of attached cable: 15.54 V
PV panels in parallel (no.) = 1 (120 Watt)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x 6.86 / 1,000 x 10 = 0.24 V
When,
e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for the calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp

From the above calculation, in the case of PP0, the possible voltage at input terminal of CC will be 15.3 V (15.54 V – 0.24 V).

In addition to the voltage drops mentioned above for the cable section from PV to CC, there is another cable section from CC to battery. This is also a very important factor in bringing the battery to full charge state. In this CC to battery section, the connection cable shall be as short as possible and assumed to be 3 meters (maximum). Further, the voltage drop of this cable section shall be as small as possible, and 0.1 V at most. Considering these points, the required cable size for the section will be calculated as below.

A = 35.6 x L x I / 1,000 x e = 35.6 x 3 x 6.86 / 1,000 x 0.1 = 7.33 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) =? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp

From the above calculation, to restrict voltage to 0.1 V when cable length is 3 meters, the minimum required cable size is 7.33 mm^2. As this size is not available, the nearest possible size to avoid more than 0.1 V drop will be 10 mm^2.

(2) In case of PP1 (Demand load up to 700 Wh/day)

i) When System voltage is 12 V DC

Generated voltage by PV up to end of attached cable: 15.54 V
PV panels in parallel (no.) = 2 (120 W x 2 nos.)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 2) / 1,000 x 10 = 0.49 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 mm^2 (assumed for the calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, in the case of PP1 (DC 12V), the voltage at input terminal of CC will be 15.05 V.

As in PP0, voltage drop of the cable section from CC to battery shall be as small as possible and 0.1 V at most. The required cable size for the section will be as follows:

A = 35.6 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 2) / 1,000 x 0.1 = 14.65 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) =? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, to restrict voltage drop to 0.1 V when cable length is 3 meters, the minimum required cable size is 14.65 mm^2. As this size is not available, the nearest possible size to avoid more than 0.1 V drop will be 16 mm^2.

ii) When System voltage (V) = 24 V DC

Generated voltage by PV up to end of attached cable: 31.08 V (15.64 V x 2 in Series)

PV panels in parallel (no.) = 1 (120 W x 2 in Series)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x 6.86 / 1,000 x 10 = 0.24 V

When,

e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)

L (Length of the cable) = 10 meters (assumed maximum length)

I (Rated Current flow) = 6.86 Amp

From the above calculation, in the case of PP1 (DC 24 V), the possible voltage at input terminal of CC will be 30.8 V (31.08 V – 0.24 V).

As in PP0, voltage drop of the cable section from CC to battery shall be 0.1 V at most. The required cable size for the section will be as follows:

A = 35.6 x L x I / 1,000 x e = 35.6 x 3 x 6.86 / 1,000 x 0.1 = 7.33 mm^2.

When,

e (Voltage drop across the cable) = 0.1 V

A (Cross section area of the cable) = ? mm^2

L (Length of the cable) = 3 meters (maximum length)

I (Rated Current flow) = 6.86 Amp

From the above calculation, to restrict voltage drop to 0.1 V, the minimum required cable size is 7.33 mm^2. As this size is not available, the nearest possible size will be 10 mm^2.

(3) In case of PP2 (Demand load up to 1,400 Wh/day)

i) When System voltage (V) = 12 V DC

Generated voltage by PV up to end of attached cable: 15.64 V

PV panels in parallel (no.) = 4 (120 W x 4 nos.)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 4) / 1,000 x 10 = 0.98 V

When,

e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)

L (Length of the cable) = 10 meters (assumed maximum length)

I (Rated Current flow) = 6.86 Amp x 4 PV modules

From the above calculation, in the case of PP2 (DC 12 V), the voltage at input terminal of CC is 14.56 V. Here, due to the high voltage drop, the remaining voltage is less than the required voltage of 15 V. In order to minimize the voltage drop, a larger cable size is required for this section. From the above calculations, to ensure the voltage at input terminal of CC is more than 15 V, the required minimum cable size will be more than 20 mm^2. As this size is not available, the nearest cable size will be 25 mm^2.

Even though large cable sizes are available in the market, small equipment cannot adopt larger cable sizes as their performance of workability becomes very poor.

As in other PPs, voltage drop of the cable section from CC to battery also needs to be considered. This means that here, very large cable sizes may also be required to ensure a maximum voltage drop of 0.1 V. The required cable size for the section will be as follows:

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 4) / 1,000 x 0.1 = 29.31 mm^2

When,

e (Voltage drop across the cable) = 0.1 V

A (Cross section area of the cable) =? mm^2

L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp x 4 PV modules

From the above calculation, to restrict voltage drop to 0.1 V, the minimum required cable size will be 29.31 mm^2. As this size is not available, the nearest possible size will be 35 mm^2.

From the above results, it can be considered that as PV system capacity becomes larger, it becomes less practical to design the system on DC 12 V. Where DC 12 V is not practical, it is recommended to design the system in higher voltage such as DC 24 V or DC 48 V depending on PV capacity.

ii) When System voltage (V) = 24 V DC

Generated voltage by PV up to end of attached cable: 31.08 V (15.64 V x 2 in Series)
PV panels in parallel & series (no.) = 2P & 2S (120 W x 4 nos.)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 2) / 1,000 x 10 = 0.49 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp x 2 parallel

From the above calculation, in the case of PP2 (DC 24 V), the possible voltage at input terminal of CC is 30.59 V.

As in other PPs, voltage drop of the cable section from CC to battery shall be 0.1 V at most. The required cable size for the section will be as follows:

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 2) / 1,000 x 0.1 = 14.65 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) = ? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp x 2

From the above calculation, to restrict voltage drop in this section to 0.1 V, the minimum required cable size is 14.65 mm^2. As this size is not available, the nearest possible size to avoid more than 0.1 V drop will be 16 mm^2.

The table below shows the results of the calculation of cable size for each section, when the designed PPs are adopted.

Table 2.4.4 Recommended Cable Size for each Section

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Minimum required PV array capacity (W)	114	228	458
PV module rating taken for calculation (W)	120	120	120
PV array Current rating (I_{mp})	6.86	6.86	13.72
Recommended PV array capacity (W)	120	240	480
Recommended DC system voltage (V)	12	24	24
Cable size (mm^2) for PV to CC (L=10m)	10	10	10
Cable size (mm^2) for CC to Battery (L=3m)	10	16	16

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The above table shows that from the calculations, the cable size for the section from CC to battery is 10 mm^2 for a PP0 type system and 16 mm^2 for PP1 and PP2 systems. To standardize, it is recommended to use 16 mm^2 cables for this section for all PPs. The cable for the section from CC to battery shall be of a flexible type.

The table below summarizes the total system configuration of the respective PPs.

Table 2.4.5 Summary of System Configurations for PPs

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Country min. average solar irradiation (kWh/day)	5.1	5.1	5.1
Total system design factor	0.6	0.6	0.6
Calculated min. required PV array capacity (W)	114	228	458
Recommended PV capacity (W) for installation	120	240	480
Recommended DC system voltage (V)	12	24	24
Days of autonomy (days) taken for calculation	3	3	3
Recommended Storage battery capacity (Ah)	100	100	200
Required Battery quantity (Nos.)	1	2	2
Recommended Cable size (mm^2) for the section PV to CC (L = 10 m)	10	10	10
Recommended Cable size (mm^2) for section CC to Battery (L = 3 m)	16	16	16
Recommended Charge Controller (CC) Capacity (I)	15	15	30
Recommended Inverter Capacity (Watt)	300	500	700

Prepared by JET

2.4.4 PV System for Charging Services

The charging service is considered to provide power for charging mobile phones, lanterns and hair clippers for community residents at a small fee. When charging services are provided at public schools where other PV systems are installed, the income generated can be used as financial support for the replacement of consumable equipment such as lamps, fuses, distilled water for refilling battery and so on.

The assumed utilization pattern of the charging service is as shown in the table below.

Table 2.4.6 Assumed Utilization Pattern of Charging Service

Item	Quantity	Watt (AC)	Use (hr/day)	Total Demand (Wh/day)
Mobile phone	35	2	3	210
Lantern (LED)	20	3	5	300
Hair clipper	1	20	3	60
In house light (LED)	1	5	4	20
Security light	1	10	11	110
Total				700

Prepared by JET

The total demand shown in the above table is applied to determine the PV array capacity, using the equation mentioned in section 2.3. For reference, the methods of calculation to determine PV array capacity, storage battery and voltage drop are those in section 2.4.1. The summarized results are as shown below.

(1) PV array sizing for demand load of 700 Wh/day (charging service)

The method of determining PV array size for the charging system is the same as for other systems. From the calculation, the required PV array capacity is as shown below.

PV Array capacity (Acap) = Total load (demand) / H_A x K'

= 0.7 /5.1 x 0.6 = 0.228 kW = 228 W

If, 120 W PV module is used, then total PV array capacity for the system will be 240 W (120 W x 2).

(2) Battery sizing for demand load of 700 Wh/day (charging service)

In the charging system, charging is done during the day. This means that the main tasks of the battery are to stabilize the voltage and to provide power when the installed PV array is not able to supply power at that moment or when a higher current is required for some time which cannot be maintained by the installed PV array capacity. Furthermore, by reducing the battery capacity to a minimum, the initial cost of system and replacements cost can be reduced. Considering the aforementioned points:

When,

System voltage: DC 12 V

If Days of Autonomy (A_{DY}): 1 day,

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / DC System voltage
= (1 x 700 / 0.8 x 0.9 x 0.95 x 1) / 12
= (700 / 0.684) / 12 = 85.3 Ah

From the calculation, the required storage battery capacity is 85.3 Ah. As this size is not available, it requires upward adjustment. The nearest available capacity is 100 Ah at 20°C. If the installation site has bad weather, then it is recommended to increase the battery capacity from 100 Ah to 200 Ah.

(3) Determining the cable size for demand load of 700 Wh/day (charging service)

System voltage (V) = 12 V DC

Generated voltage by PV up to end of attached cable: 15.54 V

PV panels in parallel (no.) = 2 (120 Watt x 2 nos.)

Then, using the equation for voltage drop below:

e = 36.5 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 2) / 1,000 x 10 = 0.49 V

When,

e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)

L (Length of the cable) = 10 meters (assumed maximum length)

I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, in the case of DC 12 V system for charging service, the possible voltage at input terminal of CC is 15.05 V.

For the section from CC to battery restricting voltage drop to 0.1 V, the required cable size is as shown below.

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 2) / 1,000 x 0.1 = 14.65 mm^2

When,

e (Voltage drop across the cable) = 0.1 V

A (Cross section area of the cable) = ? mm^2

L (Length of the cable) = 3 meters (maximum length)

I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, the minimum required cable size is 14.65 mm^2. As this size is not available, the nearest possible size will be 16 mm^2.

Table 2.4.7 System Capacity for Charging Service

Items	Value
Load demand (Wh/day)	700
County minimum average solar irradiation (kWh/day)	5.1
Total system design factor	0.6
Calculated minimum required PV array capacity (W)	228
Capacity of each PV module (W)	120
DC system voltage (V)	12
Adjusted PV array capacity (W) for installation	240
Storage battery capacity (Ah)	100
Required Battery quantity (Nos.)	1
Recommended Cable size (mm^2) for section PV to CC (L = 10 m)	10
Recommended Cable size (mm^2) for section CC to Battery (L = 3)	16
Recommended Capacity of CC	30
Recommended Capacity (min.) of Inverter (W)	300

Prepared by JET

If demand for charging increases in the future, it is recommended to install an additional system to serve the demand.

2.4.5 PV System for Vaccine Refrigerator

At health service institutions where grid connection does not exist, power for vaccination refrigerators is provided either by a PV system with storage battery or by LPG. Most of the existing vaccine refrigerators are operated by a dual power supply system – either by electricity or by LPG. In most cases where a PV system is used, users change the operating system to LPG once the life of the battery ends. This is due to difficulties in budgeting to replace batteries periodically. However, for systems using LPG alone, budgeting to purchase LPG periodically is also necessary.

Nowadays there are solar vaccine refrigerators approved by World Health Organization (WHO), which are directly driven by PV system without any storage battery. Such a vaccine refrigerator has already been installed at Olkinyei dispensary in Narok County by MoH for monitoring. The particular type of PV driven vaccine refrigerator installed is MKS 044, and the manufacturer recommends use of the product in temperate climate zones with ambient temperature of 32°C and below.

The Project also installed MKS 044 vaccine refrigerators at two different sites; Ilkilnyeti dispensary in Kajiado County and Latakweny dispensary in Samburu County. For the operation of the vaccine refrigerator, maximum DC input current is 15 A. Therefore, in Ilkilnyeti, two existing 120 W PV modules of 6.68 A are in use, while in Latakweny, two 125 W PV modules of 7.0 A were installed to supply power to the vaccine refrigerator.

Comparing these two installations; the one installed in Latakweny dispensary takes longer to cool and to settle inside temperature. Depending on the area, the ambient temperature in summer might be almost or higher than 32°C. Therefore, it is not recommended to install this type of PV driven refrigerator in hot areas, where ambient temperature conditions are over 32°C. Instead, it is recommended to install vaccine refrigerators approved by WHO for hot climate zones.

2.5 Installation

In existing or ongoing installations, once the contract between the owner and supplier/contractor is finalized, procurement and installation of the system should be undertaken. This includes other works such as verification of installed materials and equipment against the tender/contract document, supervision during installation and required rectification works which are additional responsibilities of the supplier/contractor.

As soon as the contract with the owner is finalized, the supplier/contractor should proceed with the installation works. For this the supplier/contractor makes a contract with the technicians on the basis of volume and type of works to be carried out and decides the time line of installation. Once the contract of work is made with the technicians, the supplier/contractor delivers the materials to the site and technicians start the installation works. If only the process stipulated in the contract for installation works is considered, the installation may look satisfactory. However, there are some important points that are not included either before or during installation works, or after completion of works that are directly related to the life of the system and installation quality. That is,

(1) After the service contract between the owner (requester) and supplier/contractor is finalized, the requested type of work is not explained in detail to the supplier/contractor, or the supplier/contractor does not go through the tender document to understand the required type of installation work properly.
(2) To understand the required installation work at the site or to plan for the installation work, the supplier/contractor normally does not visit the actual installation site before participating in bidding, after getting the work offer, or before contracting technicians for installation works. Hence, the supplier/contractor is not able to prepare shop drawings for the system installation plan or explain the required type of installation work to the technicians at the site. The supplier/contractor only adheres to the quantities or measurements stated in the tender document, which cannot be exactly the same in the case of mass installation. This means that, for example, if the wiring route or installation position of a component or equipment requires adjustment, then such a small issue will affect the whole installation and material management.
(3) Sometimes, the basic rules of house wiring are not understood or are neglected by the technicians. For example:
    - Naked (non insulated) wire of one of the three (3) cores of Vinyl Insulated Flat cable is used either as negative wire or as returned wire from lamp to ON/OFF switch.
    - Earth rod is not grounded properly. In some cases, if it cannot go down smoothly, then instead of shifting grounding position the remaining portion is bent or cut off.
(4) The installation materials are not handled carefully. Hence, even cracked or partly broken switches, sockets, lamp holders, cable turfs, etc., are installed.
(5) In some cases, all holes for mounting equipment are not used, which means the equipment may fall off at any time during system operation.
(6) Due to forceful work or unmatched use of tools, threads of terminal screws are broken or slip.
(7) PV module/array is installed on the roof without considering the inclination angle and orientation (direction) of the installation. Therefore, power generation differs drastically from the designed value (causing a mismatch with design use pattern).
(8) In case of connecting storage battery, even though there is more than one battery in the system (12 V), more than two (2) wires are connected at the same terminal.
(9) The positioning of equipment is not adequately considered during installation. Hence, DC and AC wires/cables cross over each other or the same cable turf is used for both power supply systems.
(10) Cross check during the installation or inspection after installation by the supplier/contractor is not common practice. Hence, the supplier/contractor is not sure of the actual status of the installed system, and commissioning may even be carried out by owner.

Considering all the above points, in order to avoid confusion and ensure smooth operation and good quality of work, the following points are recommended as countermeasures:

(1) The owner shall conduct inspection of procured materials, verifying against the contract document before materials are dispatched to the site.
(2) The installation materials and equipment shall be checked and confirmed before dispatching to the site, by both the technicians and supplier/contractor.
(3) The operation of equipment like inverter, CC, etc., needs to be confirmed and recorded before dispatching to the site.

(4) For transportation, materials and equipment shall be packed well to avoid any damages while transporting.

(5) The responsible engineer/personnel on behalf of the supplier/contractor shall accompany the technicians to guide the installation work, and shall explain the required work in detail to the technicians at the site. If there is more than one group/team of technicians for installation work, then the responsible engineer shall guide the installation work and explain the required work in detail to each group.

(6) During installation, the responsible engineer/personnel on behalf of supplier shall visit the installation site to cross check and confirm the ongoing installation work. At the time of each inspection, the record of the inspection with pictures shall be kept to confirm guided /requested work. The record – inspection sheet shall be prepared in such a way that the counting of materials shall also be verified at the same time.

(7) After technicians finalize any installation work, internal inspection by the supplier/contractor is essential. The record of installed materials and equipment shall be verified against the agreed contract. The final internal inspection shall be confirmed and documented in a record sheet of installation materials verification, operation status of each component/equipment and operation status of the integrated system. The final internal inspection sheet shall be signed by the system inspector and responsible engineer/personnel on behalf of the supplier/contractor. The signed internal inspection record sheet shall be submitted at the time of commissioning as a basis for commissioning and as a record of system installation work and operation status of the installed system.

(8) To finalize the system installation work, additional required documents such as installed materials list, as built drawings, manual, pictures showing the site before, during and after installation, etc., should be provided by the supplier/ contractor.

(9) There should be some form of penalty if there are drastic differences between the submitted internal inspection record sheet and actual installation at the site.

Besides the above recommended countermeasures, there are other recommendations for installation as described below.

(1) In most cases the installation areas for equipment are not smooth or flat. To fix equipment, a wooden plank shall be fixed first and equipment shall be fixed on the wooden plank.

(2) The equipment shall be covered or placed inside boxes with proper ventilation to avoid any direct contact.

(3) There should be some extra length of wire at each terminal connection point to avoid any tension either to the terminal or wire/cable.

(4) For grounding, a minimum of 50 cm by 50 cm hole shall be made below ground level and earth rod shall be grounded.

(5) Outdoor type cable shall be used to connect PV array to isolator. To offer protection and prevent cables from touching the metal roof, flexible conduct shall be used.

(6) Indoor type flexible cable shall be used to connect CC to Battery.

(7) The minimum capacity of isolator shall be 1.5 times the Current at maximum power point (Imp) of PV array.

(8) The minimum size of fuse or DC breaker installed between CC and battery shall be 1.3 times the maximum output current rating of CC, and shall be installed as close to the battery as possible.

(9) The minimum size of fuse or DC breaker installed between battery and inverter shall be 1.5 times the maximum input current rating of inverter, and shall be installed as close to the battery as possible.

(10) The best inclination angle for installation of the PV array is 0 to 5 degrees. Considering the rainy season months, position of the sun at that time, dust deposit on the modules, etc., it is recommended to incline the PV array at a minimum of 10 to 15 degree facing north.

2.6 Procurement

Procurement occurs after the distribution of the tender documents by the owner and their submission by the bidders. In some cases, the time provided between these two stages is rather short and bidders therefore submit their offer based on company catalogues, information available on the internet, or on past experience, without gathering current information. For the bidding documents, the required information to be attached is either a copy of the bidder's catalogue or information downloaded from the internet. Rarely, there may be cases where a guarantee letter of equipment supply from the manufacturer should be attached. At the time of finalizing the contract between the owner and supplier/contractor, the provided procurement period cannot be guaranteed to be sufficient. Due to the limitation on procurement period, the installation work may become patchwork in some cases.

Besides the aforementioned complicated problems, in most cases there is no practice of asking and addressing questions related to the tender documents, between the owner and bidders before submitting the bidding offer. For example, even if the supplier/contractor finds it more practical to change the system configuration or it is not possible to purchase some of the components, these kinds of discussions to solve the problem are not held before submitting the bidding offer. Instead, the changed component/equipment or system configuration is directly attached and submitted in the bidding offer. Hence, the installation work is not understood fully or clearly unless bidding is opened and evaluation is made.

Considering the above points and in order to simplify the resulting complications, the following points are recommended:

(1) At least one month should be given from the date of distribution of tender documents to submission.
(2) After distribution of tender documents, if there are any doubts or need for clarification from the bidders', or if a supplier thinks of a better technical option than that proposed by the owner, etc., a question and answer session of 7 (seven) days after distribution of document shall be scheduled, to clarify the recommendations from the bidder and requirements from the owner. Any questions or recommendations for change shall be submitted in writing. Responses to these queries shall be given in writing and shall be disclosed to all participants without disclosing the company name of the inquirer. If any amendment of clauses is made, then it shall be provided in writing to all participants.
(3) Once the contract is awarded to the bidder, a period of 3 (three) months shall be scheduled for procurement. If the supplier/contractor suggests a shorter period for procurement, then the suggestion shall be discussed and agreed between the parties.
(4) The maximum limit of installation dates and commissioning period shall be decided during the contracting process for the installation work. If these need to be changed, then at least one month's advance notice with justification shall be submitted by the supplier/contractor.
(5) The inspection of procurement shall be done before dispatching materials to the site, to confirm and verify the products and quantities against the contract document.
(6) Before dispatching the procured equipment, the supplier/contractor shall conduct operation tests of equipment in the presence of responsible person(s) representing the owner.

2.7 System Operation and Maintenance

InPV systems, generation is DC power while utilization is AC power. For trouble shooting, it is necessary to understand first how the system operates. Figure 2.7.1 summarizes the system power flow.

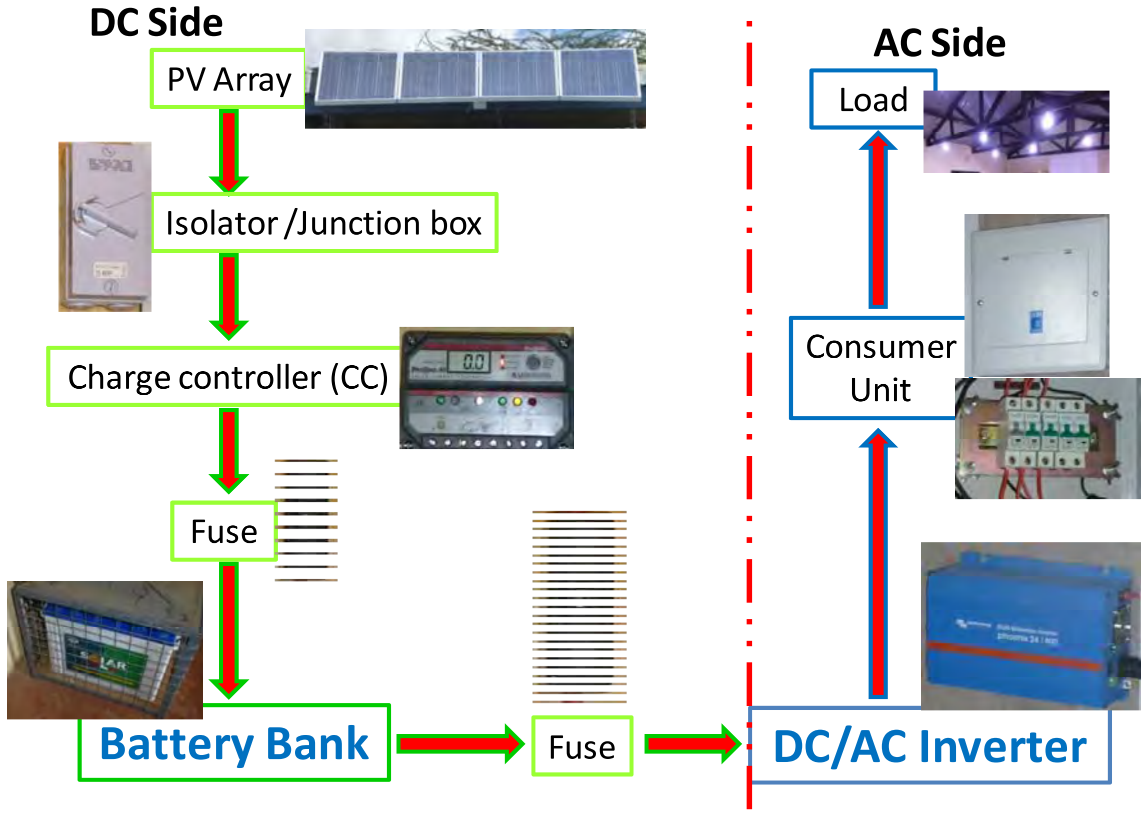

Figure 2.7.1 PV System Operation Power Flow

From the above figure, it can be considered that irrespective of PV capacity or DC system voltage during daylight hours, PV array converts the received light energy to DC electric energy, which flows to battery passing through isolator, charge controller and fuse sequentially. When load is turned on, the energy stored by the battery or generated from PV array will flow to inverter. The inverter converts DC power to AC power and supplies power to load via consumer unit.

<u>Failure and trouble shooting</u>

If the system is not working, then trouble shooting is required to find and resolve the problem. To troubleshoot:

(1) Turn off the isolator and measure the open circuit voltage (V_{oc}) of PV array at input terminal of isolator.

(2) The measured value of Voc of PV array will be:

i) If DC system voltage is 12 V, then the measured value will be within the range of V_{oc} of PV module at STC ± 10%.

ii) If DC system is 24 V, then the measured value will be within the range of V_{oc} (1st module + 2nd module) at STC ± 10%.

iii) If DC system is 48 V, then the measured value will be within the range of V_{oc} (accumulated V_{oc} of 1st to 4th module) at STC ± 10%.

The Voc may be different from the stated value depending on PV cell/module temperature at that time. For further details, refer to the technical specification of the installed PV module. Keep a record of the measured value of Voc.

iv) If V_{oc} of PV array is out of range, then measure V_{oc} of each module separately and keep a record of measurements.

v) If V_{oc} of module is out of range, then measure short circuit current (I_{sc}) of that module. The Isc will depend on the intensity of solar insolation at that time (I_{sc} at STC x intensity of solar insolation at that time). If there is no current flow, then PV module is not generating power. It is therefore necessary to change the damaged PV module. Keep a record of measurements.

Note: Only trained personnel shall conduct the measurement works. To measure I_{sc}, it is necessary to use suitable equipment such as a circuit tester that can measure current or clamp meter.

While conducting measurement works, it is necessary to concentrate and be cautious to avoid any hazards which may cause accidents. Now,

Conformation at DC side:

- ✓ If PV modules are found to be working well, then make a jumper at isolator (isolator must be at OFF position) from input terminal to output terminal and measure voltage. If there is charging voltage, then isolator is not working. In this case, change the isolator. Keep a record of measurements and the work that is carried out.
- ✓ If isolator is working, then measure PV input voltage at input terminal of charge controller. Measure voltage at battery connection terminal of CC and charging current to battery. To measure, isolator must be at ON position. Keep a record of measurements. If there is current flow, then the problem is not at CC.
- ✓ If there is no current flow toward battery, check the fuse installed between CC and battery. If fuse is blown, then change the fuse. The fuse may blow due to the effect of lightning, short circuit, rush current and so on. Before removing fuse, make sure that isolator is at OFF position. Never remove fuse without turning isolator OFF first. To turn isolator ON fuse must be inserted.
- ✓ If fuse installed between CC and Battery is normal, then check installed fuse between battery and inverter. Before removing fuse, make sure that the inverter is at OFF position. If fuse is blown then replace the fuse.
- ✓ If fuse installed between battery and inverter is normal, then measure input DC voltage and current.

Conformation at AC side:

- ✓ If measured DC voltage at input terminal of inverter is normal (nearby battery voltage) , then turn ON the inverter and measure AC output voltage and output frequency of inverter.
- ✓ If inverter is operating normally, measure AC voltage and frequency at input terminal of main breaker of consumer unit. Confirm the position (ON/OFF) of breakers at consumer unit. The breakers may turn OFF due to short circuit, overload or breakdown of used loads and so on. If breaker is at OFF position, then first check the circuit to find the problem. To turn ON the breaker first push lever towards OFF position and turn to ON position. The breaker must maintain an OFF position as long as the problem is not solved.
- ✓ Confirm the tightness at every terminal of component/equipment.

Important points to note are:

i) If operation is interrupted due to any faults, the faults must be cleared first before system operation is resumed

ii) Confirm the operation status of system at CC (digital display/LED indicator).

iii) Only authorized person should carry out the trouble shooting.

The PV system does not have any moving parts. However, for smooth system operation regular inspection of system is essential. To understand actual operation status, record keeping and timely checkups of the system are very important and recommended.

For reference, the recommended points for regular inspection and confirmation are:

a) Level of battery liquid and refilling (at least once a month)

b) Visual status of PV array and its structure
c) Permanent shadows over each PV module
e) Visual status of equipment
f) Abnormal noise from equipment
g) Bad smell or odour such as burnt wire/cable or paint on equipment
h) Temperature of room where system is installed.
i) Entry of any insects into installed component/equipment (at least once a week)
j) Working status of CC and Inverter regularly, and also after every lightning strike nearby site.
k) Dust deposit on equipment and cleaning if required
l) Record keeping of every inspection in detail

Depending on the type of cleaning work, the system may need to be stopped before proceeding with the work. Make sure that there is no electrical hazard while cleaning, at the time of inspection and when undertaking maintenance works.

To ensure years of smooth operation of the system:

i) Daily record keeping of system operation status is essential.
ii) Timely discussions among the stakeholders are recommended, to ensure they understand the system operation status.
iii) Periodic checks and replacement of individual components are essential, as recommended by the manufacturer or as per requirement.

2.8 Existing PV System and Grid Connection

In grid connected application, there are two main types of systems.

(1) Grid connected centralized system

A grid connected centralized system functions as its name suggests; centralized power generation and supply. The power generated and supplied by the system is not associated with a particular electricity consumer. Generally, such systems are directly connected to an existing distribution/transmission line, or a dedicated line is established to connect the system to an existing grid sub-station. Hence, such systems are installed in rather large capacity.

(2) Grid connected distributed system

A number of customers are connected to the grid for electricity supply. The PV system is generally integrated into the customer’s premises, often on the demand side of the energy meter. For the installation, the capacity of the PV system is dependent on the available open space, financial situation, and rules and regulations of the government, utility company and related authorities. The installation site will also vary and can be residential, public and commercial buildings, as well as hilly slopes, waste lands and so on.

In general, the PV system capacity is not a determining factor for the installation area, in most parts of the world. However, a 1 MW PV system on a roof top may be large by PV standards for distribution systems.

From the above, it can be considered that where a PV system exists and a distribution grid is extended after some time, it is possible to connect the PV powered facility to the grid with some simple modifications or replacement of some equipment.

The connection type and method may vary depending on the existing PV system capacity, demand and best match for the particular system. The possible types of connections for the PV system to work together with the extended grid are as follows:

a) Reverse flow type connection

Prior to PV system installation and grid integration, the rules and regulations for grid connection need to be established. In reverse flow type of connection, there are two options.

i) Without storage battery bank

In this type of connection, when there is excess power generated by the PV system compared to the demand, the excess power will flow to the grid. Further, if the grid system fails to supply power within the stated standard or a sudden power supply interruption occurs, grid interconnecting Power Conditioners (PCS) will stop and disconnect the grid until grid supply resumes or operates within the stated operation condition, for safety reasons. Hence, when there is no grid supply this system cannot work.

ii) With storage battery bank

In this type of connection, when there is excess power generated by the PV system compared to the demand, then the excess power will flow to the grid. Further, if the grid system fails to supply power within the stated standard or a sudden power supply interruption occurs, grid interconnecting PCS will disconnect the grid. However, the system will continue operating by supplying power from the storage battery, and the PCS will reconnect the grid when grid supply resumes or operates within the stated operation condition. When the battery is discharged, it will be charged by the PV system in daylight hours. In case of bad weather days or at night, the battery will be charged by grid power supply.

b) Non reverse flow type

As the name suggests, the system works together with the grid but does not supply power to the grid. Hence, whether there is grid connection or not, the system can also work as an off grid system. However, in order to operate as an off grid system it requires storage battery to supply power when grid supply is not available and to absorb the large surge of PV array voltage. Generally this type of system can be divided as follows:

(i) Using Inverter charger

At existing PV systems installation sites where the facility is connected to the grid, a standalone type Inverter will be replaced by an Inverter charger type inverter in order to adopt the PV system to work together with grid supply. By replacing this equipment, the system will work with PV charging the storage battery and also supplying power to the load in the day time regardless of whether the grid supply is available or not. If grid supply is not available then power will be supplied from the PV system and if grid supply is available power will be supplied directly from grid. If the battery is discharged, it will then be charged in daylight hours by the PV system, and at night time by grid supply. Therefore, days of autonomy can be reduced to a minimum, which means that battery capacity will be small and replacement costs will be low. Furthermore, as the battery discharge level becomes shallow, the battery life will be extended.

(ii) Using change over switch

This type of system will be most cost effective if the existing PV system is small, and power demand of the facility is low and mostly occurs in daylight hours. In this type of system, the power supply can be selected, by adding change over switch before input terminal of main breaker of existing consumer unit. The change over switch can be either manual or automatic. Hence, if load demand is high or the weather is consistently bad the system can be changed to grid supply. If grid supply is affected or power requirement is mostly in daylight hours, then the system can be changed to PV supply. By avoiding long hours of use or high supply at night from the PV system, it will be possible to control deep discharge of the battery to get longer life.

CHAPTER 3 O&M AND MANAGEMENT

3.1 Purpose of the Section for Management of Solar PV Systems at Dispensaries

The purpose of the management section of the guideline is that REA and MoH enhance their knowledge on the appropriate and effective actions of sustainable PV system, enhance their attitude towards the actions and give detail elements of practice. This section can be used to ensure that all stakeholders make up an effective management system, in terms of physical and O&M matters, for electrification of dispensaries in the un-electrified areas using solar PV systems. It also can be used to ensure that the facility users can enjoy the power generated by installed PV systems for as long as the lifetime of solar panels (20 years). This section of the guideline covers all solar PV systems that REA has installed and will install.

3.2 Basis of Operation and Maintenance System

3.2.1 Implementation of Pilot Projects

This guideline was prepared based on the implementation of and lessons learnt from the pilot projects implemented at ten public facilities by the JICA expert team (JET). It aims at examining feasibility and applicability of solar PV systems, in the technical, financial, social and institutional points of view, to the public facilities located in remote, un-electrified area. The target facilities are divided into Lot 1 and Lot 2. The list of the target facilities is as in Table 3.2.1.

Table 3.2.1 List of the Target Facilities of the Pilot Projects

Lot	Facility	Facility Type	County	Period
1	Ilkilnyeti	Dispensary	Kajiado	May 2013 - October 2014
	Iltumtum	Primary Boarding School	Narok	
	Olkinyei	Dispensary	Narok	
	Olemoncho	Primary Boarding School	Narok	
2	Tuum	Primary School	Samburu	January 2014 - October 2014
	South Horr	Dispensary	Samburu	
	Illaut	Primary School	Samburu	
	Latakweny	Dispensary	Samburu	
	Marti	Primary School	Samburu	
	Angata Nanyokei	Dispensary	Samburu	

Prepared by JET

3.2.2 Lessons Learnt from Pilot Projects regarding O&M (including Financial Management)

One of the important points to consider from the challenges faced was to strengthen the capacity of the facility management committee (MC) for O&M, and to manage and run the charging service. It was expected that the facilities would collect sufficient proceeds and use it for daily O&M and replacement of equipment.

The lessons learnt from implementation of the pilot projects are summarized as follows.

(1) Capacity of MC is often not adequate for stable management of solar PV systems. It is a structural problem for the end management body of public facilities all over Kenya.

- MC members are villagers living in the neighborhood and are usually busy with their normal duties. Therefore, it is not easy for them to contribute their time to the PV system management frequently.
- Basic capacity of MC is low both in human and institutional aspects because members live in remote areas where public and private investment have rarely been made up to now and they are not accustomed to reporting and calculating.
- MC members are not accustomed to managerial issues because they hardly received adequate training on the organization management.
- MC members are not permanent, the knowledge that JET trained was not transferred to new members when members were replaced.

Therefore, REA and MoH shall continue to strengthen capacity of MC.

(2) Charging service did not earn as much income as was expected, but it generates income to a certain extent. It is a scarce fund source that MC can use to meet their immediate needs.

- Market size is small. Population and population density are generally small in the service zone of the facility and economic power of the target area is the lowest in Kenya.
- The sales from phone charging service are low. There are already a lot of competitors of mobile phone charging where the mobile phone network has reached while there are very few numbers of mobile phones where the network has not reached.
- Other services such as hair clipping are more profitable though the number of customers is still small. The more important finding is that it was impossible to repair the hair clippers in adjacent town.
- However, each facility gains some proceeds and MC can use it for their urgent O&M needs such as broken bulbs and distilled water.
- The proceeds from charging service are not enough for replacement of equipment.

Therefore, REA and MoH shall consider the proceeds from charging service as an important fund for self-reliant management of solar PV system. They shall also supervise MCs to improve their O&M and management capacity.

3.2.3 Analysis of Charging Service

This is the analysis of charging service using the above mentioned lessons in Samburu County. The proceeds from charging service are estimated using the matrix of the number of households within a 5 km radius of the facility and the type of communities (dispersed or concentrated). These indicators explain the market size and also the existence of competitors[1]. Sales from charging service are identified for each category of matrix made by the indicators. As electrification of public facilities using solar PV system targets remote areas, less developed counties, data of Lot 2 (Samburu County) is appropriate and applicable. The data shows that facilities located in or near concentrated core have the potential to earn more than KSh 1,000 per month in the moderate case (average). If the network becomes available, even communities located in dispersed areas have potential to earn more than now with the "Blue Ocean" effect. Hair clipping is an important service for the MC.

[1] One lesson learnt from the pilot project is that competitors (private charging service providers) generally exist in the communities whose population size is bigger and that have core area of commercial use.

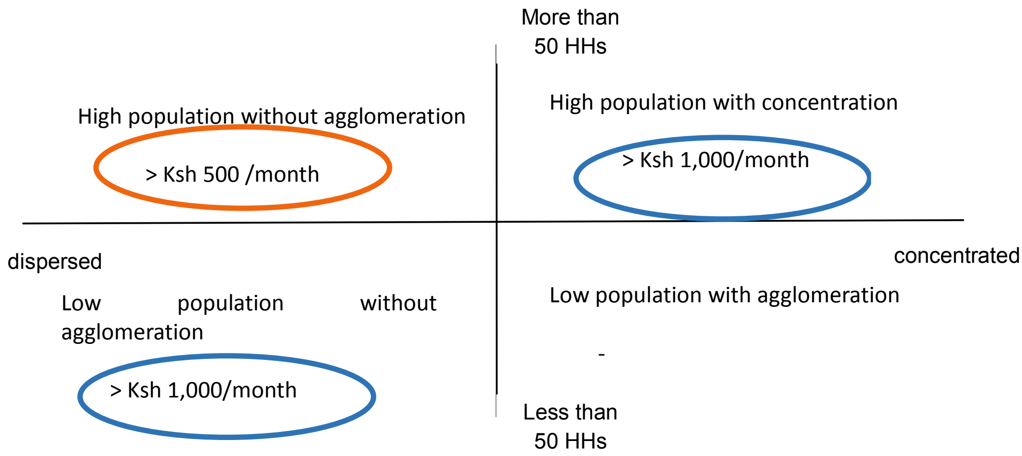

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Figure 3.2.1 Sales of Charging Service in Lot 2 Sites by Type (Moderate Case)

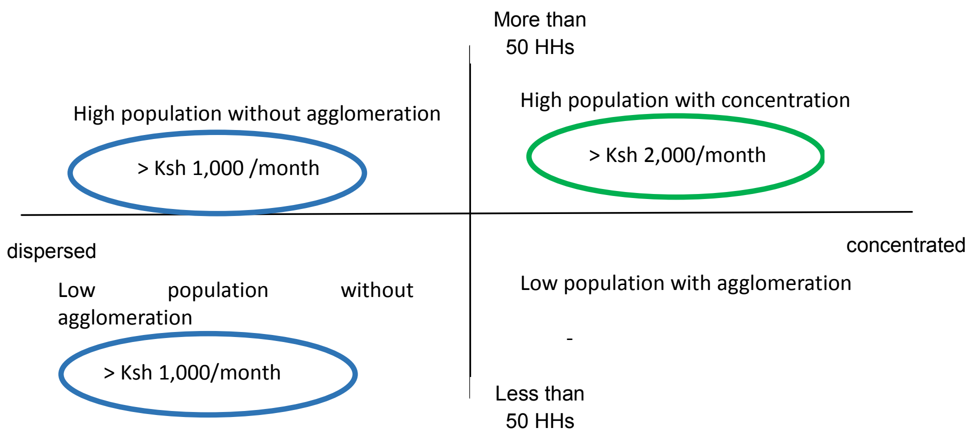

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Figure 3.2.2 Sales of Charging Service in Lot 2 Sites by Type (Optimal Case)

3.2.4 Positioning of the Charging Service in the O&M Model

Charging service is an important tool of sustainable system use at the facility level. Income from the service is used by the MC exclusively to pay for immediate needs of system O&M (e.g., repair of clipper, replacement of broken bulbs) and daily administration cost (e.g. distilled water, bulbs, transportation) in order that MCs can use the solar PV system without deep dependence on the fixed annual budget such as HSSF and FPEF. Thus, from users' point of view, charging service activity gives MCs not only free funds but also an opportunity of strengthening their activities and capacity in social development. With this independent financial source, MCs can deal with troubles more effectively and enhance their experience and skills in fund management and small business.

As mentioned above, however, the proceeds from charging service are not enough for replacement of equipment but MC can use them for daily O&M if the social and economic condition meets the need So what is the condition? It is analyzed and presented in the next section.

REA and MoH shall consider the proceeds from charging service as an important fund for self-reliant management of solar PV system. They shall also supervise MCs to enhance their O&M and management capacity. As the capacity of MC is not adequate, REA and MoH shall continue to develop capacity of MC. This income source will supplement the budget for O&M and replacement of equipment coming from MoH and will support the socialization of MCs in the remote areas in Kenya.

3.2.5 Application of the Charging Service in the Model

(1) Minimal Conditions for the Charging Service

The first or minimal condition for the applicable charging service is that income from charging service be above the initial investment, that is, construction cost of charging kit consisting of solar PV system for charging service and charging hut. The second condition is that the revenue covers both initial investment of the charging service kit and daily O&M cost; in this case target facility gets benefit for covering O&M cost and further its MC gets opportunity for their future social development; MoH gets benefit because they can reduce the budget for O&M of the solar PV system; and also REA gets benefit because the system they installs have fund for O&M to a certain extent.

The estimated amount of initial investment (installation of charging kit) and O&M of the charging service using the data from bidding document and the financial model is monthly proceeds shall be at least Ksh 1,120. Charging service of a facility does not generate loss if the proceeds from charging service are moderate case (Figure 3.2.1). It must be noted that payment for initial cost is NOT required to the facility but the JICA expert applied it to examine if REA invested only for waste or for meaningful social development.

Next question is what condition is needed to earn this income? Bargaining power of customers and intensity of competitive rivalry both seriously affect the proceeds of the charging service but also risk of substitutes and new entrants should not be underestimated. Public facilities will get favourable proceeds if these threats from these factors are low.

Then, what approach is feasible and applicable to this situation? As customers go to charge their phone as their wants that meet particular customer's particular needs, which is difficult for public facilities. One strategy is to coexist with these rivals and substitutes and the second is start earlier than rivals to catch the customer's needs and make them customer's wants.

Thus, by referring to the result of the pilot project in Lot 2 sites, the minimal conditions of potential facilities for charging service are identified and proposed as follows:

a. Mobile phone network will come soon; and,
b. Starting charging service before private service providers and M-Kopa come to the neighbourhood.
c. A facility inside or very near to an agglomeration of houses;
d. More than 50 households in five kilometres radius;

Note that these conditions or criteria are external one because internal conditions, such as coherency of MC and cleanness of financial matter, are difficult to find instantly by observation. REA and relevant ministries shall survey these factors when they start planning and before detailed design of electrification by solar PV system with charging service.

(2) Procedure of selection of potential target facilities

REA and MoH shall survey candidate dispensaries using these four criteria to identify the potential dispensaries for starting charging service. As the number of candidate dispensaries is large, the first screening must be simple and possible to implement in Nairobi. Thus, we start with abovementioned condition c., then advance to d., to a. through b.

<Step 1>

REA and MoH officers prepare a list of candidate list of non-electrified dispensaries with their location name. (identification of the candidate facilities and their location)

<Step 2>

REA and MoH officers identify the area that (i) the mobile phone networks have already covered, (ii) it will cover in a few years, or (iii) it has plan of installation in recent years. The most favourable area is (ii). REA and MoH will do this survey by communicating with mobile phone service providers, i.e. Safaricom, Airtel or Orange. After they find the potential area of mobile phone net work, they check the name of areas with the list of candidate facilities to choose potential ones being inside the area (ii). (selection of the candidate facilities located in the area where mobilephone network comes soon)

<Step 3>

REA and MoH officers check if M-Kopa service has reached the area candidate facilities by communicating with service providers, such as M-Kopa Kenya Ltd. (selection of the candidate facilities without or with small number of competitors)

<Step 4>

After screening at Step 2 and Step 3, REA and MoH officers move to the sub-county capitals. They examine if candidate facilities are located in and adjacent to the core (small trade centre) or not by interviewing sub-county officers who knows facilities well and choose facilities having core. (selection of the candidate facilities with potential customers)

<Step 5>

REA and MoH officers go down to the candidate facilities to check the size of the surrounding communities: +50 within 5km radius. (selection of the target facilities with potential customers)

<Step 6>

REA and MoH officers start baseline survey of the finally selected site as instructed in this Guideline. They use the result of the survey for designing and stakeholder meetings.

3.3 O&M Model

3.3.1 Stakeholders

There are various stakeholders for the electrification of public facilities using solar PV system.

a) Target facilities as responsible institution for daily O&M
b) Dispensary management committee members as management body
c) Community people of the surrounding communities as facility users and potential customers of the charging service
d) County and sub-county offices of MoH as the owner and supervisor of the solar PV system
e) Headquarters of MoH as advisors to the ministry county offices[2]
f) REA as project implementer, system installer and technical advisor
g) Chiefs and/or assistant chiefs of the concerned locations/sub-locations as local authority

Each stakeholder plays different roles for the sustainable use of solar PV system. JET prepared O&M model that explains role demarcation of all stakeholders including REA and MoH for the electrification using solar PV system (refer to Figure 3.3.1)

[2] The role of the ministry headquarter should be revised when the MOU is signed.

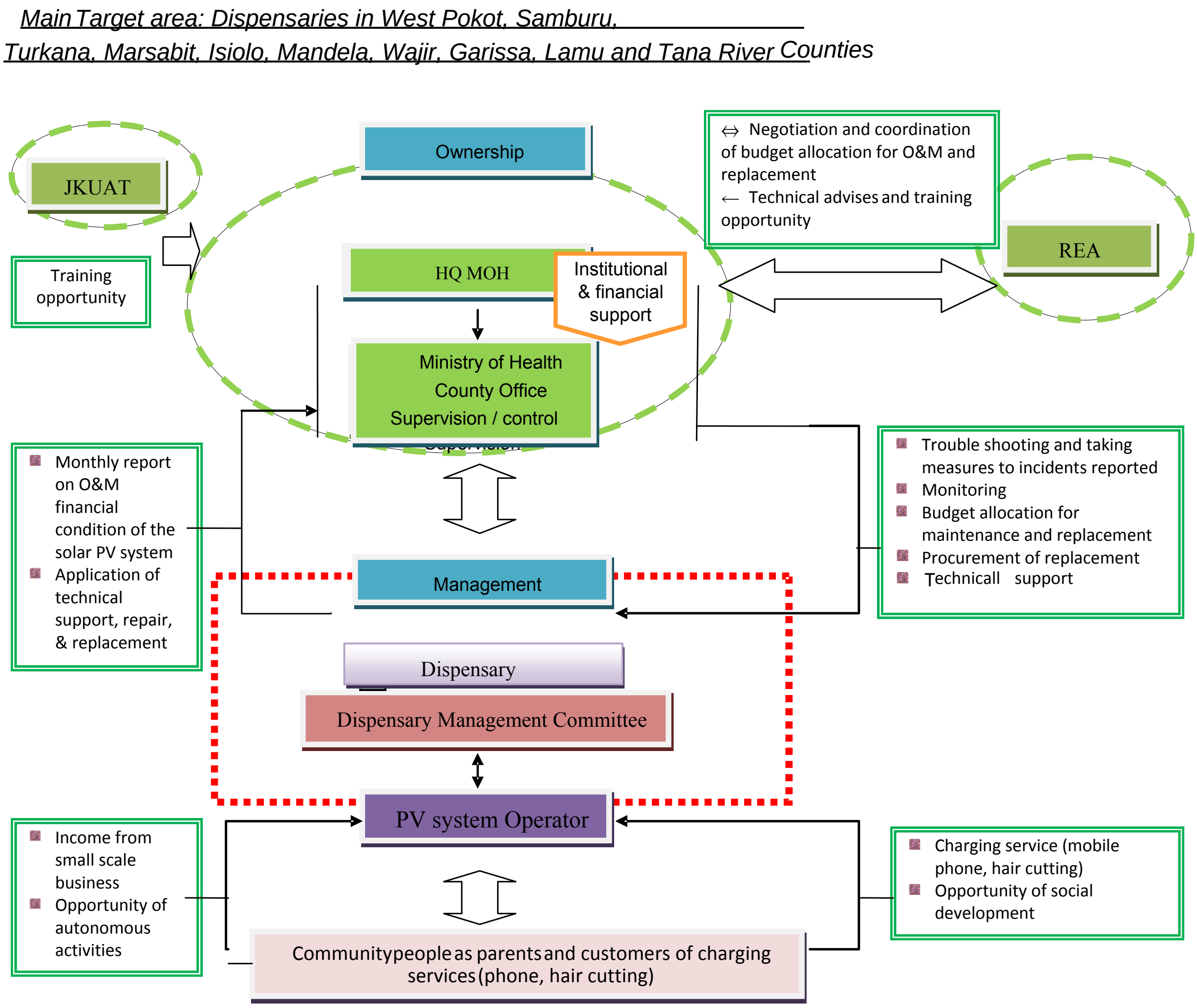

Figure 3.3.1 O&M Model for Electrification of Dispensaries

3.3.2 Ownership and Responsibility

Figure 3.3.1, Table 3.3.1 and Table 3.3.2 show important tasks of REA, MoH, MCs, etc. at each time stage. MOE&P is in charge of making policy and strategy of electrification of public facilities using solar PV system while REA is in charge of implementation. REA has responsibility for installation of solar PV systems while MoH has both ownership and responsibility for system management for sustainable system use.

Table 3.3.1 Roles of Key Stakeholders

Institution	Responsibility
REA	• REA installs solar PV system in un-electrified dispensaries using the technical model prepared by the JICA Project. • REA gives technical and managerial advices to owners of solar PV systems on the O&M.
MoH	• MoH is the owner of the solar PV systems as the system is a component of assets of facilities under their supervision. • County offices of MoH do direct supervision of system use.
Staff members	• Facility staff members and management committees are in charge of O&M

Institution	Responsibility
of the public facility	management. They do operation, maintenance, charging service and reporting.
MOE&P	• Provision of an enabling energy policy framework • Timely disbursement of funds regarding renewable energy • Timely submission of budgets to the Treasury • Sourcing for additional funds[3]

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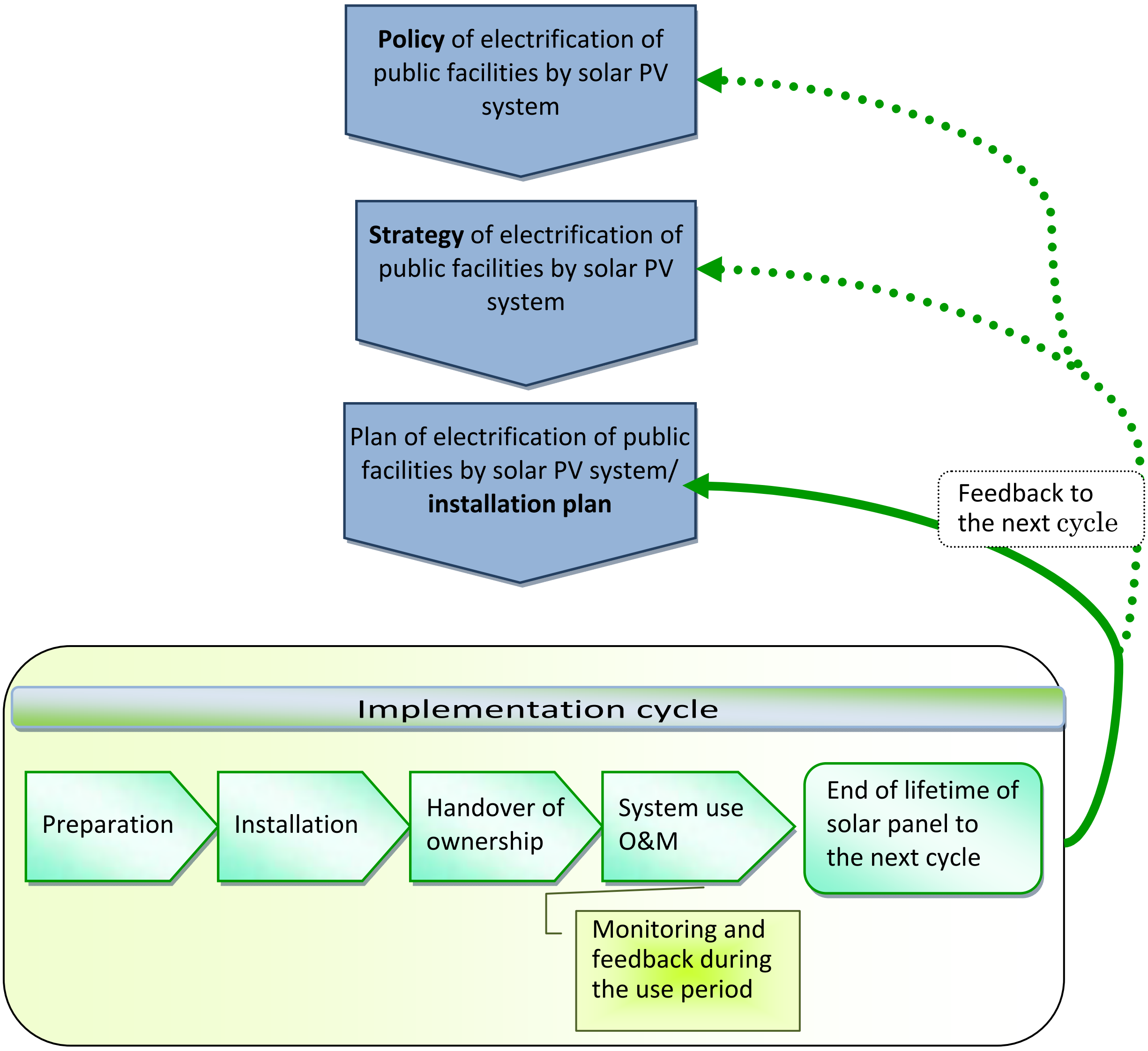

Figure 3.3.2 Project Cycle of Electrification of Public Facilities by the Solar PV System

Project is the most concrete and final stage of the governmental implementation for development. Generally the proponent implements a project in accordance with the plan and/or program, and a plan is made based on the strategy of the sector or region. The highest level is government policy that defines the nationwide direction of the sector.

[3] REA's expectation to MOE&P in Rural Electrification Authority (REA). (2013). *Strategic Master Plan 2013/2014-2017/2018, Third Draft*.

A project has cycles during its lifetime. It does not finish when the project proponent (project owner) constructs or installs facilities or equipment but the project owner and system owner shall continue periodical monitoring of the system and management and give feedback of the monitoring result to the management organization. Additionally, overall result of evaluation and lessons from the implementation shall be utilized in policies, strategies and planning of next generation.

Table 3.3.2 Tasks of Key Stakeholders at each Project Stage

Time stage	Institution	Tasks
Project planning	REA	a) monitors and collects data of nationwide electrification condition of public facilities b) makes implementation plan c) makes budget for implementation or finding fund source d) budget appropriation and execution of initial investment
Preparation	REA	a) executes baseline survey to collect basic social and economic conditions of neighbourhood community as well as the condition of the target facility b) applies the result for designing the system and O&M structure c) holds stakeholders meetings with concerned government officers and target facilities
	MoH	a) provides information of un-electrified dispensaries to REA for selection of targets and designing b) shares information on the electrification plan with REA c) starts budgeting for equipment replacement d) gets technical staff trained
	Facility MC	a) provides information of actual situation of the facility and social and economic condition of neighbourhood community b) shares information of electrification by solar PV among MC members as well as with community people
	Others	<JKUAT> a) gives technical training to MoH officers
Installation of PV system	REA	a) makes design of each facility using the data of baseline survey b) prepares bidding document including an article stipulating technical training to system users by contractor c) selects the contractor d) holds stakeholders meeting with concerned government officers on the project details and O&M cost after handover e) holds stakeholders meetings with facility staff members and MC members about the details of PV system and installation schedule f) supervises installation activities by the contractor and conducts inspection g) holds stakeholders meeting together with MoH officers and facility MC to explain necessary O&M system and charging service h) gives accounting training to MC members i) confirms responsibility of MoH for O&M and financing to maintain the PV system during the life time of solar panels and signs MOU j) hands over the ownership of solar PV system to MoH after the signature on MOU
	MoH	a) understands the details of electrification of dispensaries by solar PV system b) nominates an officer at county offices to manage the electricity use c) makes annual budget for O&M (especially equipment replacement) and submits it to the Treasury d) (gets technical staff trained)

Time stage	Institution	Tasks
	Facility & MC members	a) attend stakeholders meetings b) share the information of electrification by solar PV and charging service among members and inform it to neighbourhood communities c) select an operator from employees of the facility d) formulate a by-law regarding the O&M of the PV system and management of charging service (including service time, unit price) e) receive technical training given by contractor and financial training given by REA
Handover of ownership to MoH	REA	a) concludes the MOU with MoH that stipulates responsibility of MoH for supervision of O&M and budget for replacement of equipment b) holds stakeholders meeting at the facility to ensure the responsibility of MC for daily O&M and charging service c) gives technical and managerial advices to MoH
	MoH (county)	a) concludes the MOU with REA that stipulates responsibility of MoH for supervision of O&M and preparation of budget for replacement of equipment b) appoints one or two officers at county level to support MCs in O&M and management
	Facility & MC members	a) confirm the tasks of chairperson, secretary, treasurer and operator for the O&M and charging service
Use of solar PV system	REA	a) gives technical advices to MoH b) collects market price of batteries, inverters and charge controllers and inform it to MoH in order for the ministry to make budget for replacement
	MoH (county)	a) examines monthly report submitted by facilities to understand the condition of solar PV system and charging service b) dispatches technical officer to each facility to check the condition of solar PV system and takes action if he/she finds problems c) takes action if the system has trouble by calling mechanics d) makes budget for replacement of batteries, inverters and charge controllers according to the cash flow model in the guideline e) purchases and replaces batteries, inverters and charge controllers with new ones at the end of lifetime of each equipment
	Facility & MC members	a) conduct O&M as trained b) provide charging service as trained and advertise it to the neighbourhood community c) make monthly O&M report to submit to the county MoH office d) include the financial status of the charging service into the facility monthly report and submit it to the county MoH office e) take action when the system has trouble f) treat e-wastes as stipulated in the Kenyan regulation when the lifetime of electric devices and equipment ends
End of lifetime of solar panels	REA	a) prepares a new electrification plan to ensure electricity to the concerned facilities b) makes budget

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3.4 Tasks of REA

3.4.1 Project Planning Stage

REA shall make the implementation plan for electrification of particular public facilities by solar PV system. For this, they shall continuously monitor the nationwide electrification situation of public facilities and collect the latest electrification data. They set the criteria for selection of priority facilities.

After selection of the target facilities, REA shall start making budget estimate for implementation and request to the government. If there is a fund from other institutions or donors, REA starts getting approval to use it. REA also needs to prepare a plan of operation.

3.4.2 Preparation Stage

(1) Execution of Baseline Survey

The purpose of the baseline survey is to collect basic social and economic conditions of neighbourhood community as well as the condition of the target facility. REA shall apply the result to design the system and O&M structure. Social and economic condition of neighbourhood community is the basis of managerial and financial capability at facility level, and is also used for the feasibility study of the charging service. REA staff members in the special field of social development or subcontractor in this field goes to the site and conducts interview survey using the questionnaire sheet.

An example of the questionnaire is attached in Annex 2-2.

(2) Information sharing with Relevant Local Government

REA shall meet relevant local government officers, that is, county MoH officers, at least once before planning. It aims at reducing information gap between them at the beginning. Both sides exchange information and reach agreement regarding electrification of public facilities by solar PV system. REA explains technical specification of electrification by solar PV system, financial plan and O&M model as well as implementation schedule. County officers explain the current condition of target facilities and both sides to reach agreement on installation and demarcation of responsibilities.

(3) Stakeholders meeting with facility and management committee

To raise awareness of facility staff and MC members and strengthen their attitude toward solar PV system management, REA, together with officers of county MoH, should have stakeholders meeting before the implementation and before commencement of system use. REA staff visit facilities and meet stakeholders of the target facility. The key participants are members of dispensary management committee (MC) and nurse (secretary of MC), local authority (chief, assistant chief), elders and normal inhabitants of neighbourhood communities.

The main topics of the first meeting are:

- System design
- Role demarcation, especially roles of MC (refer to the O&M model)
- Agreement from stakeholders about the responsibility for O&M and management of solar PV system
- Installation schedule including trainings

The most important matter is that the stakeholders understand their role as being in charge of O&M management. They do operation, maintenance, charging service and reporting. Also they conduct charging service to generate income for daily expenditure for the solar PV system management.

REA also explains the activities that MC should do prior to the commencement of system use. MC shall prepare the following:

- By-law formulation prescribing rules of solar PV use and protectionn, which is a written regulation of power provision, service, service time, unit charging price, person in charge of service attendant etc.
- Fixing of tariff for charging business
- Selection of operator and determination of his/her salary

3.4.3 Installation Stage

(1) Designing

See the technical section of the guideline

(2) Bidding

See the technical section of the guideline

(3) Selection of Contractor

See the technical section of the guideline

(4) Stakeholders Meeting (1st)

a) Information sharing with officers of concerned government offices

This is the second information sharing meeting between REA and county officers of MoH. It aims at confirming the responsibility of MoH after handover, for the sustainable system management in terms of technical and financial preparation and supervision of the management by MC. It is expected that REA explains the MOU concerning the roles and responsibilities of REA and MoH and both sides agree to it at this meeting.

b) Stakeholders meeting with target facilities (2nd)

REA, together with the county MoH officers, hold the second stakeholders meeting just before the commencement of the system. It aims that the facility staff and MC members understand to take responsibility of daily system management, conduct charging service, and report to the county office. REA explains to them about these roles and responsibilities and also explains ways of solving technical troubles. REA also explains again the activities that MC should do prior to the commencement of system use and confirms if MC is ready to start management.

(5) Supervision of System Installation

See the technical section of the guideline

(6) Training

a) Technical training

As mentioned in the technical section of the guideline, suppliers that REA contracts with gives technical training to the facility staff members and MC members. They get from this training at least knowledge about the solar PV power generation and system structure, as well as the basic measures to deal with system troubles.

b) Financial training

As mentioned in the financial section of the guideline, REA staff (or subcontractor) gives financial training to the facility staff, MC members, and operator. The training aims that (i) MC and operator record daily income from charging service and expenditure for repair and purchase of small equipment, and (ii) they make monthly report of balance sheet to submit to the county MoH office. The training includes procedure of service provision and money collection on daily basis, recording of sales, making daily report and monthly report.

3.4.4 Handover

(1) Conclusion of MOU

It is indispensable to clarify roles and undertakings on the electrification of health institutions by solar PV to ensure the sustainable use of the systems. Generally REA's duty is construction or installation of solar PV system and does not cover O&M and replacement after the handover to the owner (MoH in this case). On the other hand, MoH does not have enough experience in O&M and replacement of solar PV system equipment. Thus, it is indispensable that these stakeholders share information about it to demarcate roles and undertakings of each side as a prerequisite of handover. As of the end of November 2014, REA and HQs of MoH are under discussion for such an MOU and REA is reaching consensus with MoH.

The important items prescribed in the draft MOU are that REA updates the list of un-electrified facilities, decide priority of electrification, designing, installation and monitoring. On the other hand, MoH compiles un-electrified institutions to share with REA. MoH facilitates the agreement between REA and county offices on the responsibilities, supports county offices in proper O&M including budget allocation, and introduces county offices to the available trainings.

(2) Stakeholders meeting with target facilities

REA, together with the county MoH officers, hold the second stakeholders meeting just before the commencement of the system. It aims that the facility staff and MC members understand to take responsibility of daily system management, conduct charging service, and report to the county office. REA explains to them about these roles and responsibilities and also explains ways of solving technical troubles. REA also explains again the activities that MC should do prior to the commencement of system use and confirms if MC is ready to start management. REA also explains e-Waste management (refer to the section for environmental and social considerations).

3.4.5 Use Period

(1) Technical and Managerial Advices to MoH

REA supports and gives advices to MoH on the technical issues on O&M. It is obvious that the technically proper supervision and support as well as timely and appropriate budget disbursement for equipment replacement are indispensable for sustainable system use. The owner shall be capable for conducting these matters. As staff members of MoH are not the experts of technical issues of solar PV system, REA shall mediate training opportunities. Technical staff from MoH can get training on solar PV system prepared by JKUAT. In addition, REA shall give advices to MoH about the specification of necessary equipment (batteries, inverters, charge controllers and so on) and market price of the year that REA uses for their installation project to facilitate budget making by the ministry.

(2) Monitoring of Use Condition

Periodical monitoring on the condition of solar PV system and the charging service shall be done by the county offices. In case technical advices are requested, REA will respond quickly.

(3) Update of Database of Electrified /Un-electrified Areas in Kenya

The situation of electrification and un-electrified public institutions changes rapidly in Kenya. REA shall periodically update the list of un-electrified area and institutions in collaboration with MOE&P, and MoH. Without the latest information of this kind, REA will not make plans of electrification by solar PV system to new institutions. The data shall be shared among officers in REA and, if requested, disclosed to other stakeholders and donor organizations.

(4) Support to MoH in Cost Estimate and Budget Making

REA shall support MoH when the county offices prepare budget for replacement of main equipment by:

- advising and discussing with county offices for technical and financial issues of installed solar PV systems
- advising and discussing with county offices to assist their budget proposals for equipment replacement for installed solar PV, especially specification of the equipment, market price and information of supplier (latest cost information of equipment replacements of solar PV)

3.4.6 End of Life Time of Solar PV Panels

(1) Preparation for renewal of the whole system including PV panels

REA shall prepare new electrification plan for the target institutions. As the lifetime of PV panels is twenty years by standard, REA will prepare budget to replace them. The grid electricity line will be extended to many of the remote areas in 20 years and the number of un-electrified public facilities will be reduced. To make the electrification plan for the short term, REA shall update the list of un-electrified public facilities constantly.

3.5 County Offices of MoH

County offices of MoH are the administrators of dispensaries and the owner of installed solar PV systems. Their main roles are to keep the system condition well and to prepare appropriate O&M budget for especially the equipment replacement expenditure.

3.5.1 Preparation Stage

(1) Information sharing with REA

a) Information of un-electrified dispensaries (to REA)

County offices with support from Sub-county offices have the concrete data of un-electrified facilities.

b) Information of electrification plan (from REA)

REA informs the county offices of the implementation plan for solar PV system. County offices of MoH shall supervise management committee in O&M and management of solar PV system. They start to make budget in support of the facility.

(2) Training of technical staff on solar PV system

There are several training courses on solar PV system at JKUAT. It is recommended to send technical officers and staff to the course so that they are equipped with basic knowledge and skills on this subject. After coming back from the training, these officers and staff will support facilities having solar PV system: they check the monthly O&M reports to check the condition of the solar PV systems and give advices and respond to the calls from facilities.

3.5.2 Installation Stage

(1) Establishment of management system for the solar PV system

MoH together with REA hold stakeholders meetings in which they explain to the facility staff and management members on the necessity of establishment of a management system. They also explain the roles of the management body: it is expected that the dispensary management will take responsibility for overall management of the PV system including O&M, purchase of distilled water, bulbs and other repair costs.

3.5.3 Handover

(1) Conclusion of MOU

Before official handover of the solar PV system from REA to MoH, both organizations shall conclude on an MOU regarding the responsibilities of technical and financial administration.

3.5.4 Use Period

While REA continuously updates the list of un-electrified facilities, makes the implementation plan and installs solar PV systems to dispensaries, MoH shall collect information of these facilities, examine the O&M report and financial report submitted from the facilities having solar PV system to understand the current condition of the system and charging service business, and make budget for replacement and O&M costs that the facility cannot afford.

(1) Examination of monthly reports from dispensaries

MoH must supervise the O&M and management activities of the solar PV system installed at the facilities under their supervision in terms of technical and financial status. They understand the system condition by examining monthly O&M reports submitted by the facility, and check if the systems are in good condition and water level is constantly checked or not. They also understand the amount of money collected from charging service.

(2) Biannual site observation and monitoring

It is important that the installed solar PV system functions as long as their life time by proper operation and maintenance. The technical officers who got training on solar PV system visit the public facilities at least twice in a year. They check the condition of the power generation system and give instructions and advices to the management committee members and the operator at each site.

In addition to this site inspection, these officers monitor the O&M and financial reports attached to the regular monthly reports that facilities submit and understand system condition as well as financial state. If there are technical problems they give instructions and, in case of system failure or any large repairs, prepare the budget for repair and/or call the supplier. Refer to the example of monitoring sheet in Annex 2-2.

County officers shall also instruct facility staff and management committee members on the e-waste management (For details, refer to Chapter 5). The point is that facilities cannot dispose equipment such as batteries or bulbs after their lifetime comes to end but return to the certified companies. Practically, they request suppliers who bring new equipment to the facilities to take away these used ones. As the suppliers can sell the used equipment to certified companies, management committee can receive a certain amount of income from suppliers.

(3) Making annual budget for O&M and equipment replacement

County offices shall prepare the upcoming replacement of batteries, inverters, and charge controllers.

(a) They calculate the long-term cost projection of daily O&M and replacement of batteries, inverters and charge controllers for 20 years. This is the life time of solar PV panels in accordance with the implementation plan of the nationwide program (refer to the financial section of the guideline).

(b) They make budget proposals for equipment replacement for installed solar PV system and submit to the county treasury.

3.5.5 End of Life Time of Solar PV Panels

Before the lifetime of solar PV panels come to the end (after about twenty years after installation), county offices of MoH shall discuss with REA about the future energy plan of the area and request the next cycle of electrification by solar PV system.

3.6 Headquarters of MoH

After decentralization, ministry headquarters have become policy maker instead of policy implementer. Their roles are to collect electrification status of dispensaries and inform the data to REA. They discuss with REA the countrywide plan of installation of solar PV system in the coming years. When the plan is approved, headquarters shall make cost estimates and cash flow for the O&M of the system and requests to the national treasury.

3.7 Public Facilities and Management Committees

Dispensaries and their management committees have responsibility.

Each public facility equipped with solar PV system is responsible for daily O&M and reporting to the ministry through the county office. The responsible personnel are dispensary staff and dispensary management committee. They manage charging service, conduct O&M and financial management including cash management, recording of system condition and financial status, and report to the county office.

Responsibility & Roles

a) To operate and manage charging service
b) To manage O&M and financial management for daily works
c) To record daily activities
d) To prepare monthly reports on O&M and financial management to the county office of MoH
e) To inform any problems to the county office

CHAPTER 4 FINANCIAL SYSTEM

4.1 Introduction

According to the experience of the pilot projects, the public funding for both initial and recurrent expenditure is absolutely imperative to ensure sustainable use of solar PV systems in public facilities of dispensaries in un-electrified rural areas. In addition to daily O&M expenses, solar PV systems normally require replacement expenditure for major equipment every five to seven years throughout the average system lifetime of 20 years. These costs greatly increase the required revenue from charging service and the deficit must be covered by the public funding.

The purpose of the financial section of the guideline is to facilitate all the executing agencies, facility owners, concerned stakeholders to prepare and provide the necessary funding for O&M and replacement of equipment for the solar PV systems for the long run.

These guidelines include the introduction of the financial model to provide methodology to estimate the required public funding from the government budget as well as the commercial revenue of each facility.

Besides REA and MOE&P, this financial section is expected to provide necessary information to other stakeholders, i.e. MoH as well as their county offices, as owners of solar PV systems in dispensaries. The section is also useful for those who are at dispensaries as beneficiaries and local managers of the solar PV system in the rural areas.

4.2 Roles and Responsibilities of Agencies and Stakeholders

Table 4.2.1 summarizes the roles and responsibilities of agencies and stakeholders in financial management of solar PV projects for dispensaries.

Table 4.2.1 Roles and Responsibilities by Project Stage

Project Stage	Major Role	Agency or Stakeholder	Financial Management Task
Initial Investment	National-level Programming and Installment of Solar PV Systems	**REA**	- **Budget appropriation & execution for Initial Investment** - Monitoring and data collection of nationwide implementation
Operation & Maintenance (O&M)	Technical Assistance on O&M and replacements	**REA**	- **Technical assistance** on overall O&M and replacements including provision of cost reference and updated price data - Monitoring of nationwide operational status
	National-level Financial Management	**MoH**	- National-level mid- and long-term projection for recurrent expenditure, especially replacement costs - **Ensure replacement cost budget is allocated** to responsible County Office
	County-level Financial Management	**County Health Office**	- **Budget appropriation for daily O&M and replacement cost** for each solar PV facility in the county - Project monitoring
	Facility-level Daily O&M and Financial Management of Solar PV System	**Dispensary**	- **Daily O&M** of solar PV system - Reporting to County Office on the financial state - Commercial operation of charging service

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4.3 Financial Model

The financial model is designed to provide preliminary cost estimation of initial and O&M cost as well as the revenue from charging service of the solar PV system for each project component that concerned stakeholders are responsible for. It also illustrates the methodology and information source that the concerned stakeholders should refer to when formulating their own budget proposal and planning upon implementation of a solar PV project.

The costs and revenue values in this section are estimates as of year 2014 based on the contract prices of the existing pilot projects. The values are all expressed in the 2014 constant price unless otherwise indicated. It should be noted that, since those values may change over time for many reasons, they are subject to further revision at the time of preparing each budget proposal or expenditure plan for solar PV projects. The revision should be based on the latest cost information to be collected by REA such as recent monitoring results of on-going projects, etc.

(1) Cost Components and Responsible Agency/Stakeholders

Cost components of a solar PV system consist of (i) initial cost, (ii) recurrent operation expenses, and (iii) replacement cost. Table 4.3.1 summarizes the major items and responsible agency/stakeholder for each component.

Table 4.3.1 Cost Components of Solar PV System

Cost Component		**Responsible Agency/ Stakeholders**	**Funding Source**
Initial Investment		**REA**	- REA Budget (and/or Donor finance)
Operation & Maintenance (O&M)	Recurrent Operation Expenses	**Dispensary Management Committee**	- **Charging Service Revenue** - Operational Budget allocated by County Health Office (or Dispensary Management Committee)
	Replacement Cost - Battery - Charge Controller - Inverter	**County Health Office**	- County Health Office Budget

Prepared by JET

Initial investment will be borne by REA and the investment cost will be determined based on required PV system scale. The installed solar systems require daily operations and maintenance work by certain specific persons, i.e. operators at expense of dispensaries along with other daily expenses which the management committee of each facility is primarily responsible for. The main system components i.e. batteries, inverters and charge controllers, are to be replaced at the end of each lifespan; i.e. batteries are to be replaced every five years, inverters/ charge controllers are to be replaced every seven years over the project lifetime of 20 years. It is envisaged that these replacement costs are borne by County Health Office (MoH) budget for dispensaries.

(2) Charging Service Revenue

In order to support O&M cost required for sustainable use of solar PV systems, some of dispensaries are to be equipped with the solar charging system for charging services of mobile phones, lanterns, etc. depending on the number of potential customers. The charging service is a revenue-generating operation that provides electricity for mobile phones and other devices at unit price of KSh. 20 (approx. US cent 24 as of November 2014) per time, for instance, for customers coming from communities nearby. The collected fee is saved for expenses of daily operation and consumables of the solar systems such as distilled water, stationery for accounting, transportation and so on. However, as seen in the sample cash flow projection prepared in Table 4.3.7 provided at the end of 4.3, it is projected that most part of the operational expenses will be far beyond the charging service revenue, even with funding allocation from the existing public budget for the facility operation. Such deficit from daily operation must be covered by additional budget allocation.

(3) Cost Estimation

Costs estimation of solar PV systems consists of three components: (i) estimation of PV system scale, (ii) initial cost estimation and (iii) O&M cost estimation.

Based on the information of the target facility, the required PV system scale (capacity and number of equipment) is estimated which determines factors to estimate initial and O&M costs. Necessity and size of charging service system should be determined by information on the surrounding area, demand among residents, mobile signal coverage, etc.

Figure 4.3.1 illustrates the conceptual flow of cost estimation for solar PV projects.

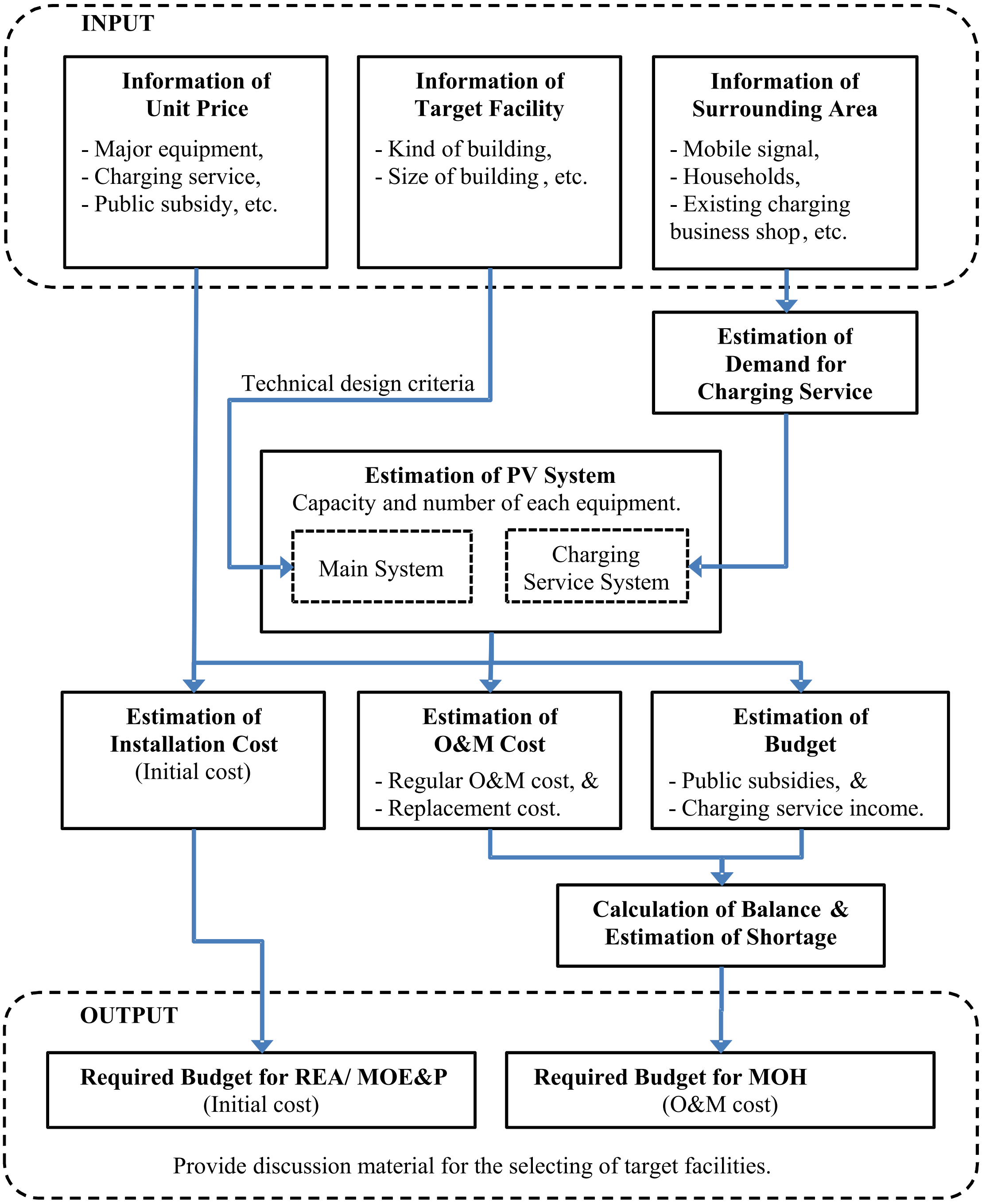

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Figure 4.3.1 Conceptual Diagram of Financial Model of PV Systems

a) PV System Scale [REA]

The PV system scale required for each facility depends on its electricity demand which is determined by number and type of rooms in its buildings. Once the demand is estimated, the suitable power package is chosen from lighting model (PP0, PP1 and PP2) and charging model.

Table 4.3.2 shows unit power demand by room type and Table 4.3.3 presents suitable power package by estimated power demand.

Table 4.3.2 Estimated Unit Power Demand of Dispensary

No.	Room Type	Unit Power Demand (Wh/day)
Dispensary		
D1.	Main building	650
D2.	Sub-building (max. 2 rooms)	300
D3.	Staff quarter (max. 2 rooms) + TV	600
D4.	Kitchen	100
D5.	Store	50
D6.	Security (10 W x11hrs) for each building	110

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Table 4.3.3 Suitable Power Package by Power Demand

No.	Unit Power Demand (Wh/day)	Power Package (cf. Table 4.3.4)
PD1	~ 350	PP0
PD2	~ 700	PP1
PD3	~ 1,400	PP2
PD4	~ 700	Charging Model

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Example: Power Package Selection for Dispensary

One building in a dispensary with one main room and one store room

- Power demand (P) = 500 Wh/day x 1 main room + 100 Wh/day x 1 store room
  = 600 Wh/day

Power package: 1 unit of PP1 (~ 700 Wh/day)

For charging model, unit power demand is estimated to be 700 Wh/day. This was assumed on the basis of number of 20 mobile phones and 20 LED lanterns each day. In general, one package of charging model would be sufficient to cover demand of mobile charging and other small power usages in a facility in rural area. In case that more customers are expected than the assumption, the number of charging models should be increased.

b) Initial Cost [REA]

The initial cost of PV system is estimated by the following formula:

$$P_{IC} = P_1 + P_2 + P_3 + P_4$$
$$P_2 = P_1 \times 0.25$$
$$P_3 = 130{,}000$$
$$P_4 = (P_1 + P_2 + P_3) \times 0.3$$

Where, P_{IC}: initial cost of PV system
P_1: costs of procurement and installation of major equipment
P_2: costs of procurement and installation of other devices (25% of P_1)
P_3: costs of construction of charging house = KSh. 130,000
P_4: commission charges
(30% of above for dispensaries)

The costs of major equipment of PV system (P_1) are estimated by required number of units of power package and unit price. The required units of each power package are estimated as mentioned above, and unit prices of major equipments in each power package are estimated as in Table 4.3.4.

Table 4.3.4 Estimated Unit Price of Major Equipment in each Power Package

Major Equipment	Lighting Model			Charging Model
	PP0	PP1	PP2	
1. Solar module (120 W)	12,000 (1 unit)	24,000 (2 units)	48,000 (4 units)	24,000 (2 units)
2. Roof mounting structure	1,800	3,500	7,000	3,500
3. Isolator	5,000	5,000	5,000	5,000
4. Charging controller	9,000	9,000	11,000	11,000
5. Battery	19,000 (1 unit)	38,000 (2 units)	54,000 (2 units)	19,000 (1 unit)
6. Inverter	25,000	25,000	35,000	25,000
7. DC fuse/breaker	9,200	9,200	9,200	9,200
8. Consumer units	8,500	8,500	8,500	8,500
Total	89,400	122,100	177,600	105,100

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The cost of other devices (P_2), such as cables, LED, switches, boxes, sockets, security light, maintenance tool box, etc. are estimated to be 25% of the amount of major equipment.

The cost of charging house (P_3) is estimated to be KSh. 130,000/unit.

The commission charges are estimated to be 30% of the total of, P_1, P_2, and P_3.

c) O&M Costs [Dispensary and County Health Office/]

The O&M costs of PV system consist of daily operation costs and replacement costs of major equipment.

Daily Operation Expenses [Dispensary]

The daily operation expenses include distilled water, consumables, transportation, etc and salary of operator if it is paid from the proceeds of the charging service[4]. It is learnt from the

[4] As the portion of salary is relatively high, it is proposed to the facilities to pay operator's salary from their budget by assigning one of their subordinates to work for O&M. However, as the assigned subordinate cannot provide his/her full working time for O&M and charging business, a trade-off between reduction of salary and reduction of income is observed.

pilot projects that the most important expenditure is purchase of distilled water and repair of hair clippers.

They are estimated by the following formula based on the monitoring results of the pilot projects.

$$P_{OM} = 1{,}000 + 100 \times N_{BT}$$

Where, P_{OM}: daily operation expenses (KSh./month)
N_{BT}: number of battery (nos.)

Replacement of Major Equipment [County Health Office]

The major equipment to be replaced during the system life are (i) battery, (ii) charge controller and (iii) inverter. The replacement costs are estimated as follows;

$$P_{RP} = P_1 + P_2$$

Where, P_{RP}: Replacement costs of major equipment
P_1: Cost of procurement and installation of major equipment
P_2: Commission charges (40% of P_1)

Expected lifetime and unit price of major equipment are estimated as shown in Table 4.3.5.

The expected lifetime of equipment is assumed to be five years for battery and seven years for inverter and charge controller on average under proper maintenance and operational conditions. Actual replacement needs depend on the quality of daily maintenance work by operators. The lifetime of equipment may be longer than expected if operators take adequate care; however, poor maintenance work may damage the equipment and lead to earlier replacement.

Table 4.3.5 Estimated Life and Unit Price of Major Equipment

Major Equipment	Capacity	Unit Price (KSh./unit)	Equipment Life
Battery			
For lighting model of PP0, 12 V	100 Ah	19,000	5 years
For lighting model of PP1, 12 V x 2 = 24 V	100 Ah	38,000	
For lighting model of PP2, 12 V x 4 = 48 V	200 Ah	54,000	
For charging model, 12 V	100 Ah	19,000	
Charge Controller			
For lighting model of PP0, 12 V	10 A	9,000	7 years
For lighting model of PP1, 12 V x 2 = 24 V	10 A	9,000	
For lighting model of PP2, 12 V x 4 = 48 V	20 A	11,000	
For charging model, 12 V	20 A	11,000	
Inverter			
For lighting model of PP0, 12 V	300 W	25,000	7 years
For lighting model of PP1, 12 V x 2 = 24 V	300 W	25,000	
For lighting model of PP2, 12 V x 4 = 48 V	400 W	35,000	
For charging model, 12 V	300 W	25,000	

Prepared by JET

The replacement cost is estimated by unit price and number of major equipment as well as the commission charge of 40% based on the experience of the pilot projects.

(4) Estimation of Charging Service Revenue [Dispensary]

Demand and revenue for charging service depends on the surrounding conditions of the target facility such as population and type of neighbourhood community. Based on the monitoring results of the pilot projects, the charging service revenue is estimated for four cases (See Table 4.3.6).

Table 4.3.6 Estimated Charging Service Revenue

	Household within 5 km	Village Type	Monthly Revenue (KSh./month)
Case 1	More than 50 HHs	Concentrated or having core area	2,000
Case 2	More than 50 HHs	Dispersed	1,000
Case 3	50 HHs and less than 50 HHs	Concentrated or having core area	1,000
Case 4	50 HHs and less than 50 HHs	Dispersed	1,000

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(5) Sample Case of Dispensary

This sample case describes financial model of a typical solar PV system for dispensary. It is assumed that this dispensary has three buildings in layout shown in Figure 4.3.2.

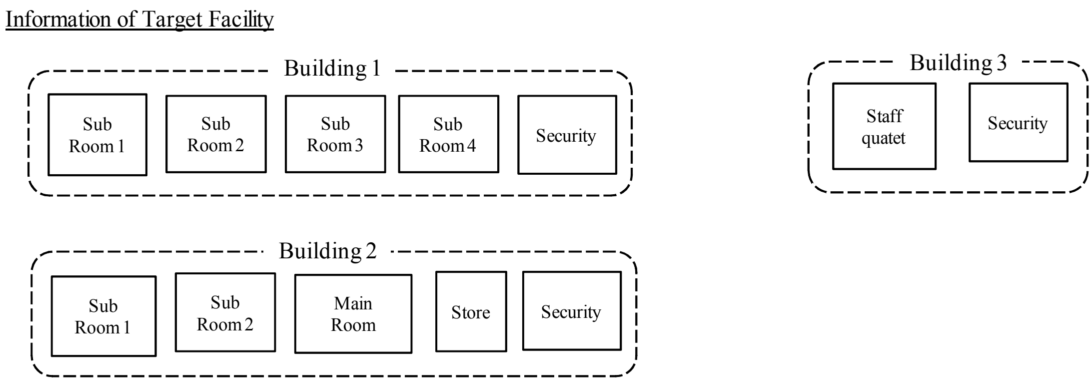

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Figure 4.3.2 Sample Target Facility (Dispensary)

a) Size of Buildings and Power Demand:

Building 1: Sub-building (1,200 Wh/day) + Security (110 Wh/day) = 1,310 Wh/day

Building 2: Main building (650 Wh/day) + Sub-building (600 Wh/day) + Security (110 Wh/day) = 1,410 Wh/day

Building 3: Staff quarter + TV (600 Wh/day) + Security (110 Wh/day) = 710 Wh/day

b) Power Packages & Initial Cost

PP0: KSh. 89,400 x 1 = KSh. 89,400

PP2: KSh. 177,600 x 3 = KSh. 532,800

Charging Model: = KSh. 105,100

P1: Initial Cost (Total) = KSh. 727,300

P2: Cables, switches, etc. = 25% of Initial Cost = KSh. 181,125

P3: Cost of charging house = KSh. 130,000

P4: Commission charge = (P1+P2+P3) x 30% = KSh. 311,738

P_{IC} = P1+P2+P3+P4 = KSh. 1,350,863 = KSh. 1,360,000

c) O&M Costs

Regular Operation (Daily operation)

$$P_{OM} = 1{,}000 + 100 \times N_{BT}$$

Where, P_{OM}: daily operation expenses (KSh./month)

N_{BT}: number of battery (nos.)

Estimation of O&M Costs

Number of Battery

	PP2	PP1	PP0	Charge	Total
Number of Power Package	3	0	1	1	
Unit number per power package	4	2	1	1	
	12	0	1	1	14

P_{OM} 2,400 (KSh./month) = 1,000+ 100 x 14

28,800 (KSh./year)

Replacement Costs

Estimation of Replacement Costs

	PP2	PP1	PP0	Charging	Total
1 Number of Equipment					
Battery	3	0	1	1	5
Charging Controller	3	0	1	1	5
Inverter	3	0	1	1	5
2 Unit Price of Equipment					
Battery	54,000	38,000	19,000	19,000	
Charging Controller	11,000	9,000	9,000	11,000	
Inverter	35,000	25,000	25,000	25,000	
3 Amount of Equipment					
Battery	162,000	0	19,000	19,000	200,000
Charging Controller	33,000	0	9,000	11,000	53,000
Inverter	105,000	0	25,000	25,000	155,000
					408,000 (KSh.)

$$P_{RP} = P_1 + P_2$$

Where, PRP: Replacement costs of major equipment

P1: Costs of procurement and installation of major equipment

P2: Commission charges (40% of above)

Replacement Costs of Battery

P_{RP1} = 200,000+ 200,000 x 40% = 280,000 (KSh.) **280,000** (KSh.)

Replacement Costs of Charging Controller and Inverter

P_{RP2} = 53,000+ 53,000 x 40% = 74,200 (KSh.) **75,000** (KSh.)

P_{RP3} = 155,000+ 155,000 x 40% = 217,000 (KSh.) **217,000** (KSh.)

d) Existing Budget for Regular Operation

It is assumed that there is no existing budget available in the dispensaries for regular operation.

e) Revenue from Charging Service

Demand for charging service is subject to the location and type of neighbourhood community. It is assumed that the surrounding households are less than 50 and the village is dispersed. In the said case the monthly revenue is estimated to be only KSh. 1,000 per month.

f) Cash Flow Projection

Table 4.3.7 shows the cash flow projection based on the assumptions of the sample case of dispensary. The projection is expressed in 2014 constant price. The annual deficit from regular operation (difference of charging service revenue and regular operation expenses) amounts at KSh.16,800 which will be borne by the dispensary. During the system lifetime of 20 years, County Health Office must allocate KSh. 1,424,000 in total for the budget for major replacements.

Table 4.3.7 Cash Flow by Financial Model (Dispensary)

Year	Initial Cost	O&M Cost (KSh)					Revenue (KSh)			Balance (KSh)		**Required Budget Allocation (KSh)**		
		Regular Operation (Local Cost)	Major Replacement: Battery (Foreign Cost)	Major Replacement: Inverter (Foreign Cost)	Major Replacement: CC (Foreign Cost)	Sub-total (1)	Existing Budget (Local)	Charging Service (Local)	Sub-total (2)	Per Year	Accumlation	Initial Cost **REA**	Reguar Operation **Dispensary**	Major Maintennace **County Health**
		(a)	(b)	(c)	(d)	(e) =	(f)	(g)	(h) = (f)+(g)	(i) = (h)-(e)	(j) = Σ (i)	(k)	(l) = (a) - (h)	(m) =
0	1,360,000											1,360,000		
1		28,800				28,800	0	12,000	12,000	-16,800	-16,800	0	16,800	0
2		28,800				28,800	0	12,000	12,000	-16,800	-33,600	0	16,800	0
3		28,800				28,800	0	12,000	12,000	-16,800	-50,400	0	16,800	0
4		28,800				28,800	0	12,000	12,000	-16,800	-67,200	0	16,800	0
5		28,800	280,000			308,800	0	12,000	12,000	-296,800	-364,000	0	16,800	280,000
6		28,800				28,800	0	12,000	12,000	-16,800	-380,800	0	16,800	0
7		28,800		217,000	75,000	320,800	0	12,000	12,000	-308,800	-689,600	0	16,800	292,000
8		28,800				28,800	0	12,000	12,000	-16,800	-706,400	0	16,800	0
9		28,800				28,800	0	12,000	12,000	-16,800	-723,200	0	16,800	0
10		28,800	280,000			308,800	0	12,000	12,000	-296,800	-1,020,000	0	16,800	280,000
11		28,800				28,800	0	12,000	12,000	-16,800	-1,036,800	0	16,800	0
12		28,800				28,800	0	12,000	12,000	-16,800	-1,053,600	0	16,800	0
13		28,800				28,800	0	12,000	12,000	-16,800	-1,070,400	0	16,800	0
14		28,800		217,000	75,000	320,800	0	12,000	12,000	-308,800	-1,379,200	0	16,800	292,000
15		28,800	280,000			308,800	0	12,000	12,000	-296,800	-1,676,000	0	16,800	280,000
16		28,800				28,800	0	12,000	12,000	-16,800	-1,692,800	0	16,800	0
17		28,800				28,800	0	12,000	12,000	-16,800	-1,709,600	0	16,800	0
18		28,800				28,800	0	12,000	12,000	-16,800	-1,726,400	0	16,800	0
19		28,800				28,800	0	12,000	12,000	-16,800	-1,743,200	0	16,800	0
20		28,800				28,800	0	12,000	12,000	-16,800	-1,760,000	0	16,800	0
Total	1,360,000	576,000	840,000	434,000	150,000	2,000,000	0	240,000	240,000	1,760,000	-	1,360,000	336,000	1,424,000
Annual Avg.	-	28,800	42,000	21,700	7,500	100,000	0	12,000	12,000	88,000	-	-	16,800	71,200

Prepared by JET

4.4 Salient Points in Financial Management

4.4.1 Nationwide Program and Mid- and Long-term Expenditure Plan

As seen in 4.3, it is obvious that solar PV projects will not generate sufficient income to even cover the daily operation expenses. Also, timely reinvestment in major replacements is inevitable to ensure sustainable operation in the long run. Therefore, when REA prepares the forthcoming nationwide program of solar PV development, it is strongly recommended that comprehensive mid- and long-term expenditure plan should be included to advise all the concerned agencies and stakeholders on their fiscal requirement derived from implementation of the program. For this purpose, the cash flow projection presented in the financial model may be utilized as a rule of thumb; however, it is recommended to estimate the O&M costs of every solar project based on actual data for more precise projection.

4.4.2 Price Data for O&M Cost

The unit prices used in this financial section are all estimated from the monitoring results of the pilot projects. Prices change over time for many reasons e.g. inflation, technology advancement, demand-supply balance, etc. especially for solar PV system. Charging service unit rate, therefore, must be adjusted to a competitive level among similar service providers in project area.

Therefore, for the annual budget proposal and allocation of O&M and replacement costs, the responsible agencies/ stakeholders should refer to the latest available data such as:

- ✓ The actual costs in the previous year;
- ✓ Price quotations from suppliers/ contractors; and
- ✓ Actual O&M costs of other operating systems

For this purpose, REA should closely monitor the operational status of the systems installed and gather price information in consultation with the system users as well as other stakeholders such as suppliers.

MoH and County Offices should use the updated data prepared by REA to formulate annual budget for replacements and subsidy for daily O&M throughout the operation period.

4.4.3 Cash Flow Projection

The cash flow projection (Table 4.3.7) is also based on the price data of the pilot projects and expressed in year 2014 constant price because there is great uncertainty in price escalation and exchange rates in such a long-term perspective as 20 years. As stated above, the stakeholders should use the latest price information by REA when updating their mid-term projections. The cash flow projection with price escalation is presented as per Annex 3-1 for further reference.

4.4.4 Planning and Budgeting

(1) Annual Plan

The county offices are responsible for planning and budgeting of electrification of facilities under their supervision. They should have both mid-term and annual plans for anticipated revenue and expenditure of its PV systems which should be revised every year. Revenue is generated from charging service operation while expenditure is for operation, maintenance, and major replacements of the PV systems. The financial model should be utilized to identify and understand the O&M cost items and charging service revenue (See Section 4.3). For actual cost estimation, however, it is proposed that REA will keep updating the latest price information from on-going projects, which the ministry county offices may refer to (See 4.3 (5)).

(2) Regular Operation Costs (See 4.3 (5))

Regular operation cost includes recurrent cost items for PV system operation such as distilled water, bulbs, small repairs, transportation, allowance for operator, bank charges, etc.

(3) Major Replacement Costs (See 4.3 (5))

Batteries, inverters and controllers are required to be replaced every five to seven years (after an average use of seven years).

(4) Charging Service Revenue (See 4.3 (5))

Charging service revenue is part of the funds to be used for daily O&M and, if possible, future replacement. As seen in 4.3 (5), the charging service revenue depends on the community type and population. Since charging service in rural communities is a private business activity in general, relevant ministries and REA shall check the prevailing market price in the project area to determine PV system's actual charging fee applicable to customers.

In most cases, the charging service income cannot even cover the regular operation cost, therefore deficit is generated every year. Since the charging fee level is determined to match the market price and hard to increase, relevant stakeholders and REA shall encourage management committees to increase number of customers.

(5) Budgeting

Deficit from regular operation and all the major replacement cost must be covered by government budget subsidy to ensure sustainable operation over system lifetime of 20 years. To receive the budget from the county treasury, county office should make budget plan to apply to the county treasury based on the budget proposal and expenditure projection.

Dispensaries have only one income source. They receive disbursement from government fund (HSSF: Health Sector Service Fund) that is provided by the National Government. However, the amount of the fund is too small to cover all necessary requirements.

4.5 Financial Management for Public Facilities

This section explains the financial management for dispensaries on their O&M of solar PV systems, including charging service operation. Dispensary staff and respective management committees are primarily responsible for the daily operation and charging service.

This section includes organizational setup, budget planning, and the proposed accounting system. REA and relevant stakeholders shall enhance capacity of facility staff and members of management committees so that they can effectively and correctly manage the solar PV system.

4.5.1 Background

REA has the mandate to promote rural electrification by both electricity grid expansion and alternative measures including solar PV systems. Recently REA has a nationwide plan to install PV systems in trading centres, secondary schools and health centres in un-electrified rural communities. However, dispensaries have also priority of electrification. Once installed, the operation and maintenance of the PV systems for system lifetime (approximately 20 years) will be handed over to these public facilities.

To cover part of recurrent O&M expenses, the PV systems may provide charging service as an income generating activity to cover part of daily operational expenses for distilled water, simple repairs, etc; however, most of the O&M costs including major replacement need to be covered by additional budget allocated by County Government and/or National Government.

The financial management for solar PV systems should be based on responsibility sharing among the users of the facility, the County Government and/or the National Government and other stakeholders. This will ensure the sustainability of the PV systems and user benefit from the installed PV systems. The financial section aims to promote awareness of stakeholders on the need for necessary funding for the O&M and replacement costs. Without appropriate planning, it will be difficult to have sustainable PV system operation. Appropriate trainings covering those basic aspects of "Financial Management" are therefore necessary for the management committees and the selected operators from every facility with PV system.

4.5.2 Objectives of Financial Management

The following are the expected objectives of the financial management of each stakeholder.

a) Provide the users with the basic knowledge on financial management

b) Explain the importance of planning, budgeting and how to manage expenditure

c) Provide better understanding of good financial control

d) Provide a simple accounting system for sustainable use of a PV system (addressed to dispensary management committee).

e) Explain how to record daily transactions, balance simple account, and prepare monthly report (addressed to dispensary management committee)

4.5.3 Proposed Accounting System for the Management Committee

Each facility with solar PV system should keep appropriate accounting records of its charging service transactions. It is the most essential part of the financial management at the facility level. REA and relevant stakeholders shall give financial training on these issues to the facility staff and management committee members. The accounting procedure in solar PV charging service is designed and proposed as follows and relevant formats are attached in Annex 3-3.

a) Daily Sales Record

Every transaction with customers must be recorded by the operator in detail on a daily basis. Incomplete records may cause incidents such as lost cash, etc.

(b) Sales Receipt

Receipt or voucher must be given to customers whenever payment for charging service is made. It will be easy to check the total sales on daily business record with the receipt copies and make sure they match.

(c) Cash Book

Cash book is prepared for operators to keep cash income and spending records on a daily basis. Simplified form is prepared for easy comprehension by operators.

(d) Bank Account

Bank account must be prepared before starting the charging service with installed PV systems. This bank account should be a separate account from the existing one for usual health services. For the purpose of security, cash should be deposited in the bank account at least once a week. The deposit slip should be retained by the treasurer or kept in file with the secretary. MoH may not permit them to open more than two bank accounts but it may be possible by requesting this matter to the county health officers.

(e) Monthly Financial Report (Revenue & Expenditure Statement)

The management committee will prepare monthly income and expenditure statement, i.e. Monthly Financial Report of PV system, showing the amount collected from the charging service, the total amount spent for O&M, the bank account balance, etc. Cash balance should be carried forward to the following month.

(4) Capacity Building Plan of Financial Management

It is envisaged that REA will enhance capacity of public facilities so that they can implement O&M and management of solar PV systems properly. This capacity building should include the financial management trainings in order to ensure appropriate O&M activities in facility including charging service operation. This section for financial management would be utilized by trainers as a basis of training contents and the users' manual would be utilized by the facility staff and management committee members who operate and manage the system at the facility.

In these financial management trainings, REA shall employ competent financial experts as trainers. Trainees shall be users of the PV systems consisting of management committee members, staff of public facilities (nurses, etc.).

It is proposed that the financial management training course will consist of two parts: "before installation" and "after installation" (Table 4.5.1).

The training done before the installation is to focus especially on the operator who is to be responsible from the day of commissioning the charging systems for services: to operate charging services, collect cash, provide receipts and to record necessary items. Most operators are not trained professionals of solar PV system operation or accounting and some of them cannot even write and count. According to their social conditions, they cannot easily comprehend the O&M and accounting. Therefore the training should be repeated after the installation within three months. The second training will be conducted to review and assure the procedures for necessary regular actions.

Table 4.5.2 is the summary for the training items to each person in charge.

Table 4.5.2 Role Sharing

Books & Forms	Purpose & Contents	Person in Charge	Check & Keep
Daily Sales Record	Income record	Operator	Secretary
Sales Receipt	Evidence	Operator	Customers
Cash Book	Monthly income & expenditure	Treasurer	Treasurer/chairman
Bank Account	Official Record	Chairman/treasurer	Chairman
Monthly Report	Monthly income, expenditure and monthly balance	Chairman/treasurer	County and sub-county offices

Prepared by JET

Training contents will include, but not limited to, contents of this section of the guideline. In general, the first training will take a maximum of two days with two sessions of two hours in each day while the second training will take a maximum of one day with two sessions of two hours each. However, the trainer, appointed among the employees of REA, may adjust the contents and the training period depending on the location and trainee level.

The trainer from REA should provide all the training materials that JET prepared including the manual for the trainees which could be utilized as reference manual at each facility. REA may issue internal certificates of training attendance for the trainees.

CHAPTER 5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

5.1 Environmental Management System in Kenya

5.1.1 National Environmental Management Authority (NEMA)

The National Environment Management Authority (NEMA) is a practical official body responsible for managing environment, reviewing “EIA Project Reports” and “EIA Study Reports” and issuing Environment Licenses for development projects in Kenya.

Under the Board and the Director General at the top of NEMA, the Authority has established six departments and one sub-department. Among those departments, the following ones have functions on EIA related activities. (Source, National Environment Management Authority Strategic Plan 2008-2012, June 2009, NEMA)

- The Director General appoints members of Environmental Impact Assessment Technical Advisory Committee (EIA-TAC) and prescribes the terms of reference and rules of procedure of the review of EIA related reports received by NEMA.
- The Compliance and Enforcement Department, identifies projects and programmes or types of projects and programmes, plans and policies for which environmental audit (EA) or environmental monitoring must be conducted under the Act and ensure EIAs and EAs are conducted.

5.1.2 Environmental Management System at County Level

(1) Decentralization and Administrative Structure Reform (Transitional Period)

Since the New Kenyan Constitution came into force in 2010, decentralization, administrative structure reforms and regulatory revisions for “Country System” in place of former “Province and District System” have started.

- ✓ As a matter of fact, NEMA issued a public notice with regard to the decentralization of its county functions on EIA as of 1st of July 2012 (See Figure 5.1.1).

As far as reforms of environmental management and EIA review procedure are concerned, the reform processes are in the transitional period as of January 2014.

- ✓ Due to the fact that the environmental management and EIA procedural reforms have not adequately come into effect in order to conform to the new constitutional dispensation especially on administrative units, the provisions of the current EMCA 1999 and EIA/EA Regulations (Amendment) 2009 are still in force until such a time that they will be reviewed. However NEMA through an administrative procedure has done away with District and Provincial offices and effectively replaced them with County offices.
- ✓ The transition period therefore means that the former systems (especially where the relevant laws are concerned) are still in operation alongside the current administrative re-alignment. Therefore, the former local systems of “Provincial Environmental Committee” as well as “District Environmental Committee” are envisaged to be reviewed.

(2) Provincial Environmental Committee (PEC) & District Environmental Committee (DEC)

According to the current EMCA 1999 and EIA/EA Regulations (Amendment) 2009, NEMA operates at provincial and district levels. Namely the Provincial Environment Committees (PECs) and District Environment Committees (DECs) are a primary mechanism for NEMA to undertake its functions, which will be reviewed to County Environment Committee in order to conform to the new administrative structure of County system.

nema

NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY

PUBLIC NOTICE

DECENTRALIZATION OF NEMA FUNCTIONS AND SERVICES

The National Environment Management Authority (NEMA), effective **1st July 2012** implemented a decentralization programme to counties. This is in adherence to the Constitution of Kenya 2010 provisions for government agencies to devolve their operations and functions to counties to ensure efficient provision of their services. The decentralization will in particular address processing of Environmental Impact Assessment, Environmental Audit, Noise and Excessive Vibration Control and transportation of waste (garbage and sewage) licences.

SPECIFIC CRITERIA FOR DECENTRALIZATION

A. Low impact Environmental Impact Assessment (EIA) projects

The EIA for the following low impact projects shall be submitted and processed at respective offices of the County Director of Environment:

1. Residential houses (bungalows, maisonettes, flats) in zoned area (of not more than 30 units)
2. Commercial buildings (of not more than 10 storey's) in zoned areas
3. Go-downs for storage of goods only in zoned areas
4. Community based and/or constituency development Fund (CDF) projects such as:
   - i. Water projects, boreholes and water pans
   - ii. Roads (small feeder roads) and bridges
   - iii. Markets
   - iv. Cattle dips
5. Cottage industry/jua kali sector/garages
6. Car and bus parks
7. Restaurants (excluding tourism facilities in or surrounding National parks and game reserves).
8. Expansion of existing facilities for same use especially socially uplifting projects (SUPs) such as schools and dispensaries
9. Afforestation/re-afforestation programmes
10. Sand harvesting, quarrying and brick making
11. Slaughter houses (handling not more than 15 animals a day)
12. Construction of churches and mosques
13. Timber harvesting

B. Medium and low risk Environmental Audit (EA)reports

Medium and low impact project audits will be processed at respective offices of County Directors of Environment. These include:

1. Animal feed milling
2. Apartments
3. Colleges
4. Campsites
5. Metal welding
6. Restaurants
7. Schools
8. Tea farms
9. Transport Companies
10. Timber Products
11. Warehouses
12. Stadiums

C. High impact/risk projects will be processed at NEMA headquarters

All high impact/risk projects will be processed at NEMA headquarters. These include:

1. Asbestos manufacturing /based industries
2. Battery recycling
3. Airports
4. Airports hangars
5. Base transceiver stations(BTS)
6. Cement factories
7. Chemical factories
8. Distilling and blending spirits
9. Geothermal plants
10. Hydroelectric power generation plants
11. Incinerators
12. Landfills
13. Large scale irrigated agriculture farming (exceeding 50ha)
14. Molasses plants
15. Petroleum refining
16. Paper mills
17. Vegetable oil refineries
18. Steel mills
19. Sewerage works
20. Thermal power generation
21. Tanneries
22. Tourist facilities in protected areas
23. Wood preservation

N.B. All other facilities/projects not included in the high risk category list shall be submitted and processed at the respective offices of the County Director of Environment.

D. Noise and excessive vibration control licensing

Noise and excessive vibration control licences and permits shall be issued at the county level for one off activities, where noise emitted is expected to go beyond maximum permissible noise levels. Such one off activities include: weddings and birthday parties, road shows, ceremonies, parties, religious festivals, mobile cinemas among others. The licence is valid for a maximum of seven days and costs Kshs 2,200.

Permits will be issued for the following one off activities: demolition activities, construction sites, fireworks, mines and quarries, firing ranges, specific heavy duty industry. The permit shall be valid for a period of up to three months and costs KShs 5,500.

Commercial activities, discos/ live bands/ pubs, entertainment joints, places of worship among others, shall not be licenced as they are required to sound proof their premises to keep their noise to within permissible noise levels.

E. Waste transportation licensing

Licenses to transport garbage and sewage waste shall be issued at the county level. All the other categories of waste management license applications will continue to be received at county level. These will be forwarded to NEMA Headquarters for processing.

Office contacts of respective County Directors of Environment (CDE) can be found on the NEMA website at www.nema.go.ke.

For further information, please contact:

PROF. GEOFFREY WAHUNGU
DIRECTOR GENERAL
NEMA
Popo road, off Mombasa Road
P.O. Box 67839- 00200, Nairobi, Kenya
Tel: (254 020) 6005522, 020 2101370, 0724 253398, 0735 010237
Fax (254 020) 6008997

Email: dgnema@nema.go.ke Website: www.nema.go.ke
Face book: National Environment Management Authority
Report any environmental related corruption to: anticorruption@nema.go.ke

Source: a Clip DAILY NATION, Monday July 9, 2012

Figure 5.1.1 Public Notice on Decentralization of NEMA Functions and Services

5.2 EIA Procedures and Licensing System in Kenya

5.2.1 Projects Sectors Subject to EIA

Project Sectors subject to EIA procedures in Kenya are specified in the Environmental Management and Coordination Act of 1999 (EMCA) as “Second Schedule” as shown in Table 5.2.1.

Table 5.2.1 "Second Schedule" specified in EMCA (Project Sectors Subject to EIA)

Sector	Including	
General	· An activity out of character with its surrounding, any structure of a scale not in keeping with its surroundings	· Major changes in land use
Urban development	· Designation of new townships · Establishment of industrial estates · Establishment or expansion of recreational areas	· Establishment or expansion of recreational townships in mountain areas, national parks and game reserves · Shopping centers and complexes
Transportation	· All major roads · All roads in scenic, wooded or mountainous areas and wetlands, Railway lines	· Airports and airfields · Oil and gas pipelines · Water transport
Dams, rivers and water resources	· Storage dams, barrages and piers · River diversions and water transfer between catchments	· Flood control schemes · Drilling for the purpose of utilizing ground water resources including geothermal energy
Aerial spraying	-	-
Mining	· Quarrying and open cast extraction of · Precious metal, Gemstones, Metalliferous ores, Coal, Phosphates, Limestone and dolomite	· Stone and slate · Aggregates, sand and gravel, Clay, Exploration for the production of petroleum in any form, Extracting alluvial gold with use of mercury
Forestry related activities	· Timber harvesting · Clearance of forest areas	· Reforestation and afforestation
Agriculture	· Large scale agriculture · Use of pesticide · Introduction of new crops and animals	· Use of fertilizers · Irrigation
Processing and manufacturing industries	· Mineral processing, reduction of ores and minerals · Smelting and refining of ores and minerals · Foundries · Brick and earth wear manufacture · Cement works and lime processing · Glass works · Fertilizer manufacture or processing · Explosive plants · Oil refineries and petrochemical works · Tanning and dressing of hides and skins · Abattoirs and meat processing plants · Chemical works and processing plants · Brewing and malting	· Bulk grain processing plants · Fish processing plants · Pulp and paper mills · Food processing plants · Plants for manufacture or assembly of motor vehicles · Plant for the construction or repair of aircraft or railway equipment · Plants for the manufacture or assembly of motor vehicles · Plants for the manufacture of tanks, reservoirs and sheet metal containers · Plants for manufacture of coal briquettes · Plants for manufacturing batteries
Electrical infrastructure	· Electrical generation stations · Electrical transmission lines	· Electrical sub-stations · Pumped storage schemes
Management of hydrocarbons	· Storage of natural gas and combustible or explosive fuels	
Waste disposal	· Sites for solid waste disposal · Sites for hazardous waste disposal · Sewage disposal works	· Works involving major atmospheric emissions · Works emitting offensive odours
Natural conservation areas	· Creation of national parks, game reserves and buffer zones · Establishment of wilderness areas · Formulation or modification of forest management policies · Formulation of modification of water catchment management policies	· Policies for the management of ecosystems especially by use of fire · Commercial exploitation of natural fauna and flora · Introduction of alien species of fauna and flora · Introduction of alien species of fauna and flora into ecosystems
Nuclear reactors	-	-
Major development in biotechnology	· Introduction and testing of genetically modified organisms	

Source: Environmental Management and Coordination Act of 1999 (EMCA)

However, "Second Schedule" does not specify the scale and size of each project. Namely without reference to scale or size of a project fall under the Second Schedule, such a project shall go through the EIA procedures.

(1) Renewable Energy Projects and necessity of EIA

Renewable Energy Projects (PV, Mini hydro, Bio-gas and Wind power systems) which falls under "No. 10 Electrical Infrastructure" in the "Second Schedule" of EMCA. Therefore, all Renewable Energy Projects are naturally subject to the EIA procedures.

(2) Draft NEMA EIA Guidelines and Administration Procedures

In addition, NEMA developed a Draft EIA Guidelines and Administration Procedures in November 2002 in response to the National Policy on Environment and EMCA 1999. The NEMA Draft EIA Guidelines provides procedural guidelines for,

- Implementation of EIA
- Monitoring and Environmental Audit (EA)
- Strategic Environmental Assessment (SEA)
- Issues of Trans-boundary, Regional and International Conventions, Treaties and Agreements
- Steps in EIA studies and Environmental Audits
- The contents and format of the study reports to be submitted to NEMA
- The EIA study review process and decision-making, and others.

CHAPTER 7 of the NEMA Draft EIA Guidelines mentions that Lead agencies are mandated by section 58 of the EMCA 1999, in consultation with the Authority to develop EIA Guidelines to ensure that environmental concerns are integrated in sector development policies, plans, projects or programmes. The sector guidelines shall focus on specific mandates in line with the statutory relationships with the administration of the EIA process.

- However, such sector guidelines have not been developed by relevant lead agencies excluding the sector of petroleum (Source, A meeting with NEMA HQ).
- In addition, the Draft Guidelines is rendered a rather conceptual guidance. Practically, the processes of EIA and the licensing shall refer to EIA/EA Regulations (Amendment) 2009.

5.2.2 EIA Review Process and Licensing

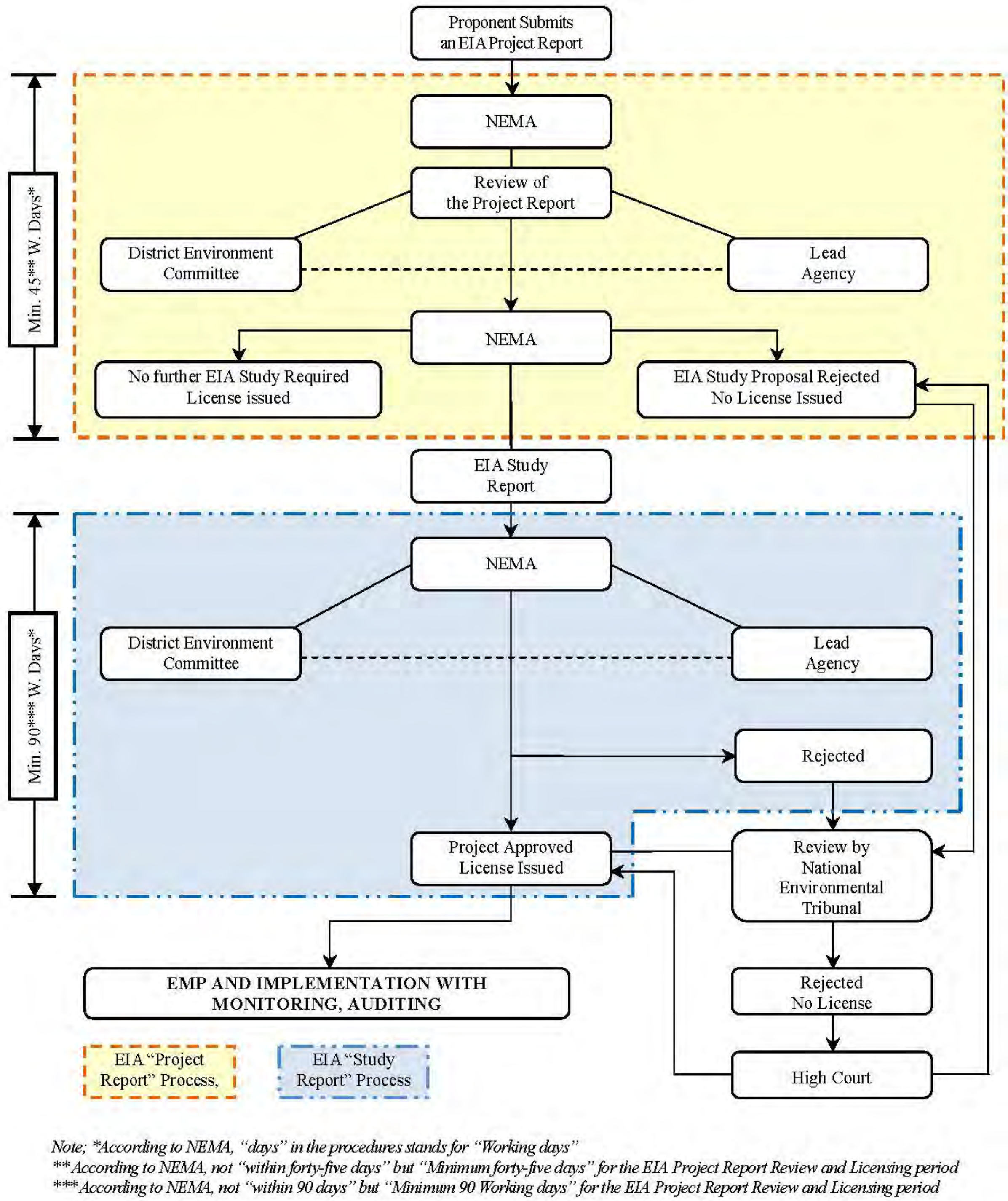
The Environmental Management and Coordination Act of 1999 (EMCA) and EIA/EA Regulations (Amendment) 2009 specify the EIA Review process which consists of the following two steps.

- EIA "Project Report" Process
- EIA "Study Report" Process

(1) Overview of the EIA Process

Based on EMCA 1999, EIA/EA Regulations (Amendment) 2009 and discussions with NEMA officials as well as considering the decentralization of NEMA's functions at the County level, Kenyan EIA entire procedures can be depicted as shown in Figure 5.2.1.

Detail flows of "EIA Project Report" and "EIA Study Report will appear afterward (See Figure 5.2.2 and Figure 5.2.3).



Source: NEMA, (modified by the JET based on discussions with NEMA Headquarters officials)

Figure 5.2.1 Overview of the EIA Process

(2) EIA "Project Report"

According to EMCA 1999, EIA/EA Regulation (Amendment) 2009 and discussions with NEMA officials as well as considering the decentralization of NEMA's functions at the County level, the EIA "Project Report" Process can be summarized as follows and depicted in Figure 5.2.2.

- The process starts by a project proponent, selecting a consultant which must be licensed and registered with NEMA as a Lead Expert on EIA/EA

- An EIA "Project Report" shall be prepared by the consultant (Registered Lead Expert on EIA/EA). The following shows contents to be stated in the "Project Report".

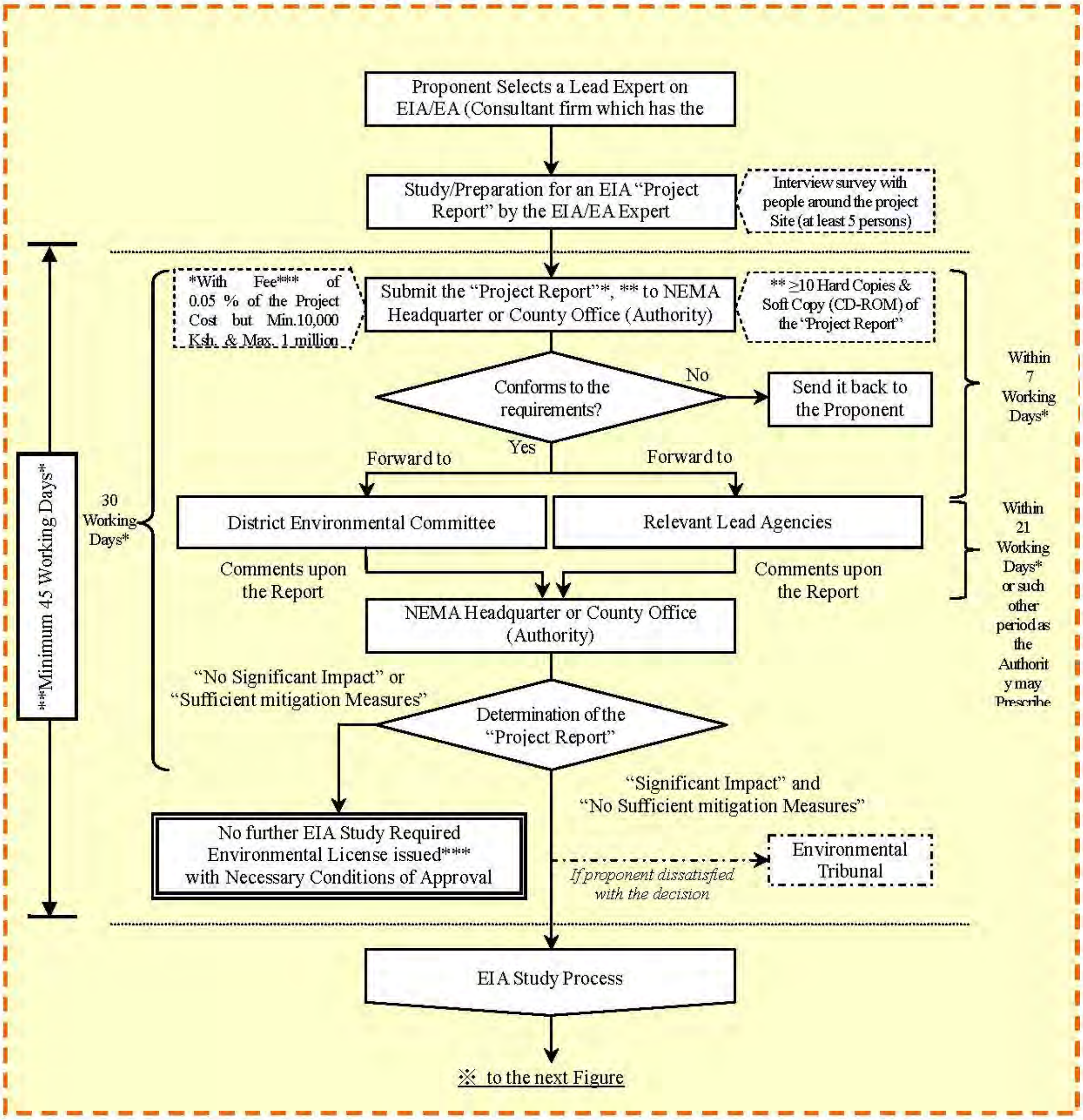
Table 5.2.2 Contents of the Project Report

· Nature of the project, · Location of the project including the physical area that may be affected by the project's activities, · Activities that shall be undertaken during the project construction, operation and decommissioning phases, · Design of the project, · Materials to be used, products and by-products, including waste to be generated by the project and the methods of their disposal, · Potential environmental impacts of the project and the mitigation measures to be taken during and after implementation of the project,	· Action plan for the prevention and management of possible accidents during the project cycle, · Plan to ensure the health and safety of the workers and neighbouring communities, · Economic and socio-cultural impacts to the local community and the nation in general · Project budget, and · Any other information the Authority may require.

Prepared by JET

- The proponent shall submit at least ten copies and one soft copy (CD-ROM) of the EIA "Project Report" to the Authority (NEMA HQ or its County Office(s)) accompanied by the prescribed fees of 0.05% of the project cost. (50% of the 0.05 of the project cost paid at the time of submission of the EIA "Project Report" and the remainder of 50% paid at the time of collection of license)
- The Authority shall **within seven (7) days** upon receipt of the project report, where the "Project Report" conforms to the requirements of regulation, distribute a copy of the "Project Report" to Relevant Lead Agencies and Relevant District Environment Committee(s) (DEC(s)) for their review and written comments.
- Those comments of Lead Agencies and DECs shall be submitted to the Authority **within twenty one (21) days** from the date of receipt of the "Project Report" from the Authority, or such other period as the Authority may prescribe.
- On receipt of the comments or where no comments have been received **by the end of the period of thirty (30) days** from the date of receipt of the "Project Report", the Authority shall proceed to determine the project report.
- On determination of the "Project Report", the decision of the Authority, together with the reasons thereof, shall be communicated to the proponent **within forty-five (45) days**[5] of the submission of the "Project Report".
- Where the Authority is satisfied that the project will have no significant impact on the environment, or that the project report discloses sufficient mitigation measures, the Authority may issue a license
- If the Authority finds that the project will have a significant impact on the environment, and the project report discloses no sufficient mitigation measures, the Authority shall require that the proponent undertake an EIA study.
- A proponent, who is dissatisfied with the Authority's decision that an environmental impact assessment study is required, may **within fourteen (14) days** of the Authority's decision appeal against the decision to the Tribunal.

5 According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period



*Note: *According to NEMA, "days" in the procedures stands for "Working days"*
***According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period*
*** 50% of the 0.05 of the project cost paid at the time of submission of the EIA Project Report and the remainder of 50% paid at the time of collection of license

Source: Prepared by the JET referring to the EIA/EA Regulations (Amendment) 2009 and based on discussions with NEMA headquarters

Figure 5.2.2 EIA Project Report Review Process and Duration

(3) EIA "Study Report"

According to EMCA 1999, EIA/EA Regulation (Amendment) 2009 and discussions with NEMA officials as well as considering the decentralization of NEMA's functions at the County level, the EIA <u>"Study Report"</u> Process can be summarized as follows and depicted in Figure 5.2.3.

- An EIA study shall be conducted in accordance with a TOR (Terms of Reference) to be developed during the "Scoping" exercise, Then the TOR shall be submitted to be approved **<u>within seven (7) days</u>** by the Authority, Every EIA study shall be carried out by an EIA/EA Lead Expert

- During the process of conducting an EIA study, the proponent shall in consultation with the Authority, seek the views of persons who may be affected by the project.
- Namely, holding at least three public meetings with the affected parties and communities to explain the project and its effects, and to receive their oral or written comment
- A proponent shall submit to the Authority, an environmental contents of EIA "Study Report" incorporating but not limited to the following information:

Table 5.2.3 Contents of the Study Report

· Proposed location of the project, · Concise description of the national environmental legislative and regulatory framework, baseline information, · Any other relevant information related to the project, the objectives of the project, · Technology, procedures and processes to be used, in the implementation of the project, · Materials to be used in the construction and implementation of the project, · Products, by-products and waste generated project, · Description of the potentially affected environment, · Environmental effects of the project including the social and cultural effects and the direct, indirect, cumulative, irreversible, short term and long-term effects anticipated, · Alternative technologies and processes available and reasons for preferring the chosen technology and processes, · Analysis of alternatives including project site, design and technologies and reasons for preferring the proposed site, design and technologies,	· Environmental management plan proposing the measures for eliminating, minimizing or mitigating adverse impacts on the environment, including the cost, time frame and responsibility to implement the measures, · Provision of an action plan for the prevention and management of foreseeable accidents and hazardous activities in the cause of carrying out activities or major industrial and other development projects, · Measures to prevent health hazards and to ensure security in the working environment for the employees and for the management of emergencies, · Identification of gaps in knowledge and uncertainties which were encountered in compiling the information, · Economic and social analysis of the project, · Indication of whether the environment of any other state is likely to be affected and the available alternatives and mitigating measures, and · Such other matters as the Authority may require.

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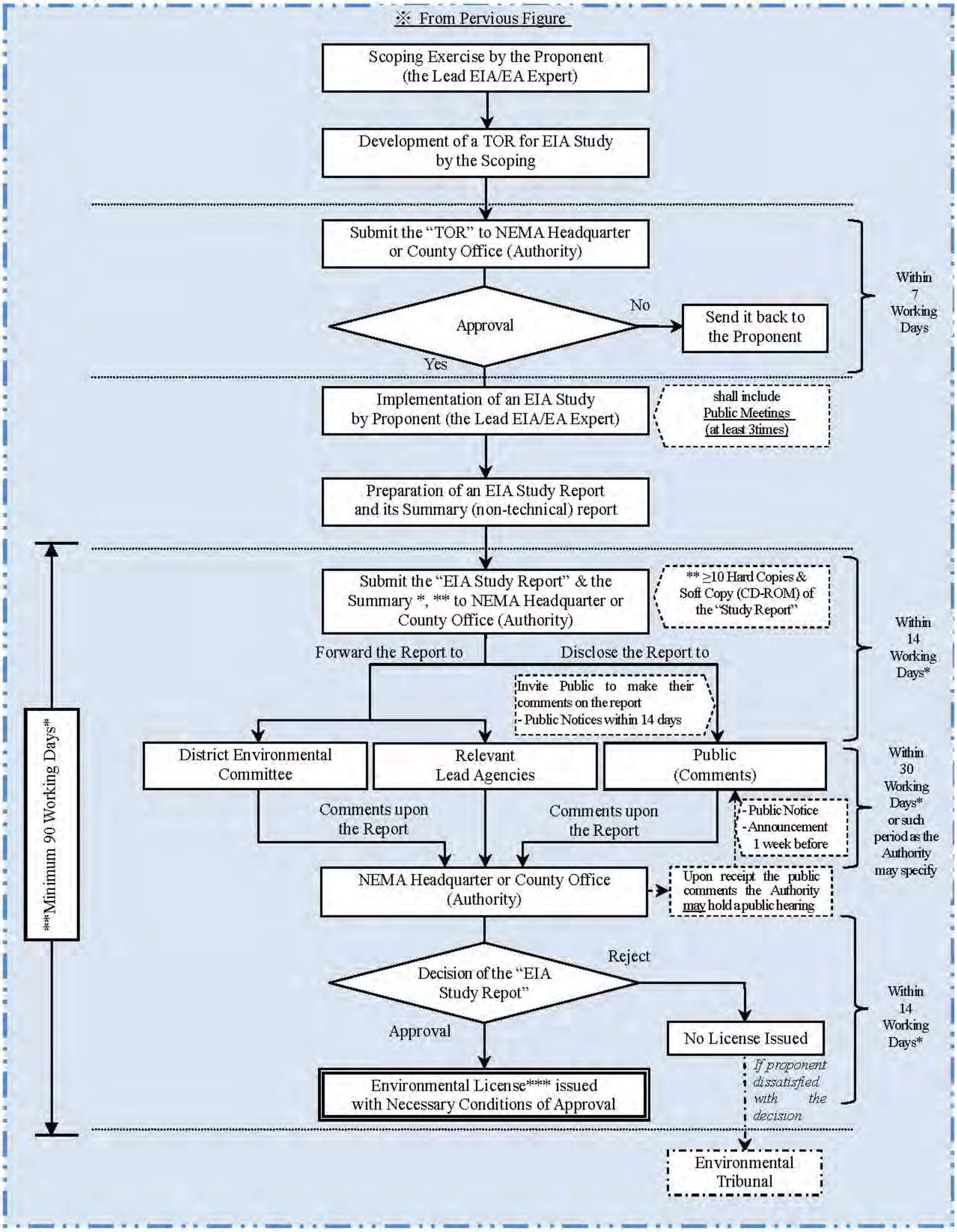
- EIA "Study Report" shall be accompanied by a non-technical summary outlining the key findings, conclusions and recommendations of the study, Proponent shall submit ten copies and a soft copy (CD-ROM) of an EIA "Study Report" to the Authority
- The Authority shall **<u>within fourteen (14) days</u>** of the receipt of the EIA "Study Report" submit a copy of the report to any Relevant Lead agencies as well as District Environmental Committee(s) (DEC(s)) for their comments.
- Upon receiving the EIA "Study Report", the lead agencies and DEC(s) shall review the report and shall thereafter send their comments on the "Study Report" to the Authority **<u>within thirty (30) days</u>** or such extended period as the Authority may specify.
- The Authority shall **<u>within fourteen (14) days</u>** of receiving the EIA "Study Report", invite the public to make oral or written comments on the report, at the expense of the proponent.
- Upon receipt of these comments, the Authority may hold a public hearing
- The Authority shall give its decision on EIA "Study Report" **<u>within three (3) months</u>** of receiving an EIA "Study Report"
- Where the Authority approves an EIA "Study Report" , it shall issue an EIA license on terms and conditions as it may deem necessary
- A person who is aggrieved by the decision may appeal to the Tribunal against the decision.



Note: *According to NEMA, "days" in the procedures stands for "Working days"
**According to NEMA, not "within 90 days" but "Minimum 90 Working days" for the EIA Project Report Review and Licensing period
**** 50% of the 0.05 of the project cost paid at the time of submission of the EIA Project Report and the remainder of 50% paid at the time of collection of license

Source: Prepared by the JET referring to the EIA/EA Regulations (Amendment) 2009 and based on discussions with NEMA

Figure 5.2.3 EIA Study Report Review Process and Duration

(4) Public Comments and Public Hearing in the EIA Study Report Process

Table 5.2.4 shows differences between "Public Comments" and "Public Hearing" in the course of the EIA Study Report Process. Both public comments and public hearing are means of public consultation.

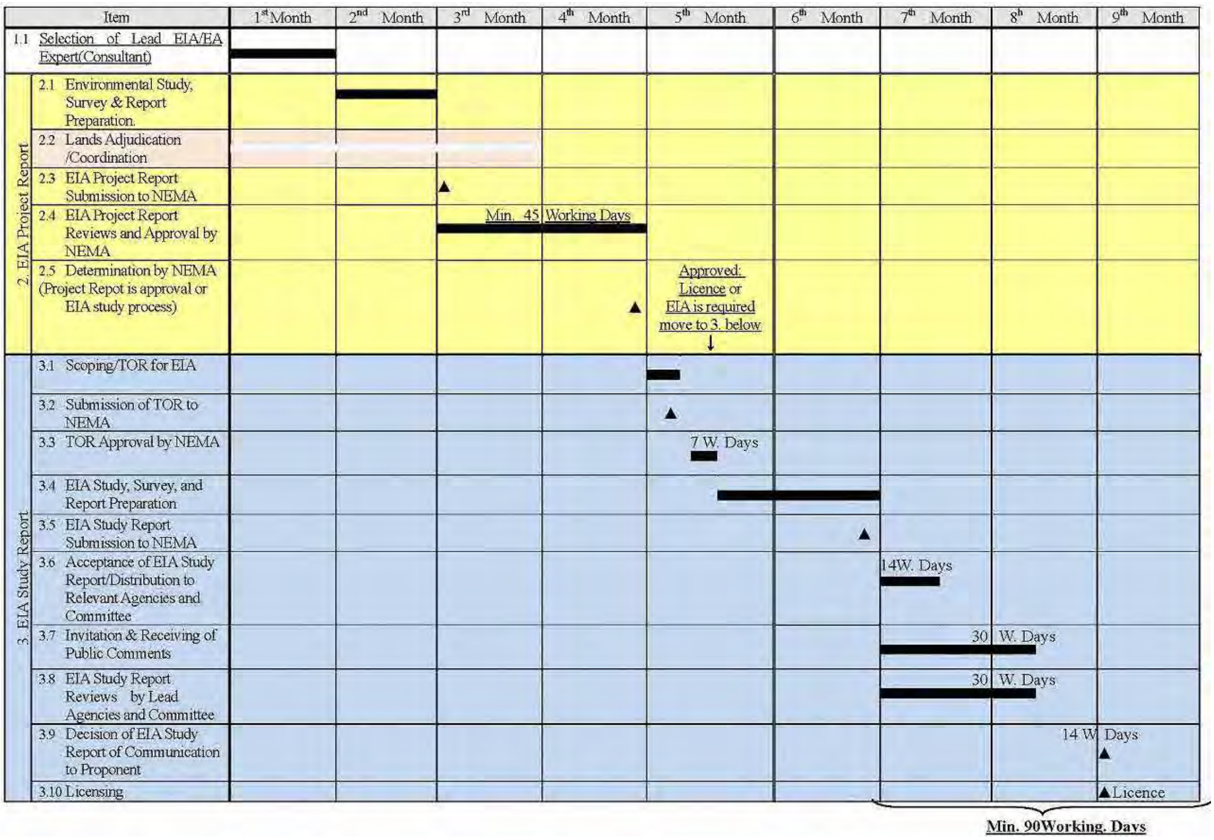
Table 5.2.4 Public Comments and Public Hearing in EIA Study Report Process

Public Comments	Public Hearing
- Invitation is done both at the time of conducting EIA and after submission of Study report.	- Conducted only after submission of the EIA study report at NEMA offices
- Invitation of public comments must be done as follows. - At least three public meetings for comments must be done by the EIA consultant in the course of the study. - One public comments window after submission of EIA study report at NEMA office.	- Public hearing done only once after submission of EIA study report.
- Comments are received both by EIA consultant and NEMA.	- Sessions for public hearing only organized by NEMA and the report of the public hearing only prepared by the presiding NEMA official.
- Invitation for public comments is mandatory as per the regulations.	- Conducting public hearing sessions is at the discretion of NEMA based on the nature of the proposed study and adequacy of the study report.

Prepared by JET

(5) Possible Schedule of EIA Review Process and Licensing for Renewable Energy Projects

In accordance with EIA processes noted above, a possible schedule of EIA reviews and licensing for renewable energy projects can be depicted as a bar-chart shown in Figure 5.2.4.



Prepared by JET

Figure 5.2.4 Possible Schedule for EIA/Environmental Licenses

(6) Revision of EMCA and EIA/EA Regulation in 2014

In light of the new constitution enacted in 2010, the relevant laws and regulations, especially EMCA 1999 and the EIA/EA regulations 2009 are being reviewed (as of January 2014) to conform to the expectations of the new constitution. Therefore, revised EMCA and EIA/EA regulations may apply to relevant projects after 2014. For more details on any revisions, contact NEMA.

5.3 Specific Subject (Solid Waste Management)

Solid waste management issues shall be addressed in compliance with the following laws and regulations in Kenya.

- Environmental Management and Coordination Act of 1999 (EMCA)
- Environmental Management and Coordination (Waste Management) Regulations 2006
- Guidelines for E-Waste Management in Kenya 2010
- Others (if any)

5.3.1 Construction Stage

All trash and packaging materials which might result from the construction process will be collected by the contractor(s) for adequate disposal, which shall be one of the prerequisites for the contract(s) for the contractor(s) to be employed. In this regard, the solid waste management during construction stage can be secured as follow.

- REA is required to instruct contractor(s) to ensure such solid waste management.

5.3.2 Operation Stage

Replacement of used batteries, fluorescent tubes and other electrical appliances shall be managed by each project facility. REA is required to have discussions with each facility, and/or initiate stakeholder meetings in each site to discuss and find solutions for management of such solid waste as follows.

(1) E-waste

The issues of “e-waste management” are prominent. Especially e-waste components like used batteries, used fluorescent lamps and other used electrical appliances including solar PV panels, inverters, etc. are the core issues as summarized in Table 5.3.1.

Table 5.3.1 E-waste Components in Renewable Energy Projects

E-waste	Hazardous Element
Used Lead-acid batteries	Lead and Sulfuric Acid
Used Fluorescent tubes	Mercury
Used PV panels, Inverters and other appliances	Other heavy metals

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(2) Hazardous and Non-Hazardous Elements

Hazardous elements and Non-Hazardous Elements in Table 5.3.1 are regulated by EMCA, especially by the Guidelines for E-Waste Management in Kenya (See Table 5.3.2 and Table 5.3.3).

Table 5.3.2 Hazardous Elements in Electrical and Electronic Equipment

Element	For example found in electrical and electronic equipment such as:
Americium	Smoke alarms (radioactive source).
Mercury	Fluorescent tubes (numerous applications); tilt switches (pinball games, mechanical doorbells, thermostats)
Sulfur	Lead-acid batteries
PCBs	Prior to ban, almost all 1930s-1970s equipment, including capacitors, transformers, wiring insulation, paints, inks and flexible sealants used PCBs.
Cadmium	Light-sensitive resistors, corrosion-resistant alloys for marine and aviation environments and nickel-cadmium batteries.
Lead	Old solder, CRT monitor glass, lead-acid batteries and formulations of PVC.
Beryllium oxide	Filler in some thermal interface materials such as thermal grease used on heat sinks of CPUs and power transistors, magnetrons, X-ray-transparent ceramic windows, heat transfer fins in vacuum tubes, and gas lasers.
Polyvinyl chloride	PVC contains additional chemicals to change the chemical consistency of the product. Some of these additives can leach out of vinyl products e.g. plasticizers that are added to make PVC flexible.

Source: Guidelines for E-Waste Management in Kenya, December 2010, National Environmental Management Authority

Table 5.3.3 Non Hazardous Elements in Electrical and Electronic Equipment

Element	For example found in electrical and electronic equipment such as:
Tin	Solder, coatings on component leads.
Copper	Copper wire, printed circuit board tracks, component leads.
Aluminum	Nearly all electronic goods using more than a few watts of power, including electrolytic capacitors.
Iron	Steel chassis, cases, and fixings.
Germanium	1950s-1960s transistorized electronics (bipolar junction transistors).
Silicon	Glass, transistor, ICs, printed circuit boards.
Nickel	Nickel-cadmium batteries.
Lithium	Lithium-ion batteries.
Zinc	Plating for steel parts.
Gold	Connector plating, primarily in computer equipment.

Source: Guidelines for E-Waste Management in Kenya, December 2010, National Environmental Management Authority

Possibility of “hazard to health and environment” caused by the hazardous elements shown in Table 5.3.2, which is one of the reasons for the necessity of e-waste management.

(3) Handling Procedure of E-waste

Not like domestic waste which is generated daily, e-waste is generated after life span of each component of the project facilities has finished.

Namely, the life span of batteries and fluorescent lamps are up to about two years and that of electrical appliances including solar PV panels, inverters, etc. are up to 10-25 years. Their disposals shall be handled as summarized in Table 5.3.4.

Table 5.3.4 Handling Procedure of E-waste

Component	Possible Life Span* (years)	Handling	Remarks
Battery	3 to 8	- In order to prevent diffusion of toxic substances in batteries, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly disposed. - Used batteries can be sold to licensed e-waste handlers and/or battery producing companies in Kenya.	- Licensed e-waste handlers (See Table 6.3.5) or contact each NEMA county office to get updated information on such handlers. - Battery Producing Companies (See Figure 6.3.1 or contact each NEMA county office). - Purchase Prices are subject to the market trends.
Fluorescent Lamp	2 to 4	- In order to prevent diffusion of mercury in fluorescent lamps, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly disposed. - Used Fluorescent Lamps shall be transported to licensed e-waste handlers in Kenya to be disposed.	- Licensed e-waste handlers (See Table 6.3.5) or contact each NEMA county office to get updated information on such handlers.
LED Lamp	5	- Used LED Lamps shall be transported to registered e-waste handlers in Kenya to be disposed.	
Solar PV Panel	20 to 25	- Used solar PV panels shall be transported to registered e-waste handlers in Kenya to be disposed.	
Inverter	5 to 10	- Used Inverters shall be transported to licensed e-waste handlers in Kenya to be disposed.	

* Note: Vary depending on the intended use as well as status of use

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Taken by JET

A battery manufacturer already has a program to buy used batteries at KSh. 40 per kilogram.

Figure 5.3.1 Used Battery Purchasing by a Battery Manufacturer

Table 5.3.5 Licensed E-waste Handlers in Kenya (As of August 2013)

Handler	Contact	District	Waste Type
East Africa Computer Recyclers Ltd.	P.O. Box 49266-00100, Nairobi Email: eastafricancomputer@yahoo.com 07215036515, 0729308221	Mombasa	Electronic Recycling
Waste Electrical and Electronic Equipment Center	P.O. Box 48584-00100, Nairobi Email: infor@weecenter.com 0733-986-558, 202060921	Nairobi	Electronic Recycling

Source: NEMA (tabulated by JET)

(4) E-waste Management Structure

Used batteries, fluorescent tubes and other used electrical apparatuses/devices can be handled by organizing an e-waste management sub-committee under the Pilot Project management structure to be set up by each community and/or facility as follows:

i) The structure (sub-committee) to be organized for the e-waste management shall be discussed among stakeholders on the initiative of REA
ii) Each community is to be enlightened that even the electrical apparatuses/devices such as PV panels and inverters which have a longer lifespan eventually need replacement
iii) Each community is to be enlightened that those hazardous elements shown in Table 5.3.2 are hazardous to health and environment, and some hazardous substances like “lead” in batteries and some non-hazardous elements shown in Table 5.3.3 can be recycled and reused.

(5) E-waste Disposal System

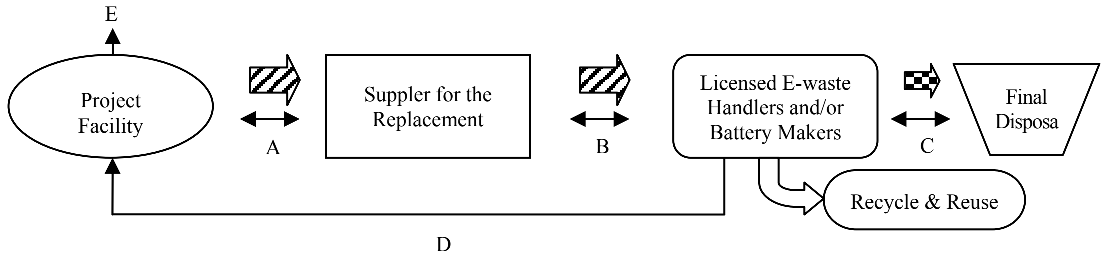
Practically, the aforementioned e-wastes shall be transported to the licensed E-waste Handlers and/or battery manufacturers, in the following approach:

i) Request suppliers to take away used ones from each facility when carrying out replacements (this shall be set as a condition for carrying out replacements).
ii) Public property of the project, earnings from the sale of used e-waste including batteries shall be remitted using the “m-pesa” system by suppliers receiving earnings from the licensed E-waste Handlers and/or battery manufacturers.
iii) The earnings shall be kept in each facility as revenue.
iv) In order to ensure proper transportation and treatment, an e-waste manifest system shall be introduced in the e-waste disposal system as shown in Figure 5.3.2 and Table 5.3.6.

* Manifest system: A system to keep all logs from e-waste discharge stage to transportation as well as final treatment in order to prevent illegal dispose of e-waste during the transportation as well as to make sure appropriate final treatment of such waste.

** The following web site of USEPA on Hazardous Waste Manifest System can be referred as reference.

http://www.epa.gov/waste/hazard/transportation/manifest/index.htm



Flow of e-waste

Residue of e-waste after treatment for recycles and reuse.

Logs and records

A	Keep two logs on e-waste between Generator (facility) and Suppler which will transport e-waste to the (2 logs: one is for the generator and one is for the suppler)
B	Keep two logs on the e-waste between the Suppler and Licensed e-waste handler and/or Battery Maker for the treatment of the e-waste (2 logs: one is for the suppler and one is for the Licensed E-waste Handlers and/or Battery Makers)
C	Keep two logs on the reside of the e-waste between the Licensed e-waste handler and/or Battery Maker and a final disposal site (2 logs: one is for the Licensed e-waste handler and/or Battery Maker and one is for the final disposal facility like a landfill)
D	Send two copies of the logs of B and C to Generator (project facility) by which each project facility can identify the proper transportation, treatment and final disposal of the e-wastes by mail.
E	After receiving the copies in D, each facility shall report showing one of the copies to REA, as well as regulatory agency such as Ministry of Education (for Primary Schools) or Ministry of Health (for Dispensaries).

Prepared by JET

Figure 5.3.2 Conceptual Diagram of E-waste Manifest system

Table 5.3.6 Draft E-waste Manifest Log From

	Date:		No. of Manifest	
1	Facility (Generator)	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	E-waste	name 1:	Quantity	mode of packing
		name 2:	Quantity	mode of packing
		name 3:	Quantity	mode of packing
		name 4:	Quantity	mode of packing
		name 5:	Quantity	mode of packing
2	Suppler (Transportation)	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	Received the above listed e-waste from the Facility on date and Sign			
3	Licensed E-waste Handler and/or Battery Maker	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	Received the above listed e-waste from the Suppler on date and Sign			
	Treated appropriately the e-waste on date and Sign in compliance with the relevant laws and regulations in Kenya, especially the followings ✓ Environmental Management and Coordination Act of 1999 (EMCA) ✓ Environmental Management and Coordination (Waste Management) Regulations 2006 ✓ Guidelines for E-Waste Management in Kenya 2010			
4	Final Disposal	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	Received the residues of above listed e-waste from the Licensed E-waste Handler and/or Battery Maker on date and Sign			
	Disposed the residues on date and Sign n compliance with the relevant laws and regulations in Kenya, especially the followings ✓ Environmental Management and Coordination Act of 1999 (EMCA) ✓ Environmental Management and Coordination (Waste Management) Regulations 2006 ✓ Guidelines for E-Waste Management in Kenya 2010			

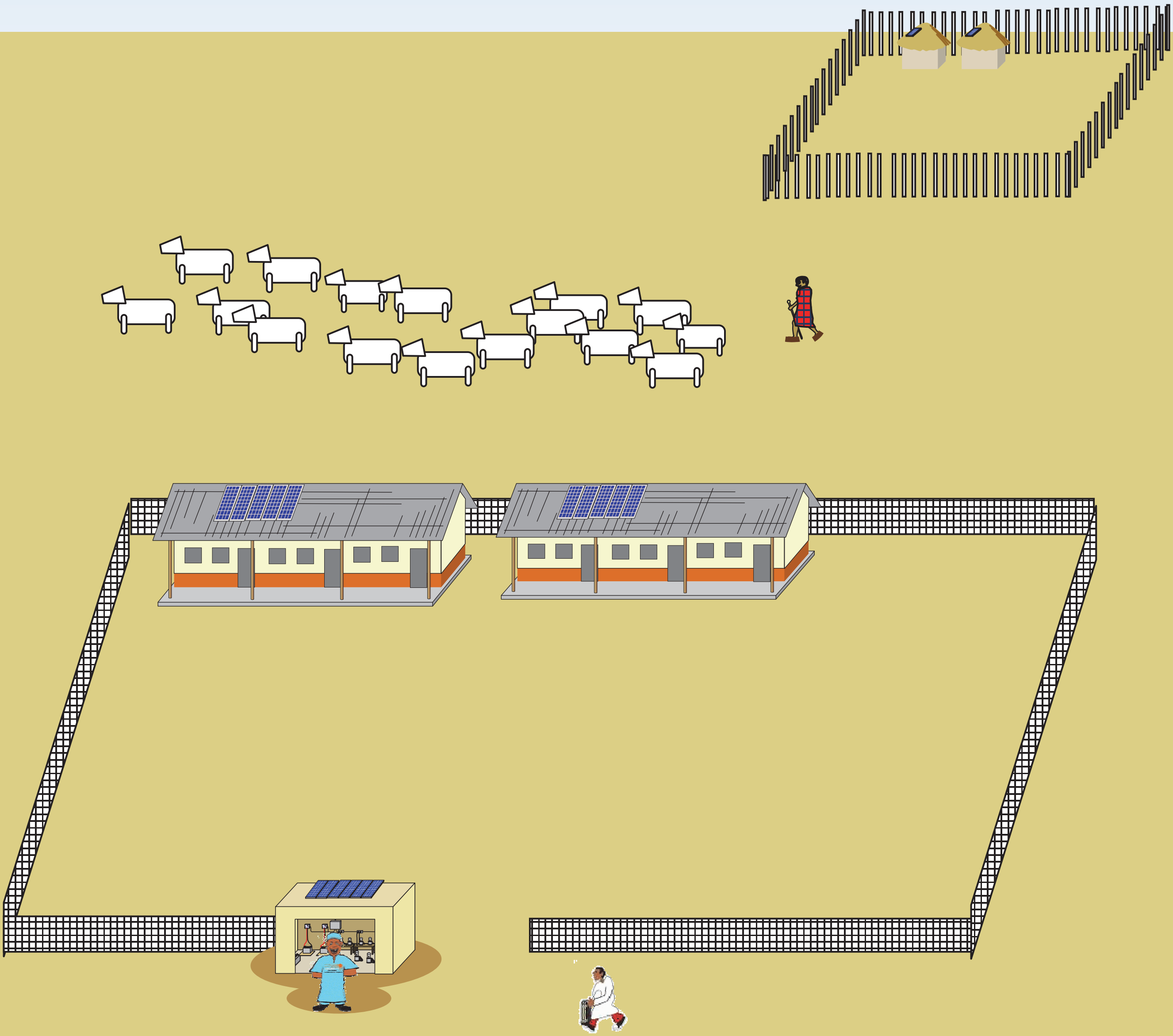
Note: At least eight copies are necessary.

Prepared by JET

List of Annexes

Annex 1 Solar PV Operation Manual

Solar PV Operation Manual

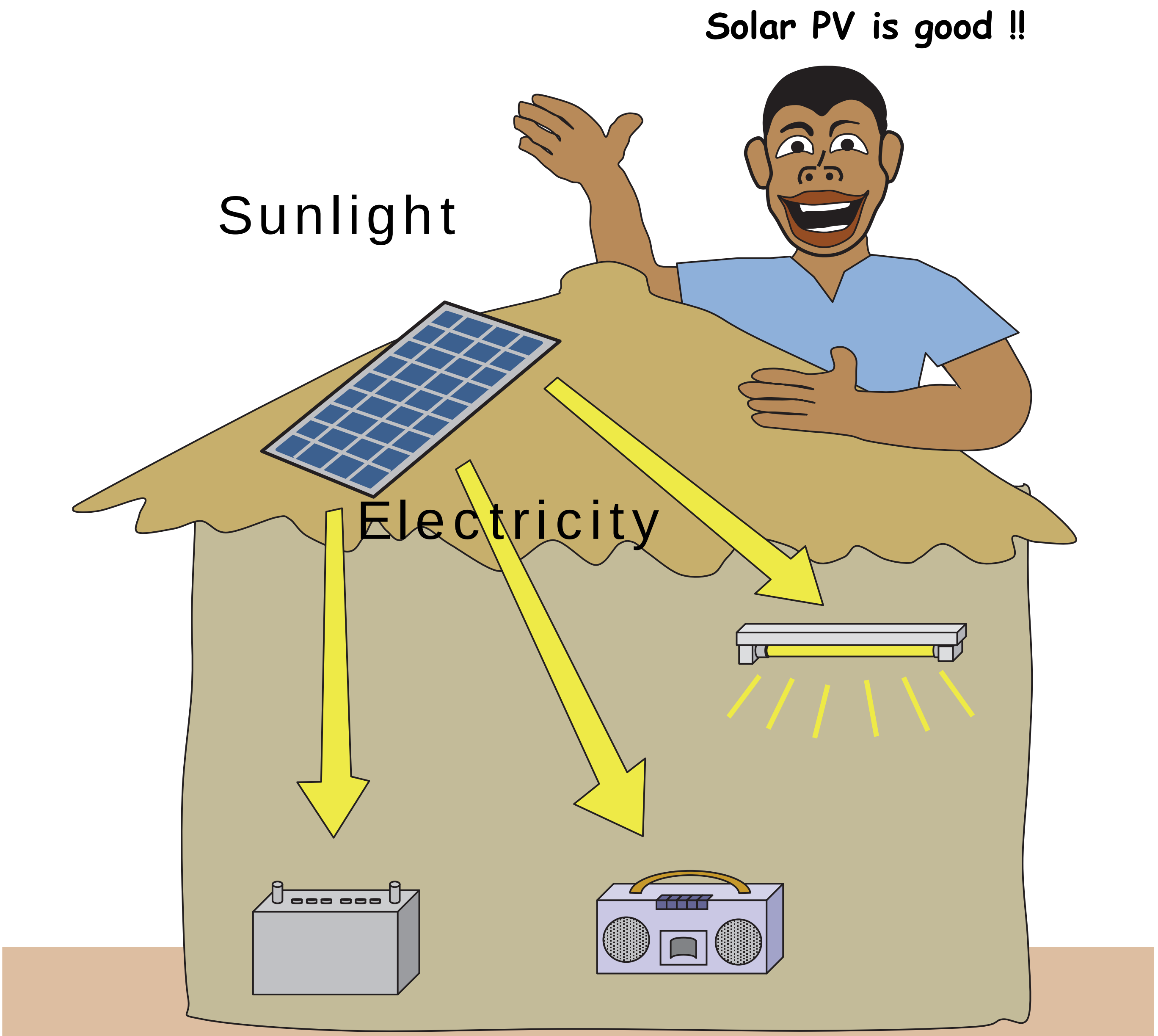


JICA

Rural Electrification Authority

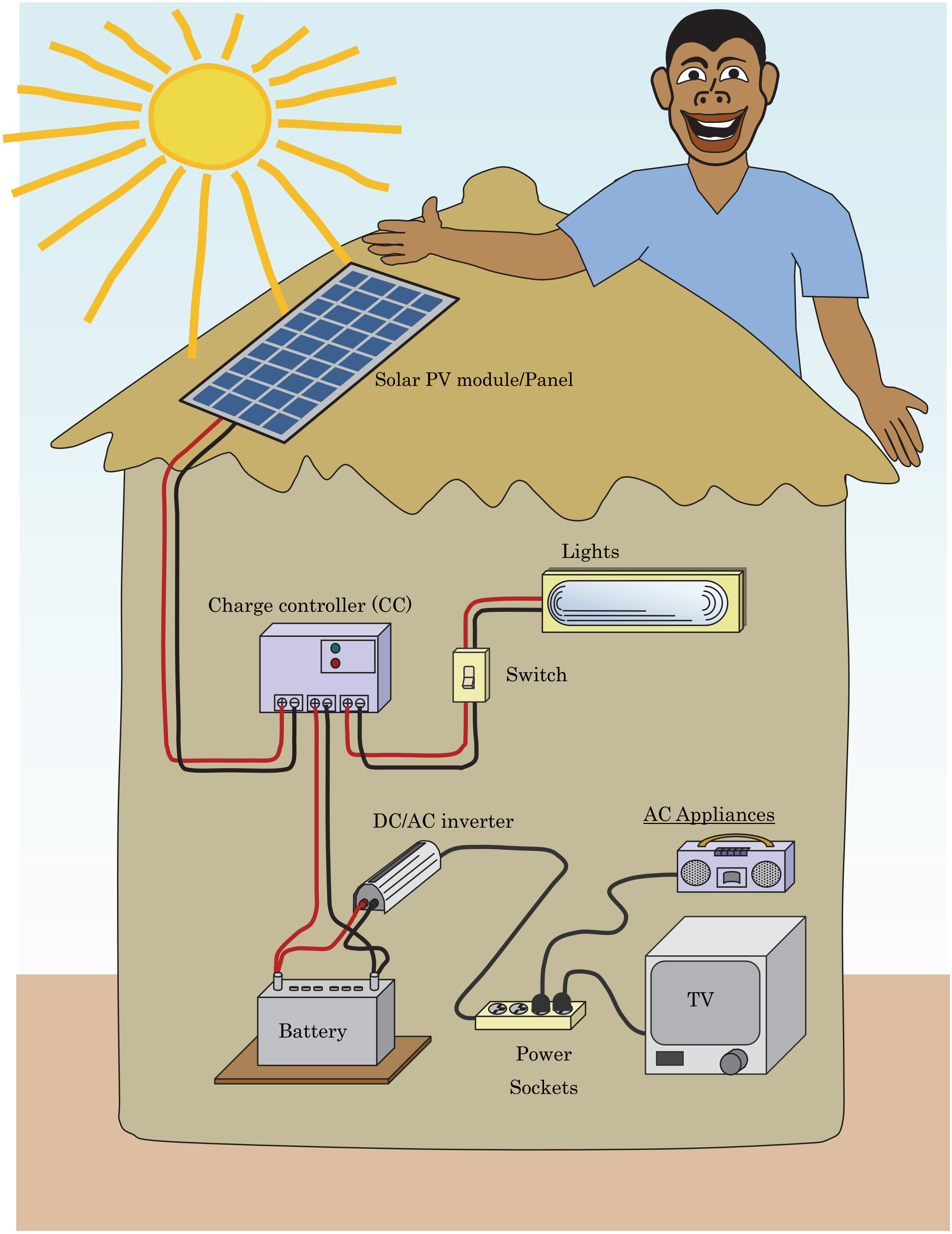
Table of Contents

Solar PV Operation Manual

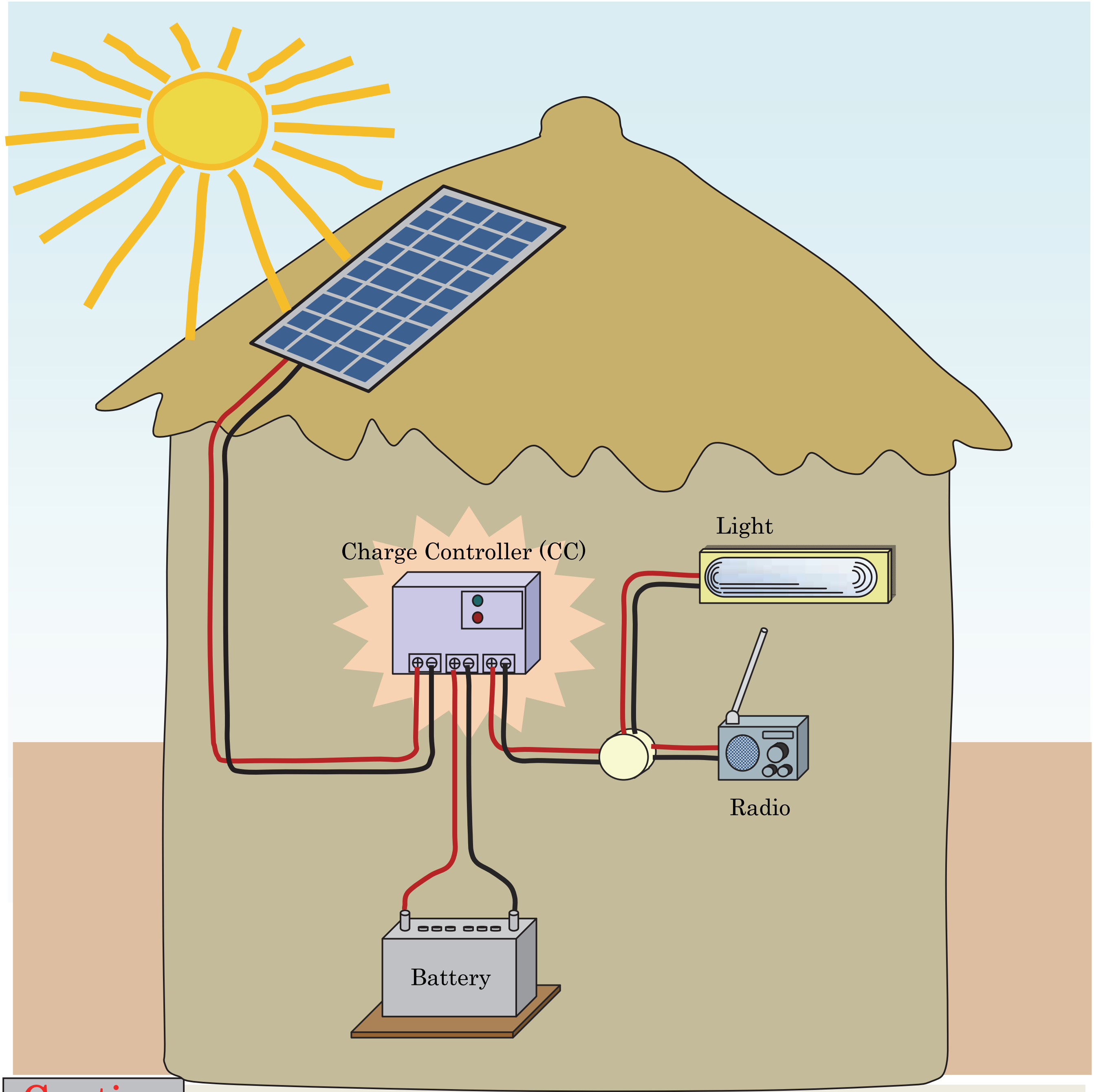


The solar PV is a device which changes light energy to electric energy. Solar PV does not store energy. The light energy (sunlight) acts as a "fuel" for conversion process to produce output (energy).

Basic configuration



DC system

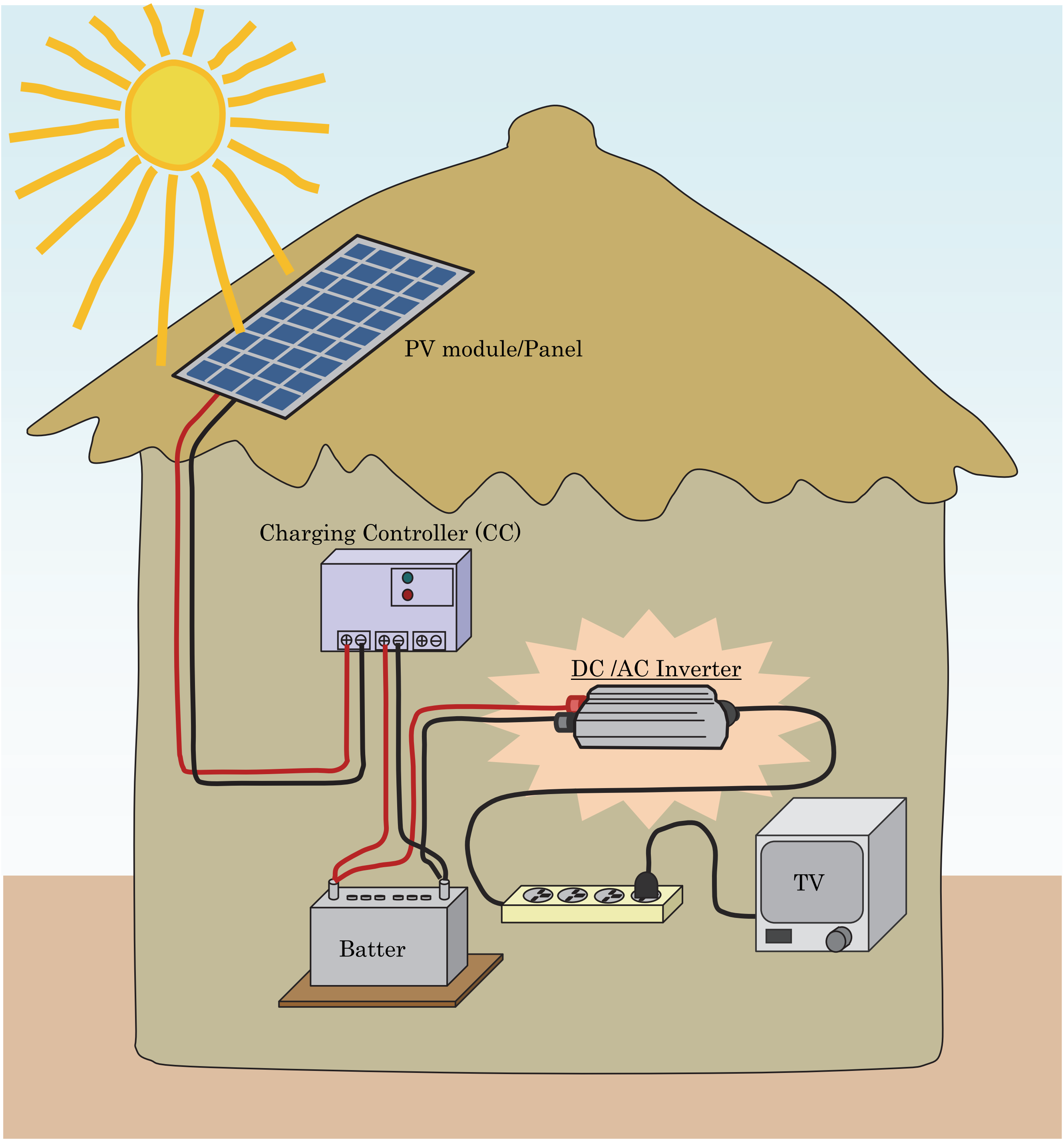


Caution

Direct Current (DC) systems have polarity ("Positive" and "Negative"). The Positive (+ tive) wire is red, while the negative (- tive) wire is black.

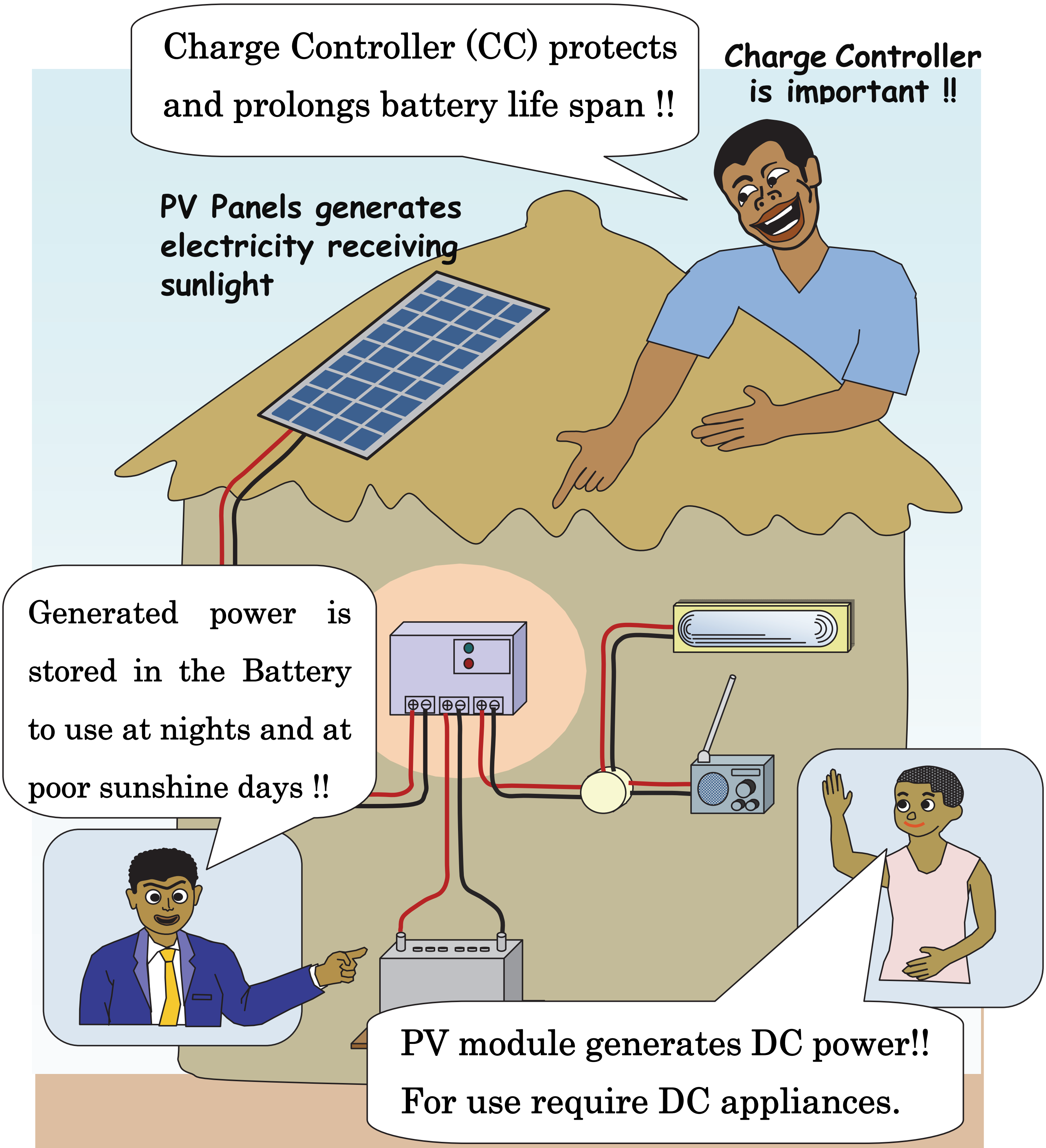
DC systems are similar to the car battery power supply

AC system



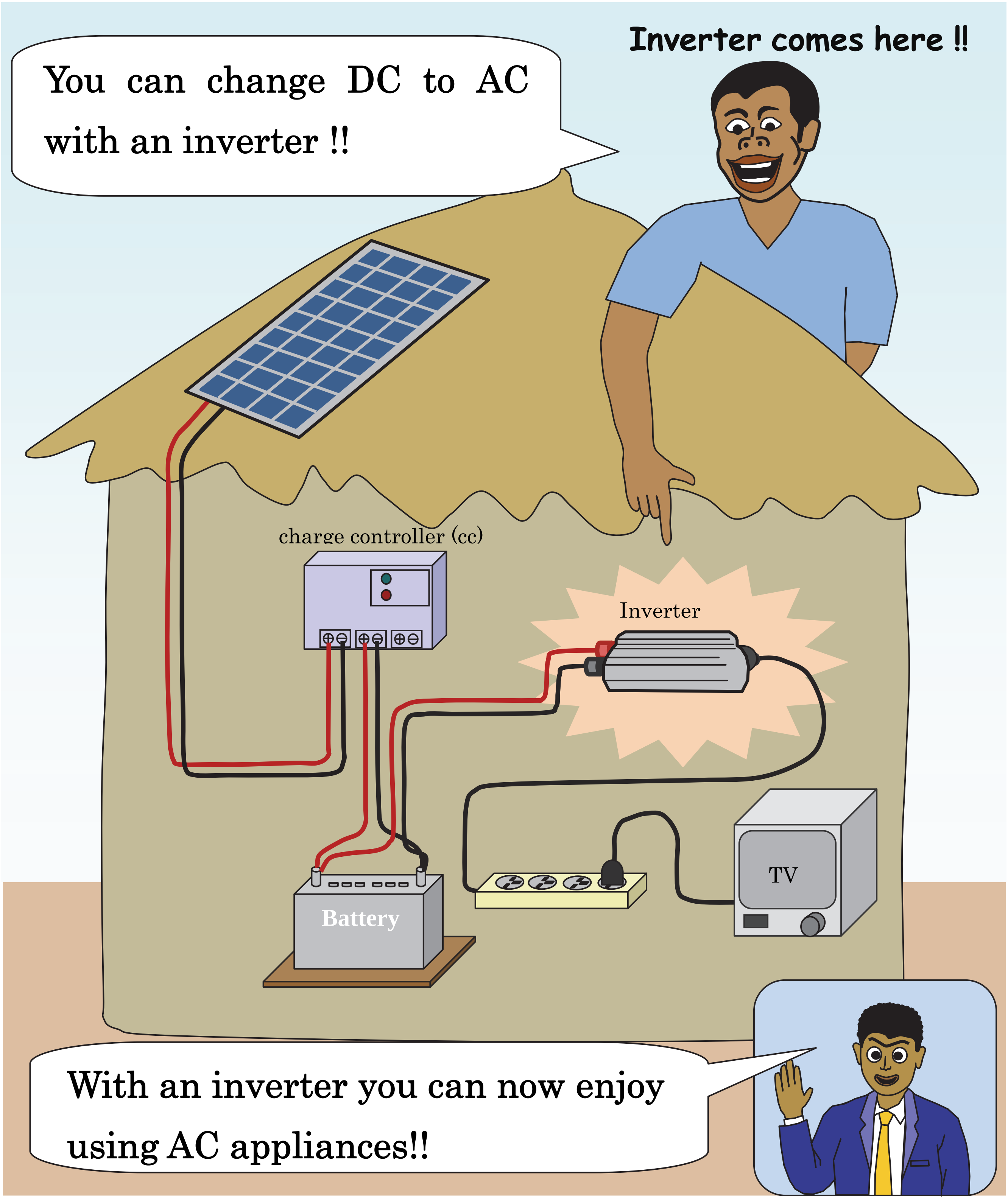
An inverter converts DC power to AC power. This means after the inverter (output), we recive AC power. Therefore, appliances which run on AC are possible to use.

Function of PV components

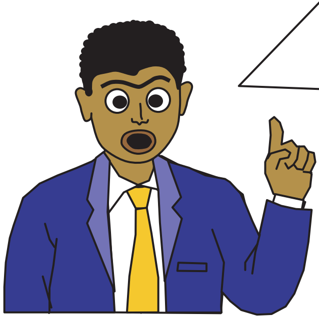


The equipment which runs on DC power does not need Inverter.
DC appliances need to match the DC system voltage to connect with installed PV system.

DC appliances are not so common in practice. But you can use AC appliances if you have an inverter



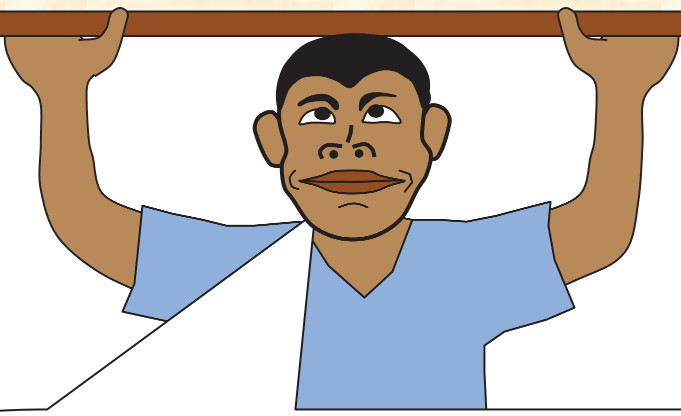
In a PV system,



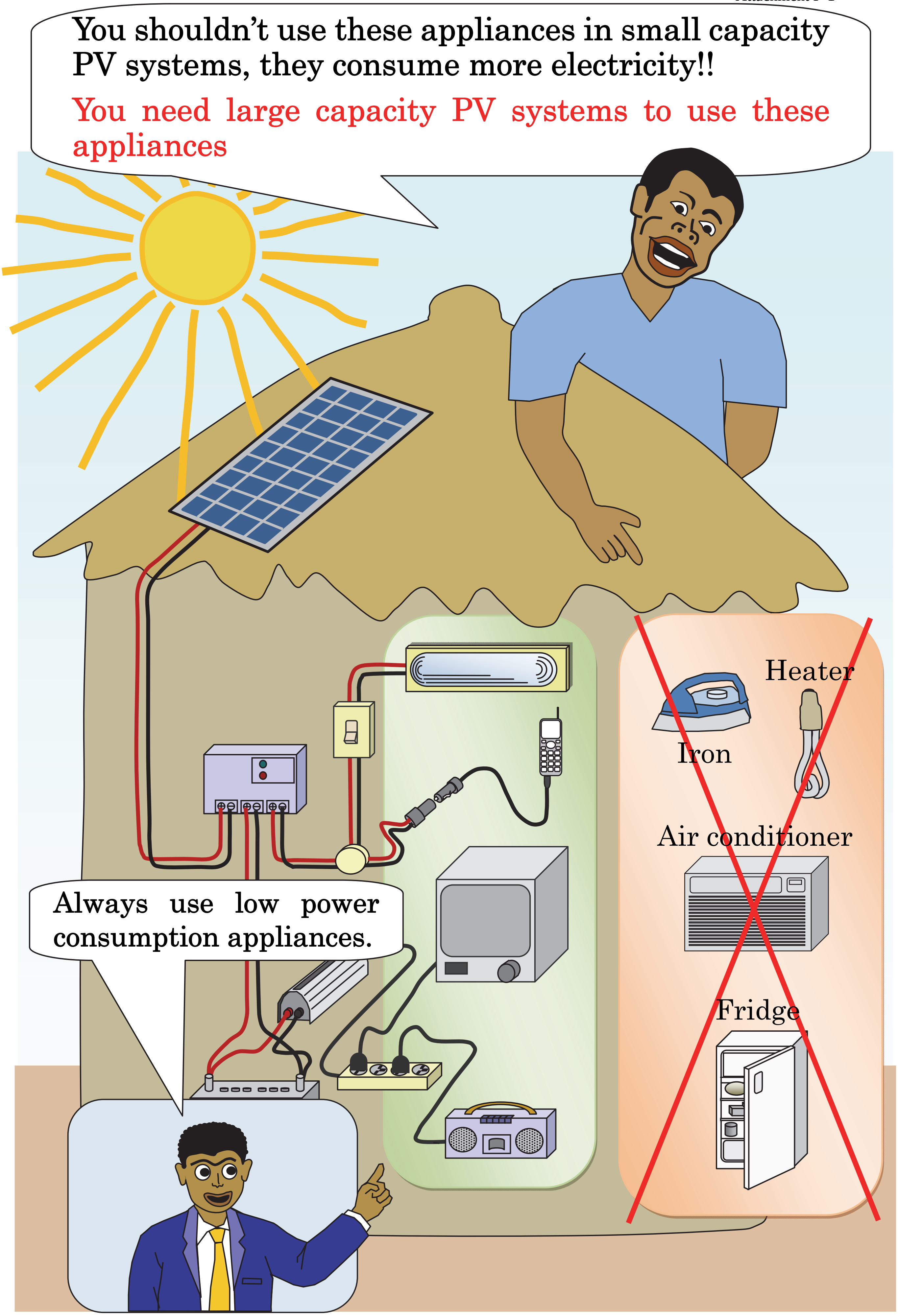
The amount of electricity generation in a day depends on

1. Brightness and duration of Sun visibility.
2. Installation capacity of the PV module/panel

If
Brightness and sun visibility are limited!!
Panel capacity is limited!!
Battery capacity is limited!!
Then,
Electricity you can use is limited.
And,
Appliances you can use are limited.

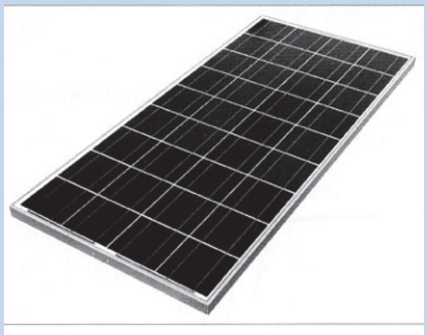


You have to be careful when you choose appliances to use in a PV system!!


You shouldn't use these appliances in small capacity PV systems, they consume more electricity!!
You need large capacity PV systems to use these appliances
Heater
Iron
Air conditioner
Fridge
Always use low power consumption appliances.

Components of PV systems

Panels



Panels generate electricity receiving sunlight.

Output: DC

Capacity: 70W–120W are popular

Lifespan: 20 – 25 years

Batteries

Batteries are use to store electricity for night and on poor sunshine days.

Sealed batteries (no refilling)

Flooded batteries (periodic refilling is necessary)

Capacity: 50 – 200Ah are popular

Lifespan: 3-8 years (depends on use conditions)

Charge Controllers (CC)

Controller protects batteries. They indicate battery condition (“battery full, battery empty, charging).

Capacity: 10-50 A are popular

Lifespan: Around 5-10 years

AC/DC Inverters

Inverters convert DC input to grid electricity (AC). You can use AC appliances with inverters.

Capacity: 300-700 W are popular

Lifespan: Around 5-10 years

Batteries

Battery is important in PV system.

It needs **replacement** in every 3-8 years and it is very expensive. (Life of battery depends on type, intended use and use status).

Savings is necessary for replacement.

In addition, **some batteries** need special care.

There are two types of batteries !!

Flooded type

This type needs maintenance, but cheaper comparing to sealed type

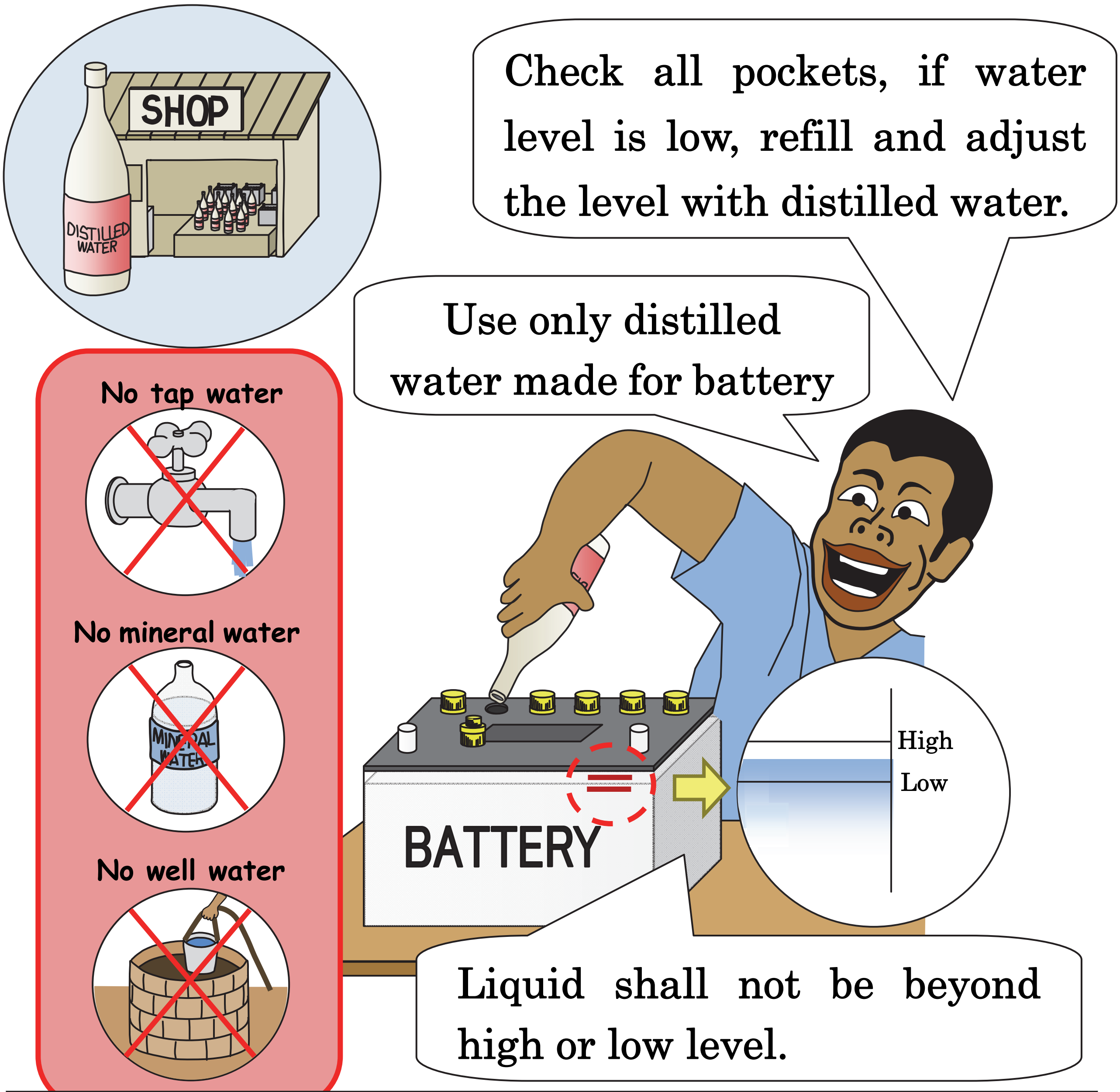
Sealed type

This type does not need maintenance but expensive comparing to flooded type

Battery maintenance

(Flooded type battery)

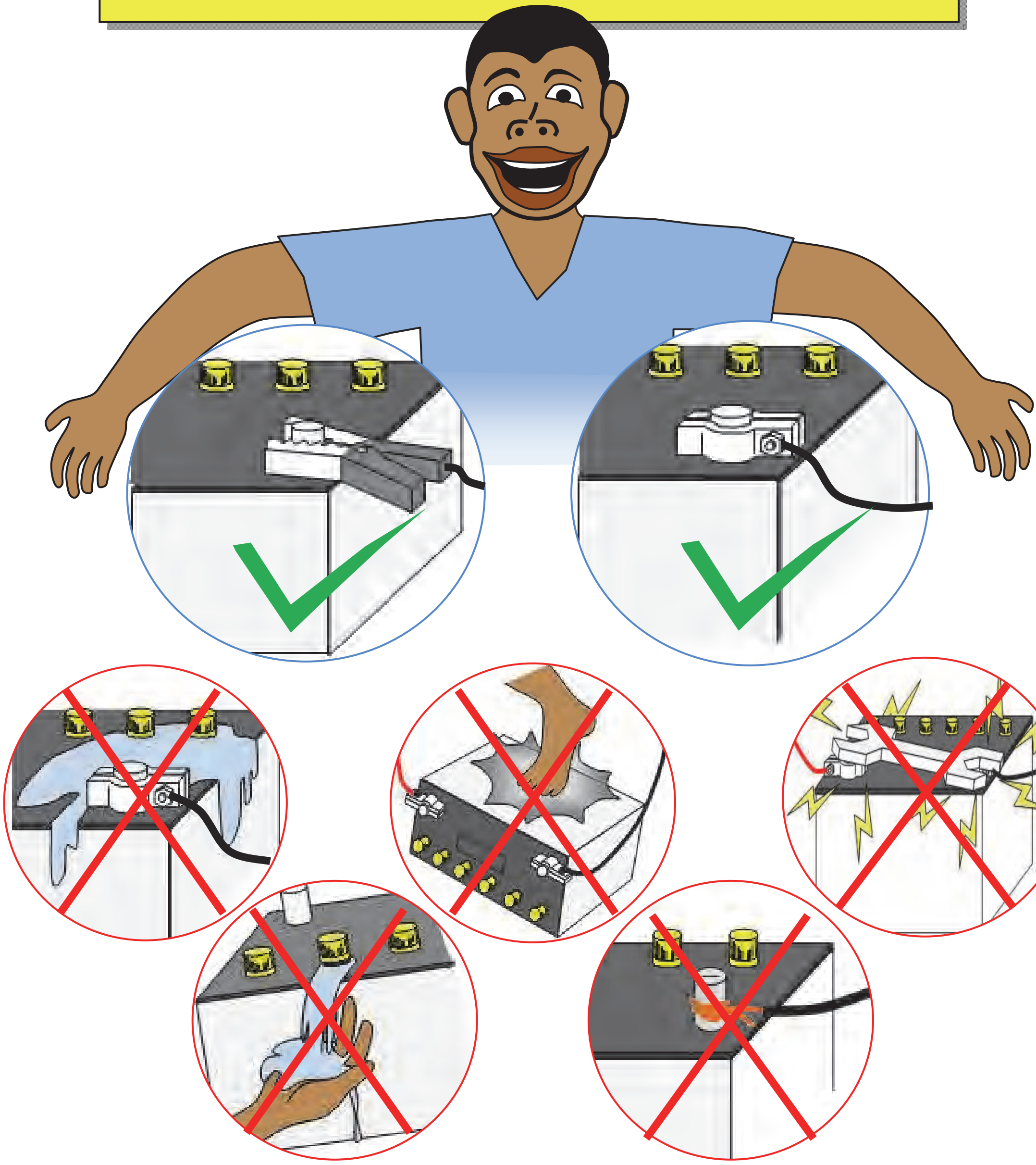
You have to check the water level at least once a month.



CAUTION

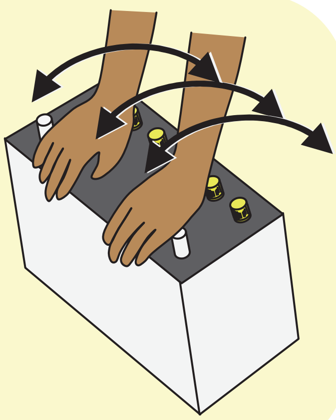
1. Every time you touch battery or battery liquid wash your hands with soap and clean water.
2. Do not touch battery terminals by hand or metallic objects.
3. Do not touch any installed equipment by wet hands, wet clothes or by metallic objects.

Tips on battery use



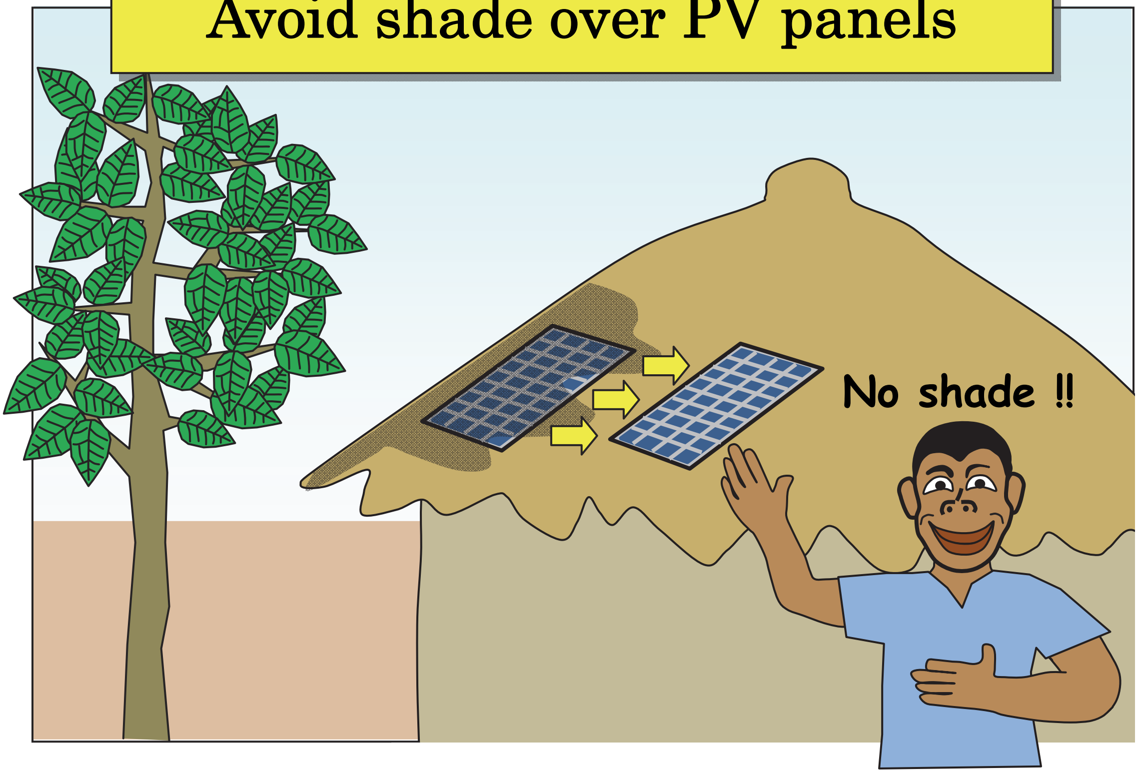
If possible, ...

Shaking prolongs battery life span. Around once a month more than 10 times shaking. **But don't force and should not be unreasonable.**

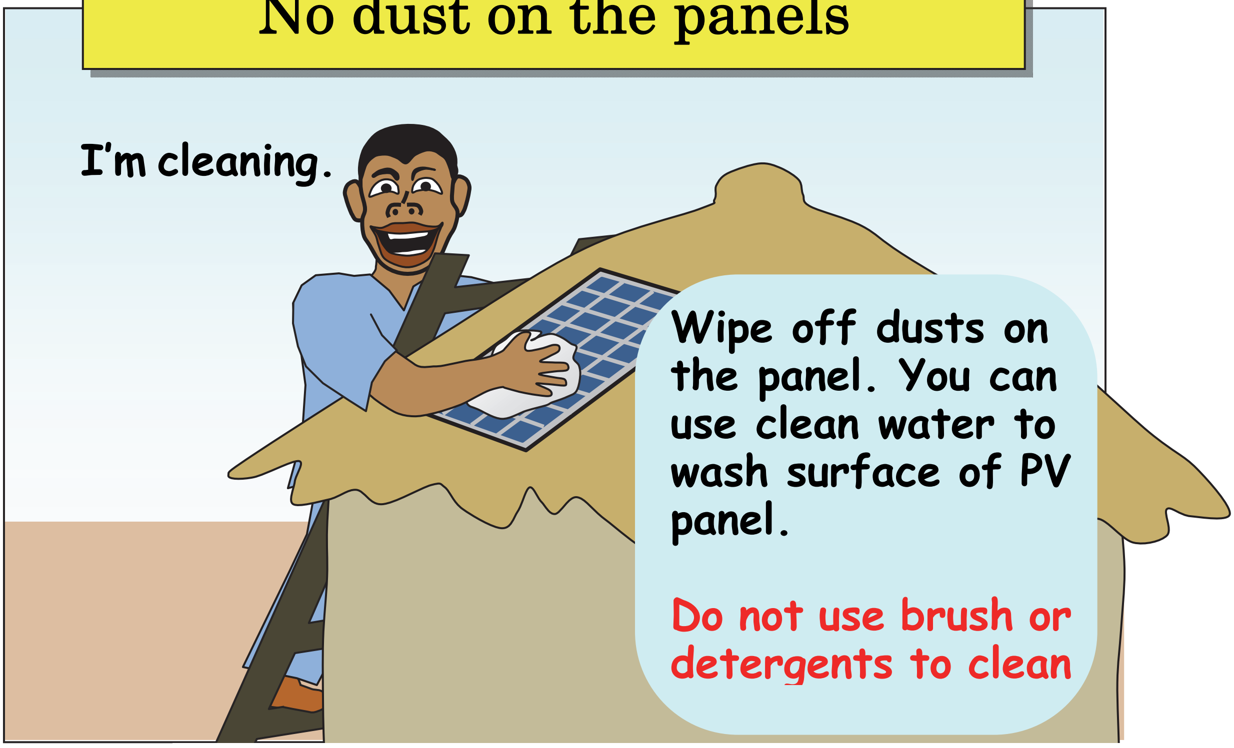


Other maintenance for PV system

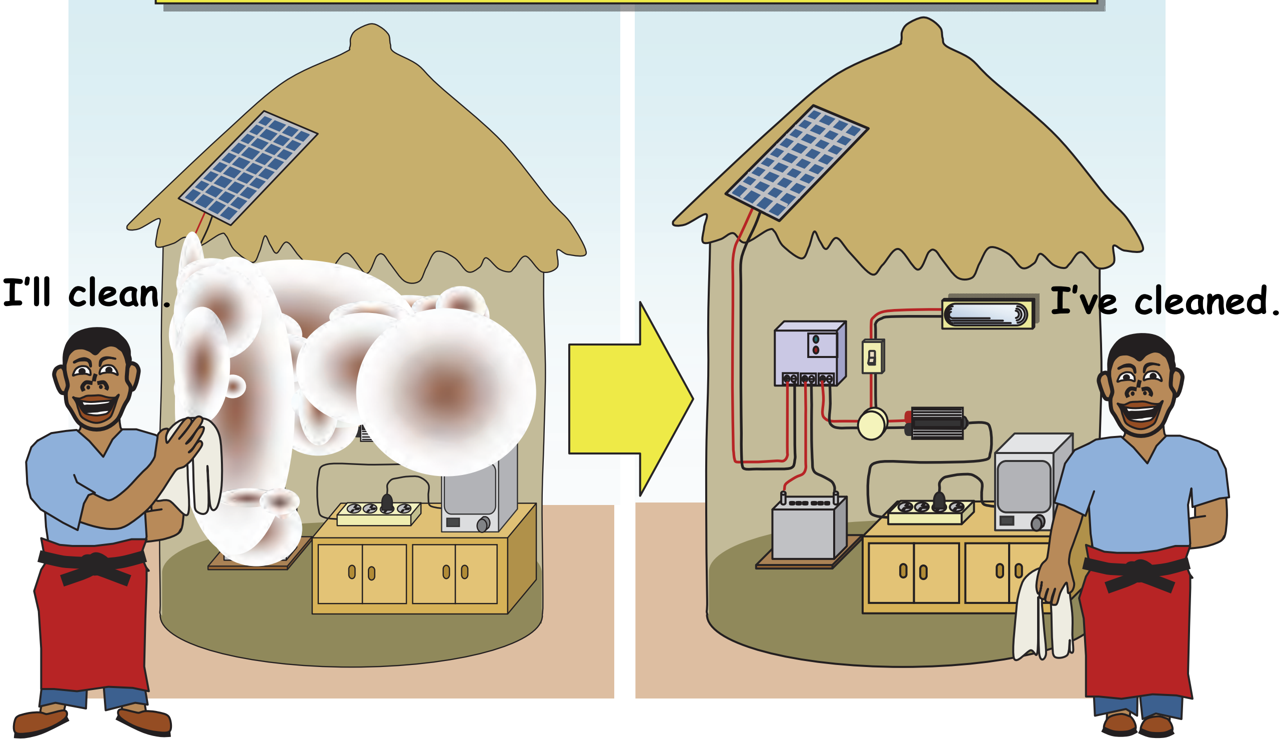
Avoid shade over PV panels



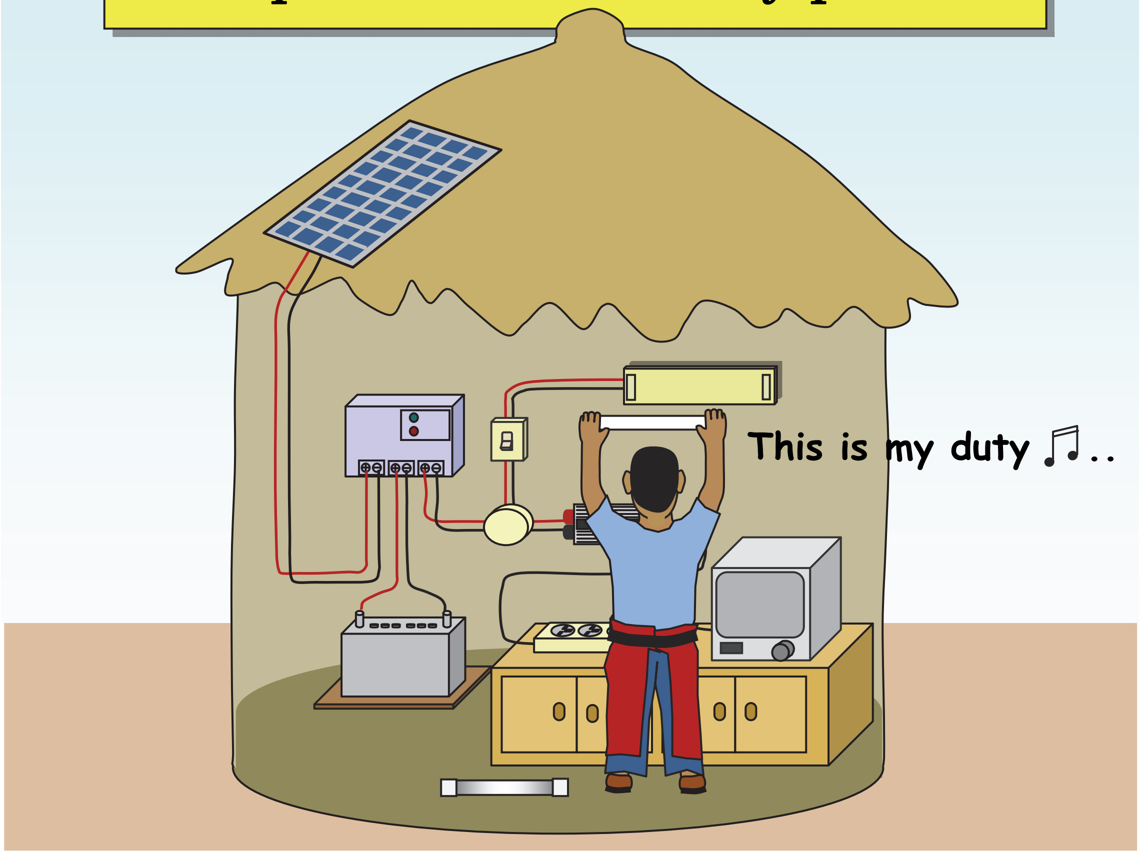
No dust on the panels



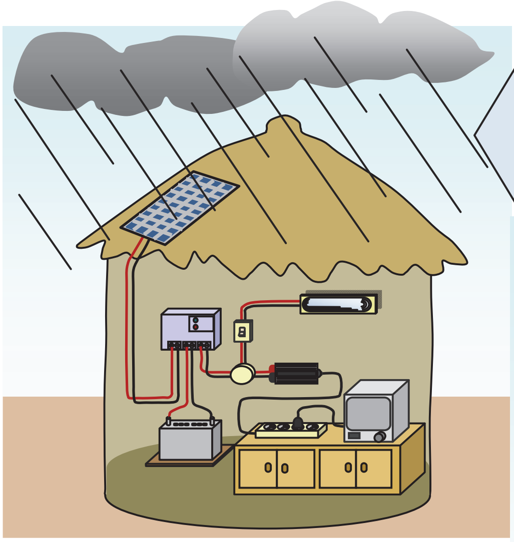
Cleaning of PV system



Replacement of faulty parts

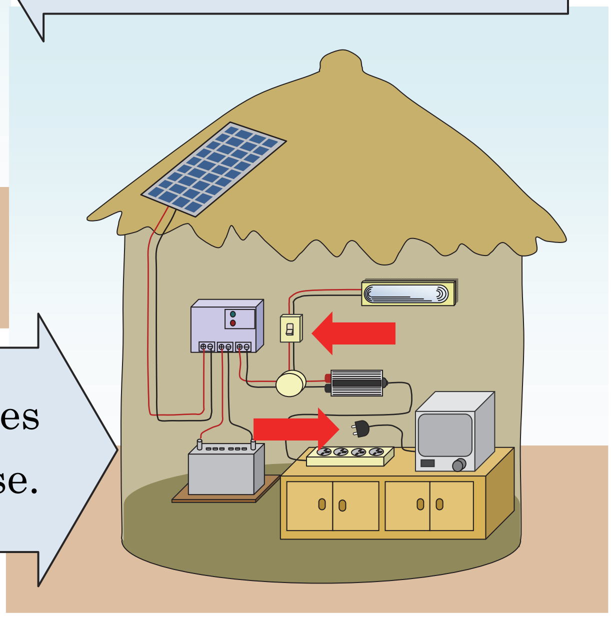


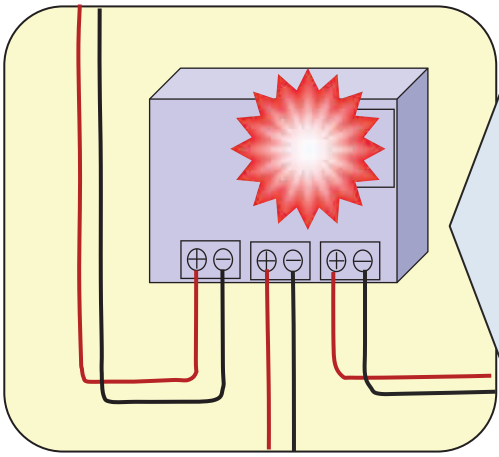
General operation tips



Save energy use on rainy days and cloudy days.

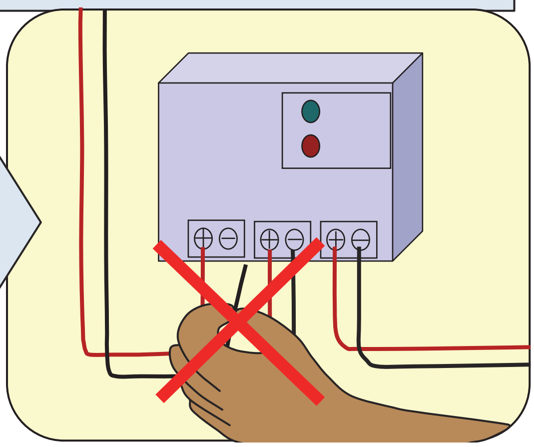
Switch off appliances when they are not in use.





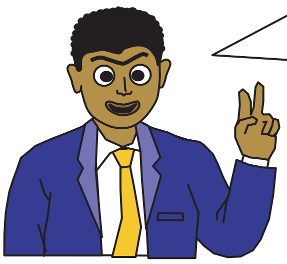
Check the indicator on the controller. If “battery is low”, then switch off appliances and manage the supply until Battery indicates charged.

Don’t change wiring.



PV systems at public institutions

Electrification of public institution is important. Solar PV is often used for electrifying remote rural public institutions. The government is responsible for the electrification, but maintenance is left to each institution's hand.



Two issues for PV maintenance.

- Saving money. **Financial issue**
- Having proper knowledge. **Technical issue**

With charging business,

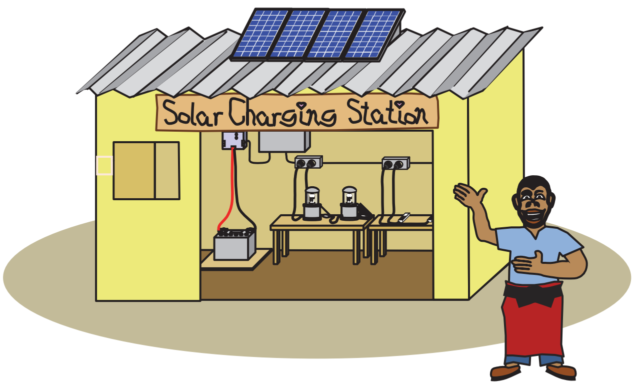
Financial issue

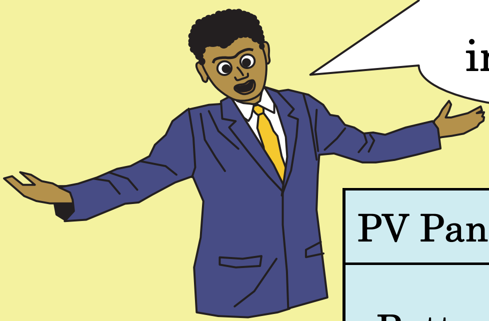
The business can generate money. You can use it for maintenance.

Technical issue

The operator must have proper knowledge on operation and maintenance.

The community people can enjoy rechargeable appliances, in addition.



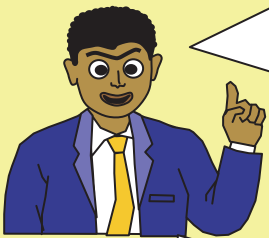


Life of equipment depends on the type and use status. Replacement is an important part of sustainability.

How long they will work?

PV Panel/module		20 - 25 years
Battery	Solar battery	3 - 8 years
	*Car battery	2 - 3 years
Inverter and Controller		5 - 10 years
Lamps	Tube	2 - 4 years
	LED	5 - 10 years

*Generally Car batteries are not recommended for Solar PV systems



Battery should be periodically replaced.
And battery is very expensive.

A lot of money is needed periodically !!

Financial issue

The operator of the charging station should be **trained properly** so that replacement will be possible to carry out properly.

Technical issue

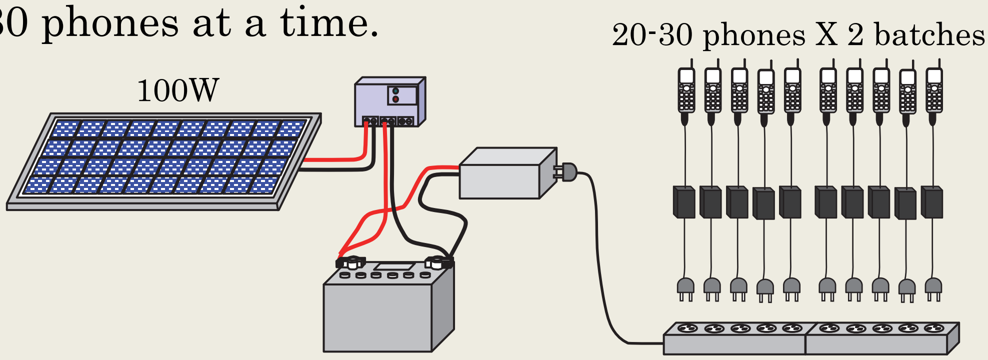
I am trained!!

I can repair the system!!

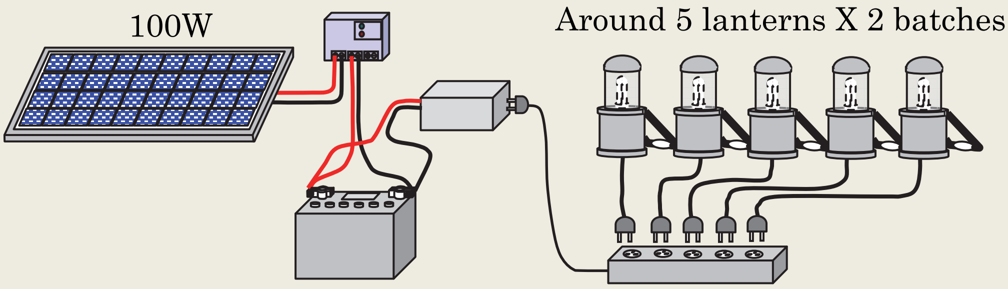
Save energy use and prolong battery life. Then you can save battery replacement cost.

Possible number of charges (Example)

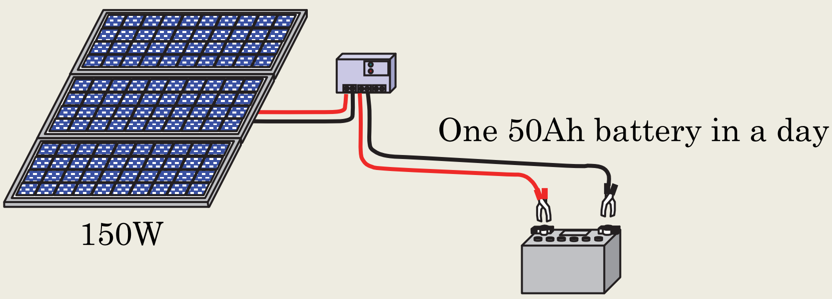
Around 50 Mobile phones can be charged in a day by a 100W panel.
20-30 phones at a time.



10 lanterns can be charged in a day by a 100W panel.
5 lanterns at a time.



One 50Ah battery needs 150W panel to charge in a day.
Battery needs much energy to charge.



Business tips

- **Lanterns shall be recharged at least once a month even it is not used.**

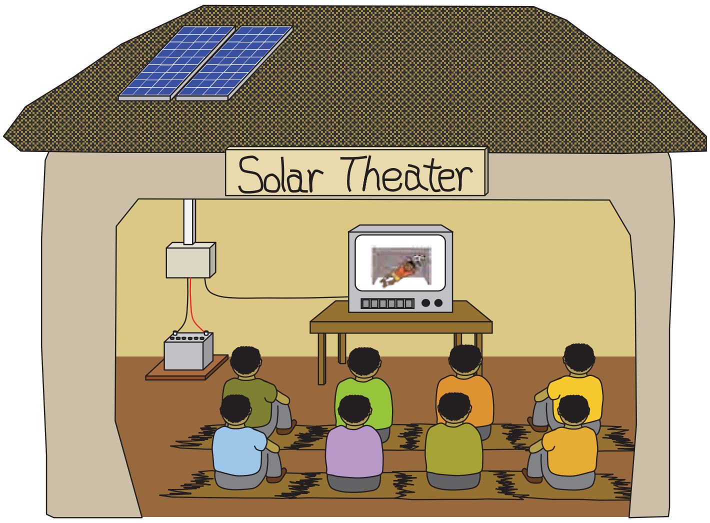
Most batteries in lanterns are sealed type lead acid. If lanterns are left uncharged for several months, these batteries will be damaged. Even if the lanterns are not used, they have to be charged at least once a month. This should be known to users so that they would not store lanterns for a long time without charging. Less discharge and frequent charge will extend the life of the battery.

- **Maintenance tools**

Good tools are needed for good maintenance. The charging station has to be equipped with such tools.

Possible PV business

- TV viewing



100 – 200W PV system is needed.

DVD player and TV are necessary.

- Hair salon

Minimum 50W PV system is needed.

The barber can use electric hair clippers.

Any other business ?

Troubleshooting

Clean and retighten!!

Many Problems are caused by loose connection, rust and dusts.

Before going into troubleshooting,
you should check wirings and retighten connections!

After this,

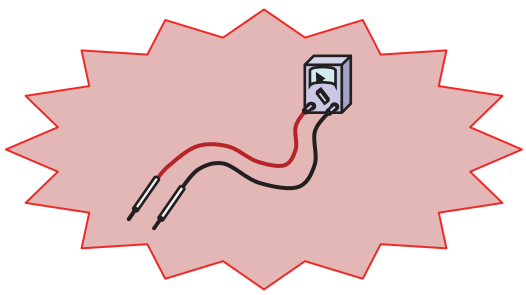
If only one appliance is in trouble, problem is the appliance itself or the wiring to it. Replace the appliance or the wiring.

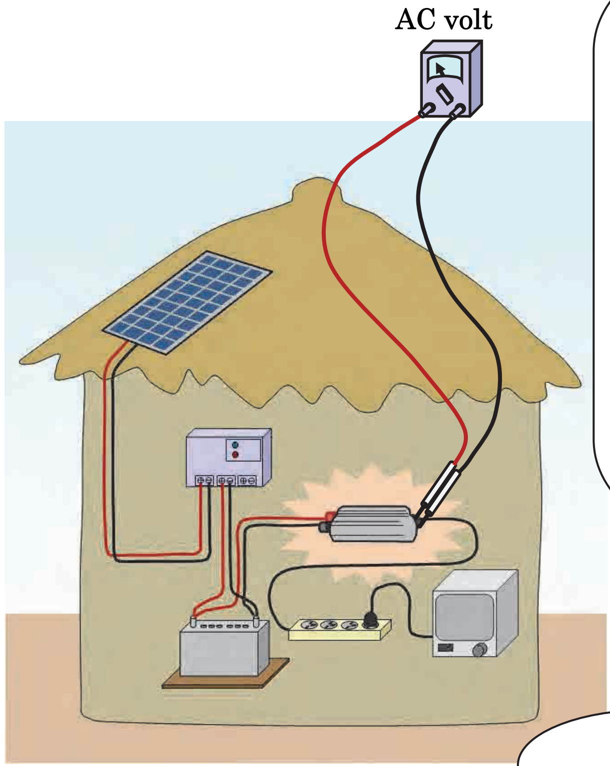
If many appliances are in trouble, then the power supply system is doubtful.

Then, you have to start checking the system.

- - - - - next page

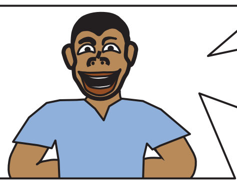
You need a multi-meter!!

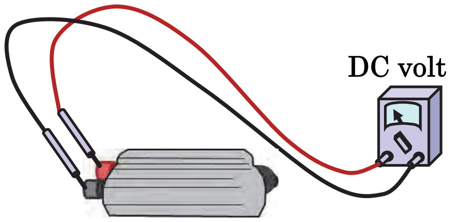




1. Inverter check

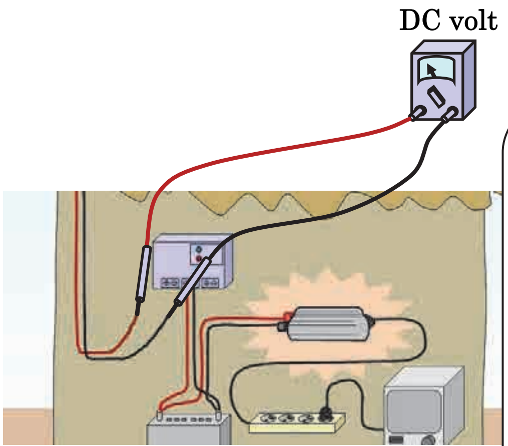
Measure the inverter output. If it is around AC220V to 240V, then Inverter is OK, check the AC wiring and connections.
If it is less than AC220V, then check the inverter input. If it is around DC12V for 12V system, DC24V for 24V system and DC48V for the 48V system (laptop system) then the inverter is faulty.





2. Battery check

If Voltage is less than DC12V for a 12V PV system or less than 24V for a 24V PV system, and DC48V for the 48V system (laptop system) in sunny day then the battery is faulty.



Disconnect panel line.
Then, measure voltage.

3a. Panel check

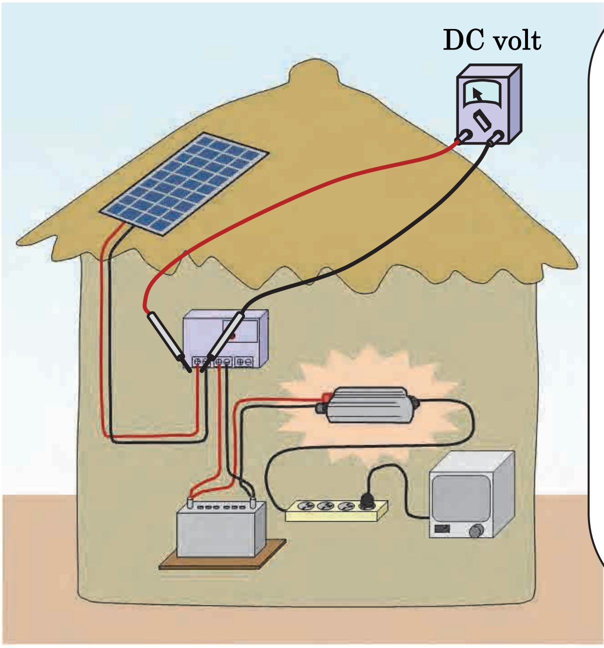
Disconnect panel lines from the controller (turn Isolator to OFF) and measure panel voltage at the isolator. If PV panel voltage is less than DC16V for 12V system or 32V for 24V system on a sunny day then the panel is faulty.
If panel output is more than DC16V or DC32V then panel is OK.

3b. Panel check for laptop system

Disconnect panel lines from the controller (turn off all the breakers at Junction Box) and measure panel voltage at the sub breakers inputs. If PV panel output voltage is more than DC64V then the panel string is OK. If PV panel Voltage is less than DC64V on a sunny day then that panel string is faulty.

Measure all strings one by one and keep record. There will be some difference. It should not be more than ±10%

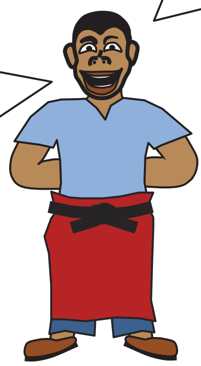
If PV panel output voltage is more than DC64V for all the strings then turn on the sub breaker one at a time and check the voltage at the input of the main breaker. If the voltage is nearly the same as the one on the input of the sub breaker then the diode is OK, If there is a very big difference between the voltage at the input of the main breaker and the input of the sub breaker (when the other 3 sub breakers are off) then the diode might be faulty.



4. Charge Controller check

Measure DC voltage at battery terminal of the controller. If it is around DC 12V for 12V system or 24V for 24V system, then the battery is OK.

Reconnect the PV panel lines to the controller (turn Isolator to ON) and check the PV panel terminal of the controller. If it is more than DC 16V for 12V system or 32V for 24V system, then the controller is faulty.



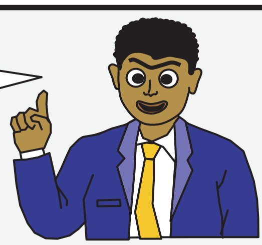
If you are using DC output (load terminals) of the controller, check the load terminal of the controller.
If the output is not nearly the same as the battery voltage, then the controller is faulty.

To decide whether the controller is faulty or not, first disconnect the PV panel by turning isolator to OFF position. Then check the fuse installed in between the Charge Controller (CC) and the battery, if the fuse is blown then change the fuse.
To reconnect, follow exactly opposite of disconnection.

CAUTION

Never take out the fuse installed in between the CHARGE CONTROLLER and BATTERY before turning OFF the ISOLATOR, installed between PV panel and Charge Controller (CC)

You have to report the results to the installer or a local PV technician and discuss how to repair it.



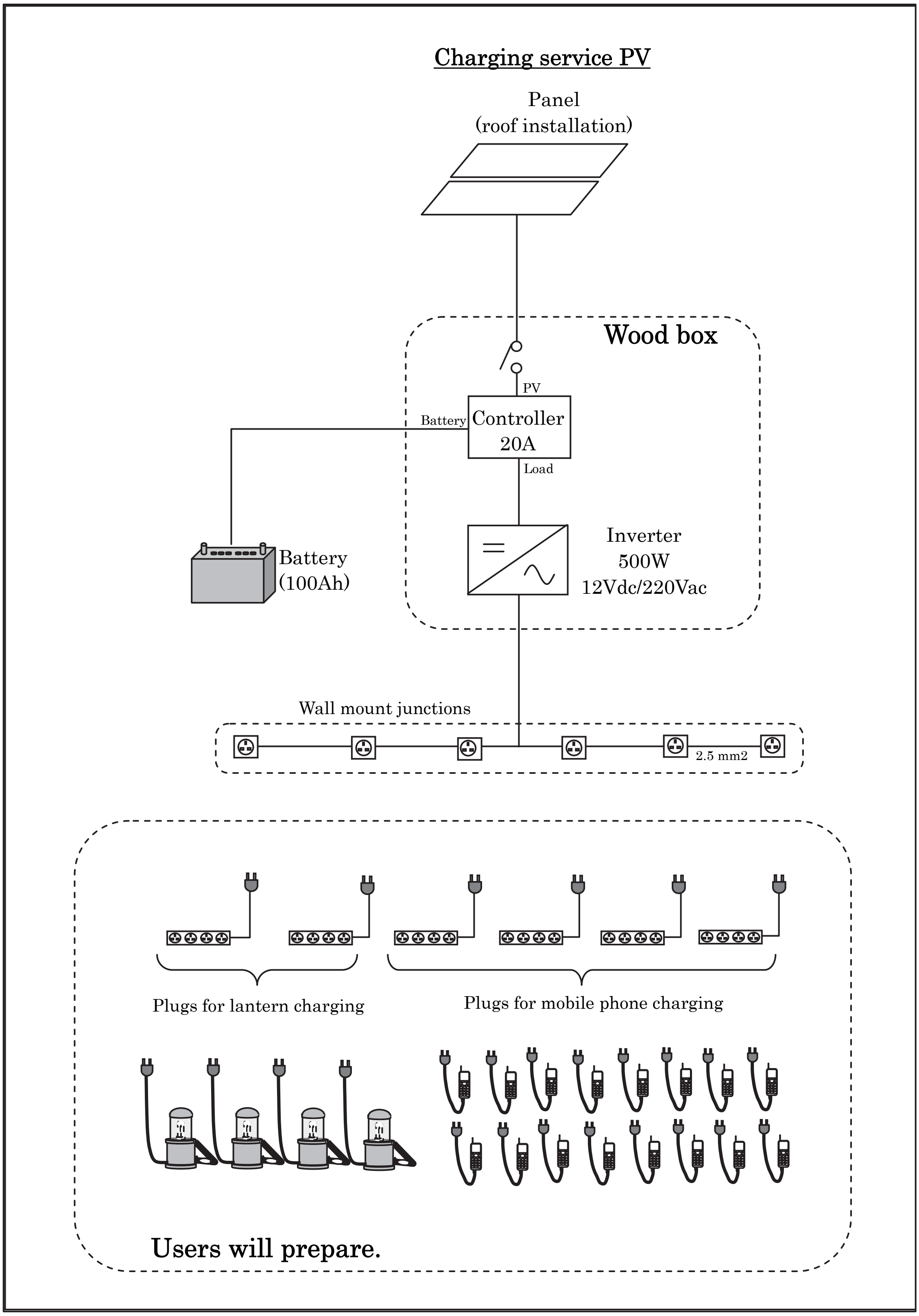
Charging station

Charging station is not so large.

Operating by Technician.

Power outlets on the wall and a shelf are convenient for the operation.

line drawing of PV charging system



Important Tips

Isolator is a switch which can isolate PV panel from connecting to the Charge Controller (CC)

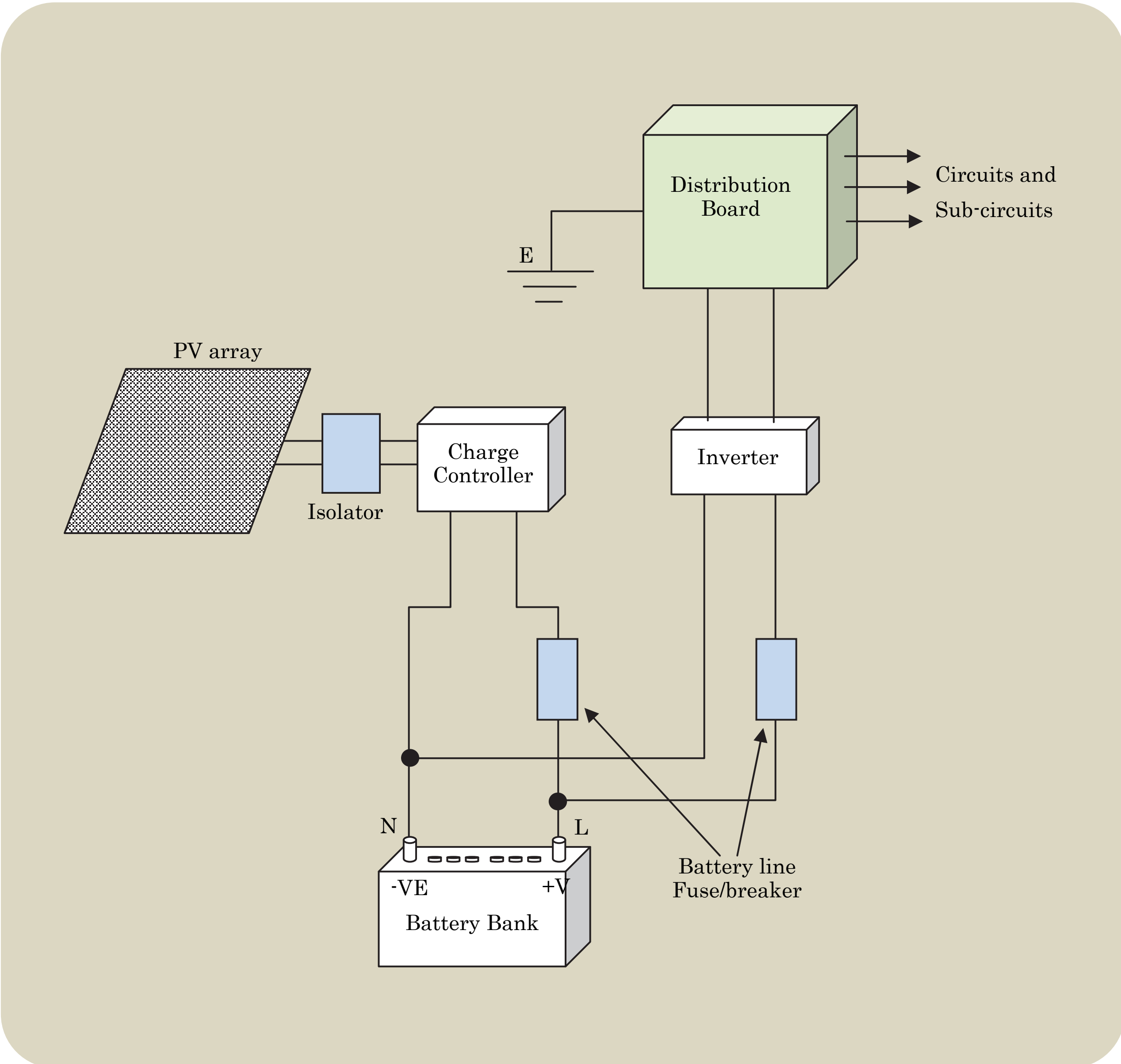
SW off when thunder comes and during O&M when required.

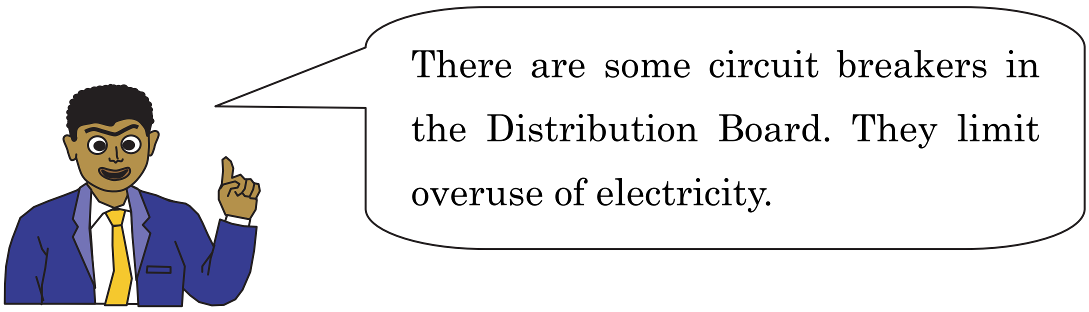
Fuse/Breaker is necessary in between;

1. Charge controller and Battery
2. Battery and Inverter

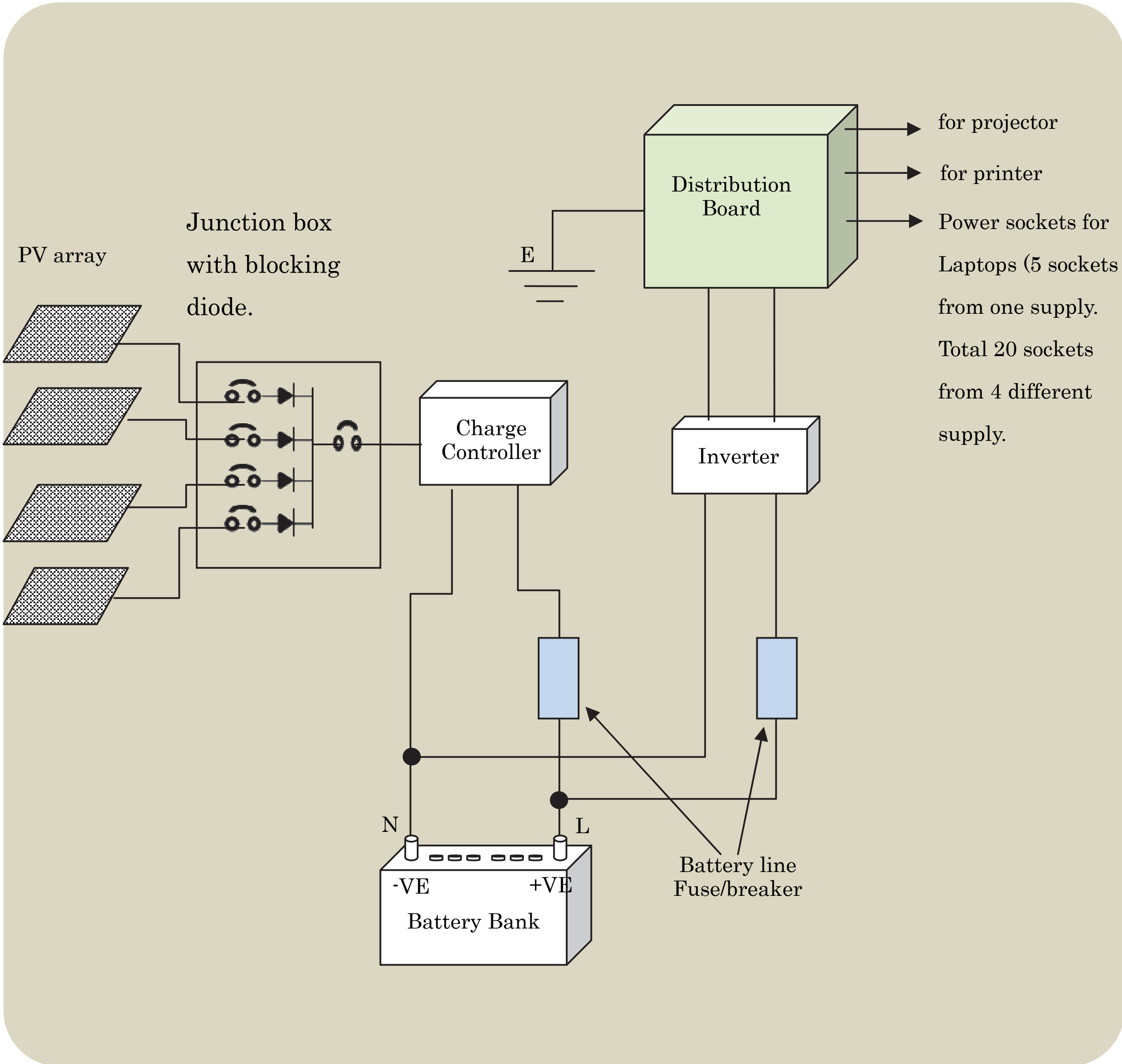
The Fuse/breaker protects the circuit from short circuit trouble

General configuration
of PV power supply system



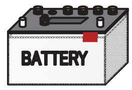
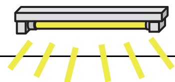
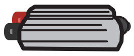
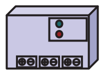
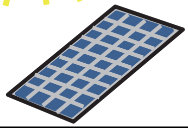


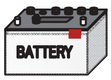
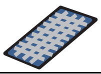
General configuration
of laptop PV power supply system



Manual for E-waste Disposal

E-Waste is generated after long life span of equipment.

E-waste	Hazardous Element
Used Lead-acid batteries	Lead and Sulfuric Acid 
Used Fluorescent tubes	Mercury 
Used PV panels, Inverters and Other appliances	Other Heavy Metals   

Component	Possible Life Span* (years)	Handling	Remarks
Battery 	3 to 8	・ To prevent diffusion of toxic substances in batteries, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly dispose them. ・ Used batteries can be sold to licensed e-waste handlers and/or battery producing companies in Kenya	・ Get latest information from licensed e-waste handlers or NEMA county offices. ・ Purchase prices of used batteries are subject to the market trends
Fluorescent Lamp 	2 to 4	・ To prevent diffusion of mercury in fluorescent lamps, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly dispose them. ・ Used Fluorescent Lamps shall be transported to licensed e-waste handlers in Kenya to be disposed.	Get latest information from licensed e-waste handlers or NEMA county offices. 
LED Lamp 	5	・ Used LED Lamps shall be transported to registered e-waste handlers in Kenya to be disposed.	
PV Solar Panel 	20 to25	・ Used PV Solar Panels shall be transported to registered e-waste handlers in Kenya to be disposed.	
Inventor 	5 to 10	・ Used Inventor shall be transported to licensed e-waste handlers in Kenya to be disposed.	

* Note: Vary depending on the intended use as well as status of use

E-wastes such as used-batteries shall be transported to the licensed E-waste handlers and/or battery makers. You can ask for disposal when replace used batteries!!

2. Solar PV Organizational Management Manual

Public facilities, i.e. dispensaries and primary schools and people of their neighbourhood communities benefit from solar PV systems for health care and improvement of education. Solar PV systems will not function well if they not operated and maintained properly.

Public facilities and management committees have responsibility to take care of the PV systems by establishing management system and finance for sustainable system use.

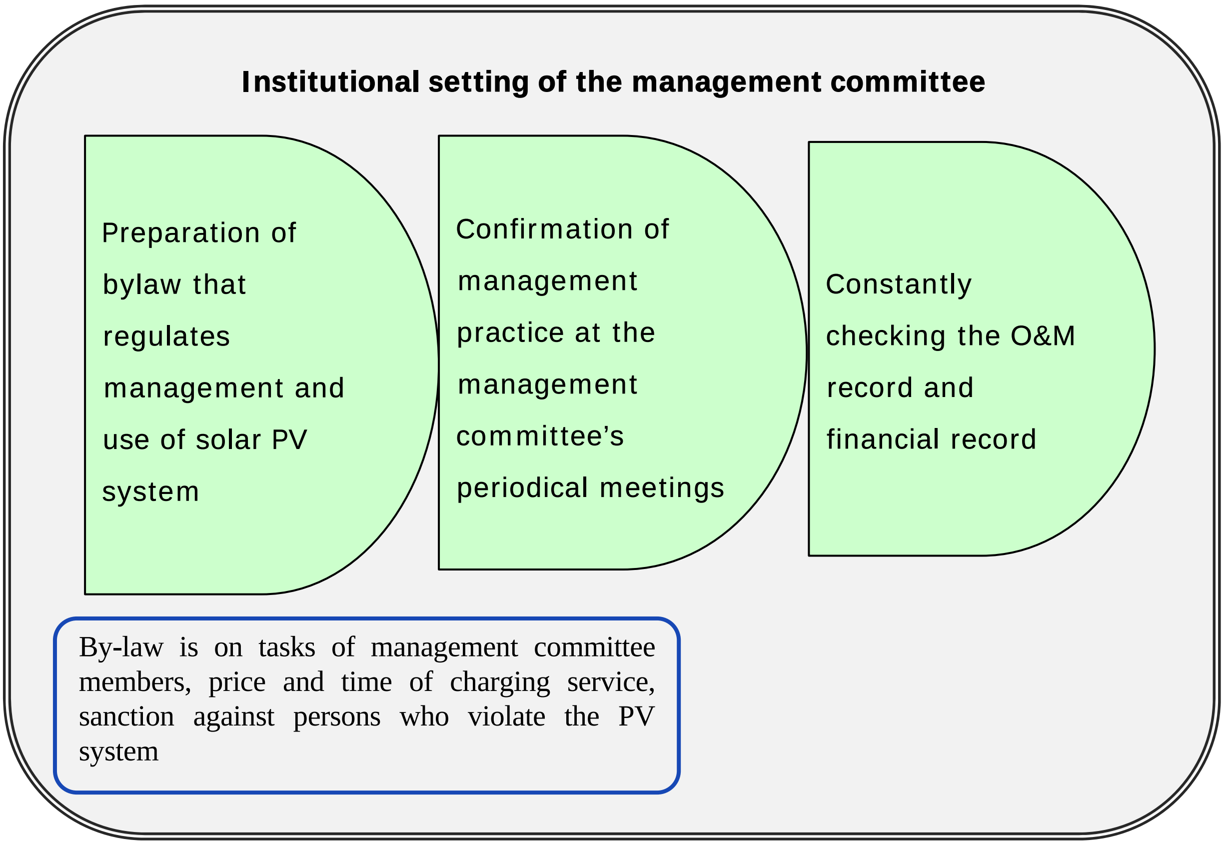
This manual explains to dispensary/school staffs and management committee members how they should manage the solar PV system to get long time use up to the life time of solar panels.

(1) Tasks of management committee members and operator

Organization	Responsibility
Operator	• operation and checking condition of solar PV system daily, • periodical water topping, • collecting and recording proceeds from charging service, hair shaving, and other businesses • informing daily sales to treasurer (or secretary)
Treasurer and/or secretary	• examining the daily record and collecting proceeds • keeping account book • reporting the financial state to the chairman and other members • deposit of proceed at the bank account • purchase of distilled water and other necessary equipment and tools
Chairperson	• Confirmation of the financial report and O&M report • Submission of the financial report and O&M report to the county ministry office (monthly) • Overall supervision about the solar PV system management
Dispensary, school and management committee	• advertizing and implementation of charging service, • securing the safe condition of solar panels
Users (community people, pupils):	• use of the charging service, • keeping solar panels safe
County offices of MOH (and MOEST)	• budget preparation for future replacement of batteries, inverters and controllers, • receiving financial status report (included in the regular report) and

Organization	Responsibility
	O&M report, • identifying problems of solar PV system mentioned in the reports, • by-yearly inspection of system condition = MOH

(2) Institutional setting

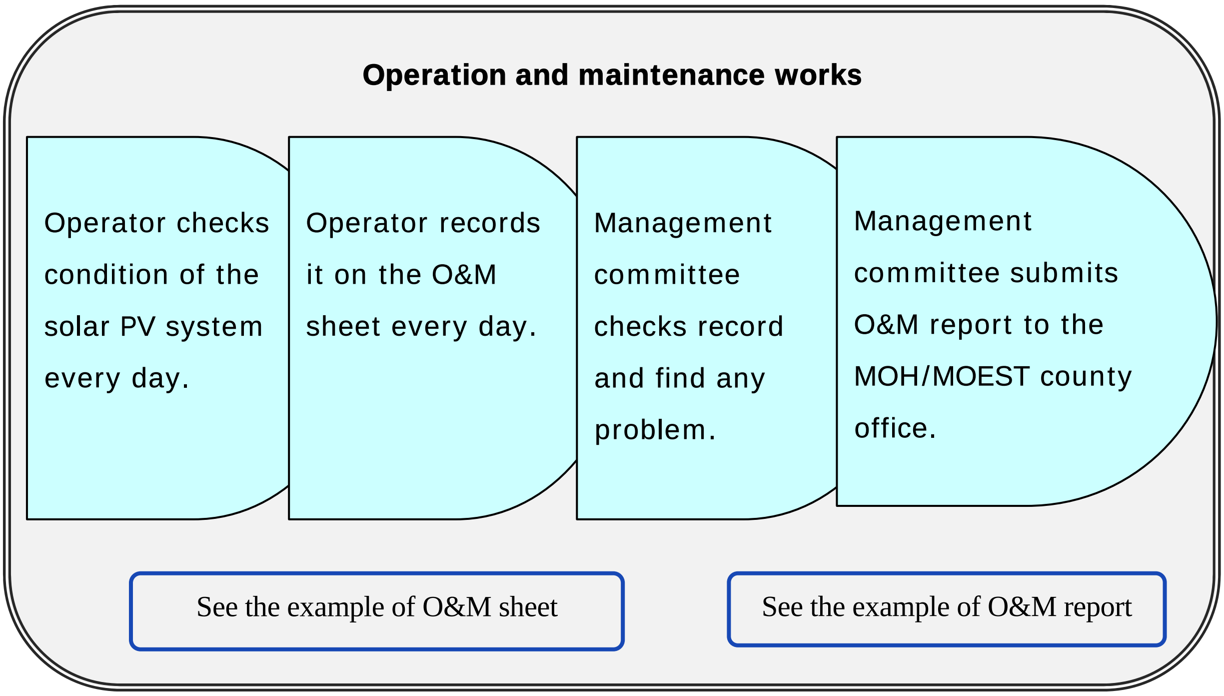


What is important for management committee? Management committee and facility staff members are responsible persons for PV system management. They need to establish institutional framework within the committee to ensure sustainable system use.

What is important for management committee? Management committee and facility staff members are responsible persons for PV system management. They need to establish institutional framework within the committee to ensure sustainable system use.

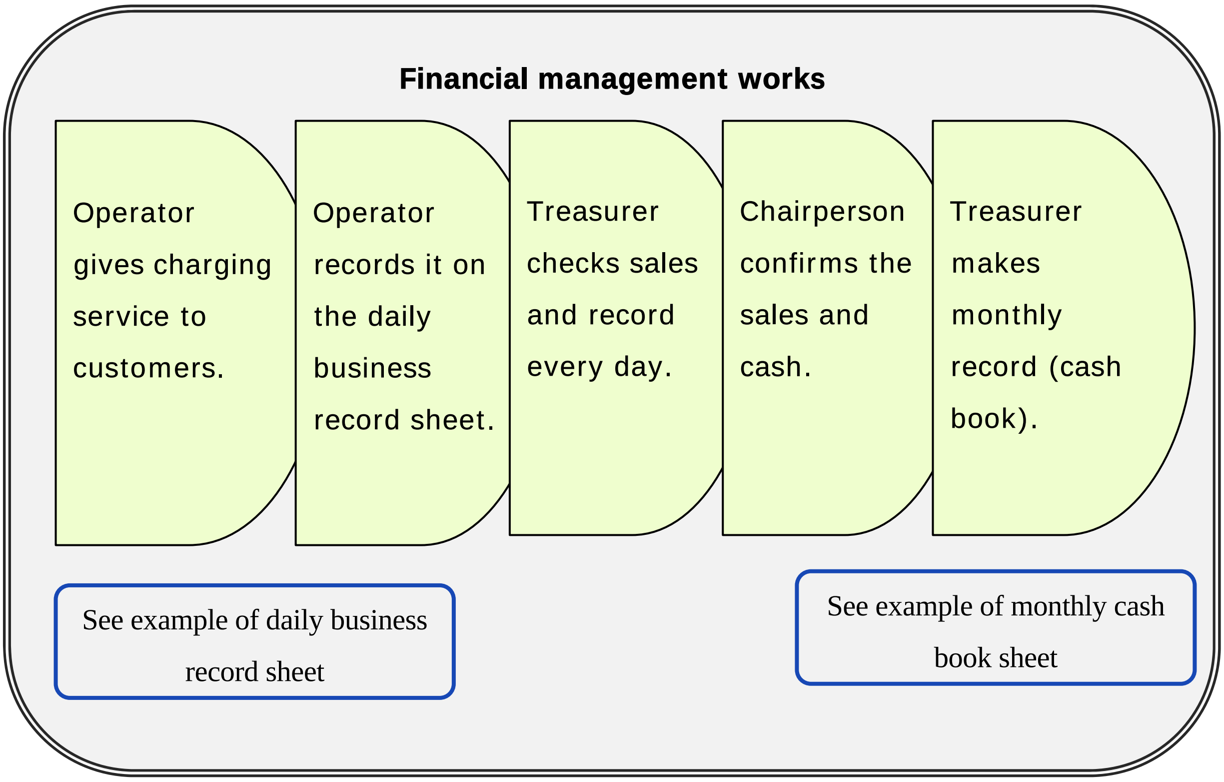
By-law contains works of management committee members and operator, time and price of charging service, sanction against persons who violate the solar PV system and other necessary items.

(3) Operation and Maintenance



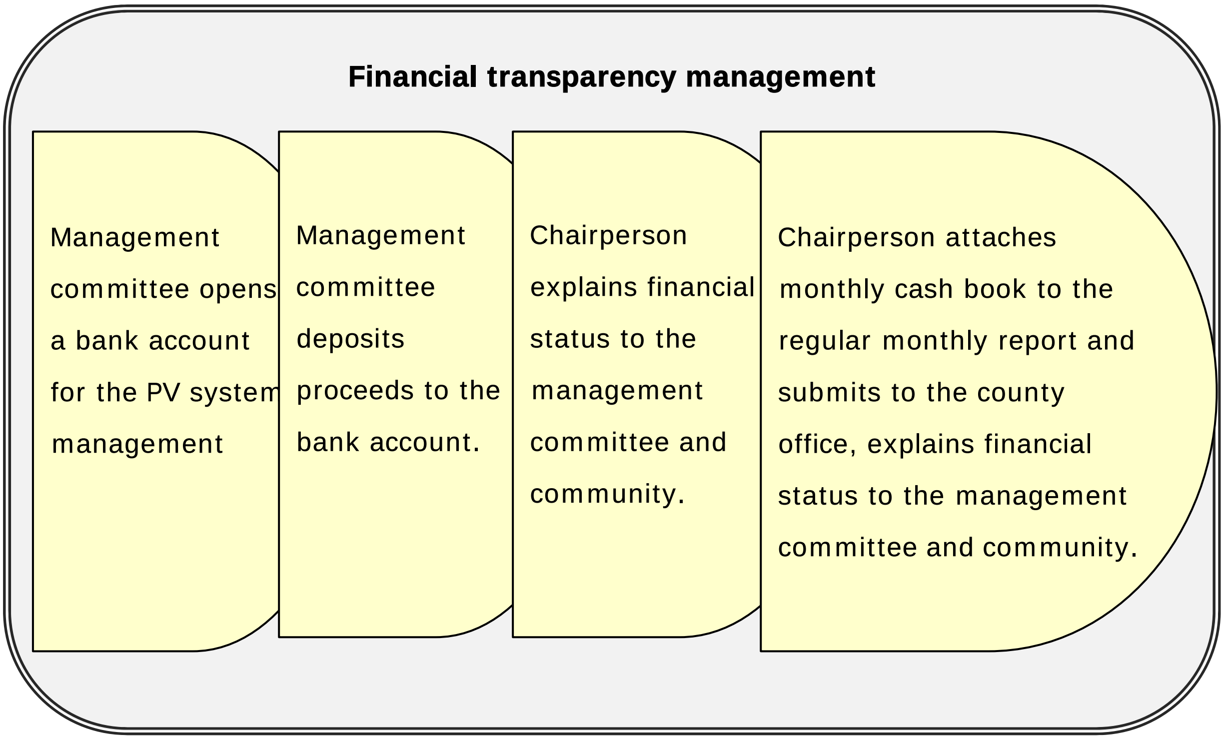
Daily operation is simple but a very important task of the operator as the basis of sustainable system use. If he/she finds water level lows, he/she top up distilled water immediately.

4. Financial management at dispensary/school



Income from charging service sales is a valuable source for the cost of daily solar PV system O&M and management such as purchase of distilled water, replacement of bulbs, transportation and so on.

5. Transparency



Keeping transparency of charging service is indispensable in order that both concerned ministries and community people rely on the performance of management committee.

Reporting of the financial state shall be attached to the facility monthly report and submitted to the county office of the relevant ministries.

6. E-waste management

(i) Request suppliers to take away used ones from each facility when carrying out replacements (this shall be set as a condition for carrying out replacements).

↓

(ii) Earning from the selling of used batteries and other used substances of e-waste shall be remitted using the "m-pesa" system by the suppliers when getting selling money from the licensed E-waste Handlers and/or battery makers.

↓

(iii) The earning money shall be kept in each facility as revenue.

↓

(iv) To make sure the proper transportation and treatment, the **e-waste manifest system** shall be introduced in the e-waste disposal system

Manual for

Financial Management and Accounting for Public Facilities

Public Facilities and surrounding community people benefit by solar PV systems for health care and education. The new responsibility with the stakeholders of the public facilities to take care of the PV systems should be considered as unavoidable for sustainable use. The manual is prepared for "Management Committee" to pursue their new responsibility focusing on the financial aspect for sustainable use and its benefit.

Person in Charge

Chairman
Secretary
Treasurer

Operator

Necessary Books and etc.

Daily Business Record
Cash Book
Monthly Report

Receipt
Bank Account

Members of Management Committee, Chairman/ Secretary/ Treasurer and Operator share the responsibilities for sustainable use of solar PV systems as follows:

Role Sharing

Tools	Purpose & Contents	In Charge	Check & Keep
Daily Business Record	Income record	Operator	Secretary
Cash Book	Income & Expense	Operator	Treasurer
Monthly Report	Cash Balance & Profit	Chairman	Chairman
Receipt	Evidence	Operator	Customers
Bank Account	Official Record	Chairman	Chairman

The cash balance from the result of charging service is transferred to the bank account by Chairman monthly or regularly. Cash and bank books are managed by Management Committee.

EXAMPLE FOR FILLING

Annexes

Delete not applicable

1. Daily Business Record

DAILY BUSINESS RECORD FOR

Iltumtum ~~DISPENSARY~~ / PRIMARY

Name of school or dispensary

Sheet No. : 1

Date: 1 st September 2014 Weather: Sunny

Full name

No.	Name of Customer	Type of appliance *	Amount (KSh.)	Comment/ Remarks/ Complaints e.g. customer misplaced receipt
1.	Mr.Aaaaa Bbbbb	Mobile	20	Normal
2.	Ms.Ccccc Ddddd	Haircut	35	Normal
3.	Mr. Eeee Ffffff	Mobile	20	Did not pay cash, Next day paid
4.	Ms. Oooo Ppppp	Mobile	20	Normal
5.	Ms. Qqqq Rrrrr	Mobile	20	Normal
6.	Mr. Sssss Ttttt	Mobile	20	Pay 50%, Next day paid
7.	Ms. Ttttt Uuuuu	Mobile	20	Normal
8.	Mr. Uuuu Vvvv	Mobile	20	Normal
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
Daily Total		Phone: 140 Lantern: Battery: Clippers: Other (Hair cut etc.) : 35	175	

To be checked and signed by Treasurer or Secretary.
Finally submit to Chairman together with cash and whole books

Break down of the day income

Total of the day to be checked with the break down

Daily Totals checked by: Mr. Ggggg Hhhhh

signature: *Ggggg Hhhhh*

* Type of appliance: mobile phone, LED lantern, rechargeable battery, hair clippers, other (specify)

The treasurer gives a number to the sheet and issues this sheet to the secretary who issues it to the operator.
At the end of the day, the operator returns the sheet to the treasurer who verifies the cash collected against this sheet.
When the number of customers exceeds 25 persons, continue recording on the Sheet 2 and input the daily total at the bottom of Sheet 2.

EXAMPLE FOR FILLING

Fill in name of school or dispensary

2. Copy of Sales Receipt

CASH SALERECEIPT			No. 1
Name of Customer Mr. James Kamweru Mobile: 070-111-222	Iltumtum		~~Dispensary/~~ Primary School
	P.O. BOX XXX		
Mobile phone:	DATE: 1 / 9 / 2014		
No.	**DESCRIPTIONOFMOBILE/LANTERN etc.**		**AMOUNT(Ksh.)**
1	NOKIA Mobile		20
		Total	20
Received by: Mr. Kkkkk Lllll		Signature: *Kkkkk Lllll*	

Delete not applicable one

Full name, contact number

Signed by operator
Together with cash and other books, Copy of Sales Receipt are transferred to treasure or secretary

EXAMPLE FOR FILLING

3. Cash Book

CASH BOOK FOR

ILTUMTUM DISPENSARY / PRIMARY SCHOOL

Month/Year: September 2014 **Sheet No. :** 1

Date	Revenues		Expenses		Balance (KSh.)
	Item	Amount (KSh.)	Item	Amount (KSh.)	
1.	Charging Income	175			
2.	Charging Income	140			
3.	Charging Income	170	Stationary	100	385
4.					
5.					
6.					
7.					
8.					
9.	Charging Income	180	Transportation for bank	100	465
10.	Charging Income	120	Bank charge	100	485
11.	Charging Income	160	Bank deposit	385	100
12.	Charging Income	175			
13.					
14.					
15.	Charging Income	175			
16.	Charging Income	140			
17.	Charging Income	170			
18.	Charging Income	170			
19.	Charging Income	140			1,230
20.					
21.					
22.	Charging Income	175	Distilled water	500	905
23.	Charging Income	140			
24.	Charging Income	170			
25.	Charging Income	120			
26.	Charging Income				1,495
27.					
28.					
29.	Charging Income	160	Transportation for bank	100	
30.	Charging Income	175	Bank charge	100	
31.			Bank deposit	1,000	630
Monthly Total		3,015	Monthly Total	2,385	630

Monthly Totals
Checked by: Mr.Ggggg Hhhhh
signature: *Ggggg Hhhhh*

The Cash book is kept by the treasurer who makes entries.

A Stationary

B Transportation Bank

C Bank Charge

D Bank Account

E Distilled Water

F Transportation Bank

G Bank Charge

H Bank Account

I Monthly Total

Signed by Treasurer or Secretary Together with other books and Copy of Sales Receipt are transferred to Chairman

EXAMPLE FOR FILLING

4. Monthly Record

MONTHLY REPORT OF ILKILNYETI DISPENSARY

Month/Year: September 2014			**Sheet No. :** 1
Income in the month	**(KSh.)**	**Expenditure in the month**	**(KSh.)**
Cash Balance last Month (a)		1. Operation cost	
1. Revenue from charging service (b)	3,015	(1) Distilled water	500
2. Other revenues:		(2)	
		(3)	
		(4)	
		(5) Miscellaneous	
Sub-total (c)	3,015	(e)	500
3. Withdrawals from Bank		cost	
Date			
Date			
Date			
Sub-total (d)	0	Sub-total (f)	0
		3. Administration cost	
		transportation	200
		committee expenses	
		meeting expenses	
		bank charge	200
		others (stationary)	100
		Sub-total (g)	500
		5. Deposit to bank (h)	1,385
Cash Income Total (a)+(b)+(c)+(d)	3,015	**Cash Expenditure Total** (e)+(f)+(g)+(h)	2,385
Balance (Cash income carried forward)			Ksh 630

BANK CONTROL		Unit: Ksh	
Balance in last month		Withdrawals in this month (d)	0
Deposit in this month (h)	1,385		
Deposit Total	1,385	**Withdrawals Total**	0
Balance (Cash income carried forward)			KSh. 1,385

Cash Book E
Cash Book I
Cash Book B+F
Cash Book C+G
Cash Book A
Cash Book D+H

Available Balance Cash & Bank Deposit

Form

1. Daily Business Record

Daily Business Record of ________________________Dispensary / Primary School

Sheet No. :__________				
Date: ________________			Weather:______________________	
No	**Name of Customer**	**Type of appliance ***	**Amount (KSh.)**	**Comment/ Remarks/ Complaints** e.g. customer misplaced receipt
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
Daily Total		Phone: Lantern: Battery: Clippers: Other (Hair cut etc.):		
Daily Totals checked by: ________________________ **signature:** ________________________				
* Type of appliance: mobile phone, LED lantern, rechargeable battery, hair clippers, other (specify)				

The treasurer gives a number to the sheet and issues this sheet to the secretary who issues it to the operator. At the end of the day, the operator returns the sheet to the treasurer who verifies the cash collected against this sheet.

When the number of customers exceeds 25 persons, continue recording on the Sheet 2 and input the daily total at the bottom of Sheet 2.

Form

2. Copy of Sales Receipt

CASH SALERECEIPT			No.
<u>Name of Customer</u>			Dispensary/ School
		P.O. BOX	
Mobile phone:		DATE: / /	
No.	DESCRIPTIONOFMOBILE/LANTERN etc.		AMOUNT(KSh)
		Total	
Received by:		Signature:	

Form

3. Cash Book

CASH BOOK FOR ILKILNYETI DISPENSARY

Month/Year: ____________________					Sheet No. : _1_
Date	Revenues		Expenses		Balance (KSh.)
	Item	Amount (KSh.)	Item	Amount (KSh.)	
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
Monthly Total					

Monthly Totals
Checked by: ______________________________
signature: ______________________________

The Cash book is kept by the treasurer who makes entries.

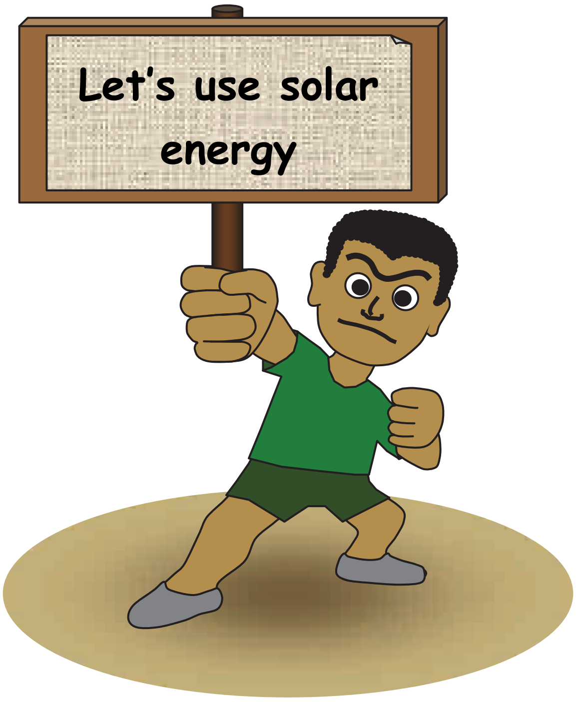
Form

4. Monthly Record

MONTHLY REPORT OF ILKILNYETI DISPENSARY

Month/Year: ____________		**Sheet No. :** 1	
Income in the month (KSh.)		**Expenditure in the month (KSh.)**	
Cash Balance last Month (a)		1. Operation cost	
1. Revenue from charging service (b)		(1)	
2. Other revenues:		(2)	
		(3)	
		(4)	
		(5) Miscellaneous	
Sub-total (c)		Sub-total (e)	
3. Withdrawals from Bank		2. Maintenance cost	
Date			
Date			
Date			
Sub-total (d)		Sub-total (f)	
		3. Administration cost	
		- transportation	
		- committee expenses	
		meeting expenses	
		bank charge	
		others	
		Sub-total (g)	
		5. Deposit to bank (h)	
Cash Income Total (a)+(b)+(c)+(d)		**Cash Expenditure Total** (e)+(f)+(g)+(h)	
Balance (Cash income carried forward)		Ksh	

BANK CONTROL		Unit: Ksh	
Balance in last month		Withdrawals in this month (d)	
Deposit in this month (h)			
Deposit Total		**Withdrawals Total**	
Balance (Cash income carried forward)		KSh.	



Contact :

Annex 2 Forms for O&M and Management

Annex 2-1 Questionnaire for the Baseline Survey

2-1-1 Baseline Survey to the Public Facilities

1. Interview data

(1) Date of interview ____________ Interviewer

(2) Name of the facility

(3) Sub-county ______________ Division

Location _______________ Sub-Location

(4) Interviewee's name, sex, age

(5) Position/title in the facility

2. Facility structure and function

(6) Number of communities in the service catchment area

(7) How many persons in the facility?

<School>

School: Teachers _____ non-teacher workers _____ Total Number of pupils ___ (number of boarders ______)

<Dispensary>

Dispensary: Medical staff __non-medical staff __ Total

Average number of patients/day ____ (average number of night patient/day ____)

(8) 1) Does the facility have any expansion plan? /______/

2) If yes, please explain (area expansion, number of rooms, etc.)

3) Has the facility got the budget already? /______/

4) When the construction starts? /______/

3. Actual energy use

(9) Source of actual energy use. Please add the device names used in your facility.

Purpose of energy use	Type (& fuel type)	Number	Amount consumed in a month (unit)	Amount of money Ksh/month
Lighting 1				
Lighting 2				
Radio and/or TV				
PC				
Vaccine refrigerator				
Security light				

Note: Energy source: Grid, generator, dry cell, kerosene, etc.

4. Experience of power generation

(10) Does the facility have or had power generation system?/

Item	Generator	PV system
Number		
Does it function now or stopped?		
Number of system actually functions		
Year of installation		
Who paid and took initiative for installation?		
Capacity of power generation		

(11) 1) If the facility has/had power generation systems, who operates it?

2) Is/was there any fee for the operator?

3) If yes, how much and who pays?

3) Has that person got training of operation/maintenance technique?

4) Is/was there any trouble or problem concerning generator/PV system operation?

5) If yes, please explain.

5. Management and use of electricity to be installed by the pilot project

(12) If you start phone charging service, how much Ksh do you think is appropriate for the fee of one phone charging?

__________ Ksh/phone

(13) Do you have any idea using PV power to get income other than phone charging?

Asante Sana !

END

....

2-1-2 Baseline Survey to Chief or Assistant Chief

1. Interview data

1) Date of interview /______________/ Interviewer /_____________/ Name of facility /_____________/
2) Interviewee's name and position / ____/

2. Village profile

(4) Latest Population of
Sub-location ____(Year _) Location _____(Year___)
(5) Number of households of ____ is __HHs in the year of
(6) Ethnic groups living in the community in order of population
1.________ 2.________ 3.________ 4.________ 5.
(7) Public facilities in the sub-location. Please enter the number if it exists.
1. Primary school /__/ 2. Secondary school /__/ 3. Dispensary /__/
4. Office of governmental organization (specify) /________/

3. **Economic and social condition**

(8) Main income sources of the location (specify products, in order of importance)
1.____________ 2.____________ 3.____________ 4.____________ 5.
(9) Is there any project (on- going and planning) for community development in this village?

4. **Actual energy use and electricity (general tendency in the community)**

(10) Sources of energy in the community

Purpose of energy use	Energy source*	Place of fuel collection/ purchase/charging	Unit price of fuel and unit
Lighting 1			
Lighting 2			
Radio and/or TV (if any)			
Mobile phone charging			

Note: Energy source: Grid, diesel, dry cell, kerosene, etc.

(11) 1) Where is the nearest town where inhabitants go to charge phones?
2) How much is the transportation cost (round trip) to go there? /_______/Ksh
3) Where is the nearest town where the facility can buy distilled water?
4) Does anyone in the community do charging service using the power from their generator/PV system?

Power generation type		Diesel generator	PV system
Number in the service providers			
1. Mobile charging	Number of service in the village		
	Fee Ksh/1 time		
	Total sales Ksh/month		
2 Other	Specify the type of service		
	Number of service in the village		
	Fee Ksh/ (unit)		

(12) How many percent of the village inhabitants have mobile phone? /_________/
(13) Do inhabitants use LED rechargeable lantern? /________/
(14) 1) Does the community have an electrification plan? /________/
2) If yes, what plan? Please explain.

(15) How much Ksh/time is appropriate for inhabitants to pay to charging mobile phone? Ksh_________per phone

Asante Sana !

END

....

2-1-3 Baseline Survey to Household

1. Interview data

(1) Date of interview_____________ Interviewer
(2) Name of community
(3) Interviewee's name, sex and age
(4) Interviewee's occupation and position in the community

2. Household profile

(5) 1) Number of household members Male /_____/ Female /_____/ Total /_____/
2) Number of household members who live in the community throughout the year /______/
(6) Ethnic group of the household head
(7) Main income source of your household in order of importance and person who mainly engage in it? (in order of importance)

	Occupation/ work 1	Occupation/ work 2	Occupation/ work 3
Name of work			

(8) Household cash income of **last month** ________Ksh, and **last year**________Ksh
(9) Household expenditure of **last month** ________Ksh, and **last year**________Ksh

3. Household energy use

(10) Do you have diesel generator(s) and/or PV system?

Power generation type	Diesel generator	PV system
Number		
Generation power (kWh)		
Fuel consumption (liter/month)		-
Fuel expenses (Ksh/month)		-
Purpose of use		

(11) Do your household own following appliances? Please answer the number.
Mobile phone /______/ television /______/ Radio /_____/
(12) If you have mobile phone(s),
If no, why?
1) Where do you charge?
2) How many hours does it take to reach the charging place?
3) How many times do you charge it in **a month**?
4) How many Ksh do you pay for one time recharging? ________Ksh/time
5) How much can you pay at maximum for charging in **a month**? ________Ksh/month
(13) If the dispensary or primary school in this community starts charging service, will you use the service? /________/
(14) 1) What kind of lighting appliance do you use?
2) If it is kerosene lantern, where do you buy the fuel?
3) How much do you pay for kerosene in a month? ________Ksh/month

Asante Sana !

END

Annex 2-2 Monitoring Sheet

2-2-1 Interview to the facility staff and chairman of the management committee

1. Basic data of the monitoring

1.1 Date ____________ 1.2 Site name __________________ 1.3 Member of the monitoring team /_________________/

1.4 Name and position of interviewees /____/

2. Organizational management

(1) Bylaw (rule and manner of PV system use and charging service) drawing

1) Existence of a bylaw

Drawn and approved by the committee /______/ Drawn but not approved yet /______/ Not drawn up /______/

2) If not, future plan to make up the bylaw

(2) Do the members of management committee constantly work as planned?

1) Does the treasurer check the daily sale after closing service every evening together with operator? /______/

2) Does treasurer/secretary make monthly summary report? /______/

3) Does he/she explain the report at the committee's meeting? /______/

4) Does the committee submit the monthly financial report to the county health/education office? /______/

5) Do they explain to the surrounding community about the management of PV system? /______/

3. Financial management

(1) Has the management committee opened a bank account exclusively used for the PV system? /______/

(2) Fund raising

1) Does the management committee check the amount of money collected and accumulated for operation and administrative expenses? /______/

2) Is it sufficient for general expenditure (distilled water, transportation, etc.) till now? /______/

(3) What measure does the management committee take if the amount is not enough?

(4) If the management committee finds problem in the charging business, what is it?

(5) Does the committee advertise charging service to community people? /______/

4. Operation and Maintenance of PV system

(1) Does the operator work every day for charging service? /______/

(2) Does he/she do water topping up? Please observe the condition.

Room/building of the PV system	Water level at the proper level (G/NG)	Record of water topping (yes/ no)	Remarks

(3) Does he/she understand the contents of the Operation and Maintenance record? /_____/

(4) Does he/she fill the Operation and Maintenance record?

Record writing Yes/no	Contents of the O&M record (good/not good)	Remarks

(5) Performance of operator: evaluation of chairman (or head teacher, nurse) : mark <Good / Not Good>

Daily charging service	Recording of "Daily business record"	Recording of "Cash book" every evening	Informing mal function and other troubles to the chairman, if any

5. Change after electrification

(1) What change occurred after the pilot project had started?

<To school>

1) Has the student's studying time changed at night after the pilot project started?

<To dispensary>

2) Number of night patient in this month: total /_______/ and previous month total /_______/

<All sites>

3) Any other change?

(4) Satisfaction of the electrification by PV system (pilot project) /mark one answer /

Satisfied 5 -- 4 -- 3 -- 2 -- 1 Not satisfied

*If the respondent mentioned question or claim at the previous monitoring, the monitoring team should answer to it.

6. Description

(1) Problems the committee faced and measures taken at this moment

(2) Advice of the monitoring team to the facility and management committee

(3) Observation of the monitoring team, if any

End

ASANTE SANA!

....

2-2-2 Interview to the treasurer and/or secretary

1. Treasurer's work

(1) Do you understand the contents of the daily record sheet? Please explain to the monitoring team.

Result, observation of the monitoring team

(2) Do you check the proceeds of charging service every evening? /_______/

(3) Do you record day's total? /_______/

If not, what is the problem?

(4) Do you make a monthly summary of income & expenditure as trained? /_______/

If not, what is the problem?

(5) What are the administration expense items at this moment? /_______________________________________/

(6) Do you inform the income & expenditure to the committee members including chairman and secretary every month?

/_______/

(7) If not, what is the reason

(8) Do you advertize charging service to community people? /_______/

2. Report

<To dispensaries>

(1) Does the secretary (or treasurer) add the monthly proceeds from charging service to the monthly report and submit it to the county health director's office? /_______/

(2) If not, what is the reason?

<To schools>

(3) Does the secretary (or treasurer) make a monthly report of the proceeds from charging service? /_______/

(4) If not, what is the reason?

3. Problems and difficulties that the treasurer/secretary has faced concerning PV system financial management

4. Opinion on PV system financial management

End

ASANTE SANA!

....

2-2-3 Interview to operator

1. Working time, Working day in a week and time
2. Do you work every day?
3. Recording

(1) Do you understand the contents of the daily record sheet? Please explain to the monitoring team.

Result, observation of the monitoring team

(2) Do you record day's sale as the JET trained you? /_______/

(3) Do you use the format of daily sale as you were trained? /_______/

If not, what is the reason?

(4) Do you remember the contents of the training? /_______/

(5) Do you want to get training again? /_______/

4. O&M

(1) Do you remember the contents of the technical training? /_______/

(2) Do you keep the "Solar PV Manual"? (if the operator does not have one, please give him/her a copy) /_______/

(3) What is water topping up? Please explain

Result, observation of the monitoring team

(4) Do you check water level? If yes, how often?

(5) Do you check voltage, inverter and controller? /_______/

5. Problems and difficulties that operator has faced

6. Opinion on the operation and maintenance of the PV system

End

ASANTE SANA!

....

2-2-4 Observation by the facility staff and the expert team

1. Observation of the accounting books
2. Condition of the equipment (set of batteries, inverters and controllers) at each room.

Does the apparatus functions well without bad smell and abnormal sound?

No.	Name of Room/building of the PV system*	2.1 battery voltage (write the voltage)	2.2 inverter (indicator lamp is ON/OFF)	2.3 controller (indicator lamp is ON/OFF)
1				
2				
3				
4				
5				
6				
7				
8				

* Name of rooms

<Primary school> Class room (specify the room number), staff room, staff dormitory (specify the room number), boy's dormitory, girl's dormitory, hall, charging service room/hat

<Dispensary> Main consultation/treatment room (specify the room number), sub-consultation/treatment room, vaccine refrigerator, staff dormitory, charging service room/hat

3. Report

<To dispensaries>

(1) Does the secretary (or treasurer) add the monthly proceeds from charging service to the monthly report and submit it to the county health director's office? /_______/

(2) If not, what is the reason?

<To schools>

(3) Does the secretary (or treasurer) make a monthly report of the proceeds from charging service? /_______/

(4) If not, what is the reason?

3. Problems and difficulties that the treasurer/secretary has faced concerning PV system financial management

4. Opinion on PV system financial management

End

ASANTE SANA!

Annex 3 Financial System

Annex 3-1 Cash Flow Projection
Annex 3-2 Forms for the Financial Management at Facilities

Annex 3-1 Cash Flow Projection (Dispensary) with Price Escalation

Year	Initial Cost	O&M Cost (KSh)					Revenue (KSh)			Balance (KSh)		**Required Budget Allocation (KSh)**		
		Regular Operation (Local Cost)	Major Replacement			Sub-total (1)	Existing Budget (Local)	Charging Service (Local)	Sub-total (2)	Per Year	Accumlation	Initial Cost **REA**	Reguar Operation **Dispensary**	Major Maintennace **County Health**
			Battery (Foreign Cost)	Inverter (Foreign Cost)	CC (Foreign Cost)									
		(a)	(b)	(c)	(d)	(e) =	(f)	(g)	(h) = (f)+(g)	(i) = (h)-(e)	(j) = Σ(i)	(k)	(l) = (a) - (h)	(m) =
0	1,360,000											1,360,000		
1		28,800				28,800	0	12,000	12,000	-16,800	-16,800	0	16,800	0
2		31,144				31,144	0	12,977	12,977	-18,168	-34,968	0	18,168	0
3		33,679				33,679	0	14,033	14,033	-19,646	-54,614	0	19,646	0
4		36,421				36,421	0	15,175	15,175	-21,246	-75,859	0	21,246	0
5		39,386	300,121			339,506	0	16,411	16,411	-323,095	-398,955	0	22,975	300,121
6		42,592				42,592	0	17,747	17,747	-24,845	-423,800	0	24,845	0
7		46,059		240,805	83,228	370,092	0	19,191	19,191	-350,901	-774,701	0	26,868	324,033
8		49,808				49,808	0	20,753	20,753	-29,055	-803,755	0	29,055	0
9		53,862				53,862	0	22,443	22,443	-31,420	-835,175	0	31,420	0
10		58,246	327,316			385,563	0	24,269	24,269	-361,294	-1,196,468	0	33,977	327,316
11		62,988				62,988	0	26,245	26,245	-36,743	-1,233,211	0	36,743	0
12		68,115				68,115	0	28,381	28,381	-39,734	-1,272,945	0	39,734	0
13		73,660				73,660	0	30,691	30,691	-42,968	-1,315,913	0	42,968	0
14		79,655		271,899	93,974	445,528	0	33,190	33,190	-412,339	-1,728,252	0	46,466	365,873
15		86,139	356,977			443,116	0	35,891	35,891	-407,225	-2,135,476	0	50,248	356,977
16		93,151				93,151	0	38,813	38,813	-54,338	-2,189,814	0	54,338	0
17		100,734				100,734	0	41,972	41,972	-58,761	-2,248,576	0	58,761	0
18		108,933				108,933	0	45,389	45,389	-63,544	-2,312,120	0	63,544	0
19		117,800				117,800	0	49,084	49,084	-68,717	-2,380,837	0	68,717	0
20		127,389				127,389	0	53,079	53,079	-74,311	-2,455,147	0	74,311	0
Total	1,360,000	1,338,562	984,414	512,704	177,202	3,012,882	0	557,734	557,734	2,455,147	-	1,360,000	780,828	1,674,320
Annual Avg.	-	66,928	49,221	25,635	8,860	150,644	0	27,887	27,887	122,757	-	-	39,041	83,716

Note: 1. Price escalation applied — Local Cost 8.14% — Average inflation rates (2010-2014) in IMF World Economic Outlook Database (October 2014)
Foreign Cost 1.75%
2. Revenue projection — It is assumed that the existing budget and charging service revenue will increase at the same rate of price escalation.

Prepared by JET

Annex 3-2 Forms for the Financial Management at Facilities

1. Daily Sales Record

Daily Business Record of ________________________Dispensary / Primary School

Sheet No. :				
Date: ________		**Weather:________________**		
No.	**Name of Customer**	**Type of appliance ***	**Amount (KSh.)**	**Comment/ Remarks/ Complaints** e.g. customer misplaced receipt
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
Daily Total		Phone: Lantern: Battery: Clippers: Other (Hair cut etc.):		
Daily Totals checked by: ____________________ **signature: ____________________**				
of appliance: mobile phone, LED lantern, rechargeable battery, hair clippers, other (specify)				

The treasurer gives a number to the sheet and issues this sheet to the secretary who issues it to the operator. At the end of the day, the operator returns the sheet to the treasurer who verifies the cash collected against this sheet. When the number of customers exceeds 25 persons, continue recording on the Sheet 2 and input the daily total at the bottom of Sheet 2.

2. Sales Receipt

<table>
<tr><td colspan="4">CASH SALE RECEIPT</td><td>No.</td></tr>
<tr><td colspan="2" rowspan="2"><u>Name of Customer</u></td><td colspan="2"></td><td>Dispensary/
School</td></tr>
<tr><td colspan="3">P.O. BOX</td></tr>
<tr><td colspan="2">Mobile phone:</td><td colspan="3">DATE: / /</td></tr>
<tr><td>No.</td><td colspan="3">DESCRIPTIONOFMOBILE/LANTERN/
HAIR SHAVING/ etc.</td><td>AMOUNT(Ks.h)</td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td></td><td></td></tr>
<tr><td></td><td colspan="2"></td><td>Total</td><td></td></tr>
<tr><td colspan="2">Received by:</td><td colspan="3">Signature:</td></tr>
</table>

3. Cash Book

CASH BOOK FOR DISPENSARY/ PRIMARY SCHOOL

Month/Year: ___________			Sheet No. : _1_		
Date	**Revenues**		**Expenses**		**Balance (KSh.)**
	Item	**Amount (KSh.)**	**Item**	**Amount (KSh.)**	
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
Monthly Total					
Monthly Totals **Checked by:** ______________________ **signature:** ______________________					

The Cash book is kept by the treasurer who makes entries.

4. Monthly Record

MONTHLY REPORT OF ______________________ DISPENSARY/ PRIMARY SCHOOL

Month/Year: ___________		Sheet No. : 1	
Income in the month (KSh.)		**Expenditure in the month (KSh.)**	
Cash Balance last Month (a)		1. Operation cost	
1. Revenue from charging service (b)		(1)	
2. Other revenues:		(2)	
		(3)	
		(4)	
		(5) Miscellaneous	
Sub-total (c)		Sub-total (e)	
3. Withdrawals from Bank		2. Maintenance cost	
Date			
Date			
Date			
Sub-total (d)		Sub-total (f)	
		3. Administration cost	
		- transportation	
		- committee expenses	
		- meeting expenses	
		- bank charge	
		- others	
		Sub-total (g)	
		5. Deposit to bank (h)	
Cash Income Total (a)+(b)+(c)+(d)		**Cash Expenditure Total** (e)+(f)+(g)+(h)	
Balance (Cash income carried forward)		Ksh	
BANK CONTROL	Unit: Ksh		
Balance in last month		Withdrawals in this month (d)	
Deposit in this month (h)			
Deposit Total		**Withdrawals Total**	
Balance (Cash income carried forward)		KSh.	

Annex 4 Solar Irradiation Data in Kenya

Annex 4 Solar Irradiation Data in Kenya

Monthly Averaged Insolation Incident on Horizontal Surface (kWh/m^2/day)

Data : 1983 to 2005 (22-year Average)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation (m)
Lat 4 to 5 Lon 34 to 35	6.07	6.34	5.94	5.44	5.53	5.37	5.33	5.63	6.22	5.66	5.42	5.72	5.71	575
Lat 4 to 5 Lon 35 to 36	6.16	6.51	6.17	5.64	5.71	5.65	5.66	6.02	6.47	5.8	5.55	5.89	5.93	654
Lat 4 to 5 Lon 36 to 37	6.16	6.49	6.29	5.79	5.74	5.65	5.7	6.09	6.35	5.8	5.66	5.93	5.96	604
Lat 4 to 5 Lon 37 to 38	6.27	6.58	6.35	5.72	5.68	5.46	5.45	5.89	6.19	5.58	5.55	5.96	5.88	1104
Lat 4 to 5 Lon 40 to 41	6.52	6.95	6.41	5.37	5.09	4.22	4.16	4.73	5.51	4.95	5.22	5.95	5.41	887
Lat 3 to 4 Lon 34 to 35	6.12	6.44	6.13	5.54	5.53	5.31	5.24	5.65	6.3	5.79	5.49	5.82	5.77	1096
Lat 3 to 4 Lon 35 to 36	6.18	6.58	6.39	5.8	5.79	5.66	5.71	6.17	6.62	6.06	5.68	5.87	6.03	586
Lat 3 to 4 Lon 36 to 37	6.37	6.72	6.6	6.06	5.99	5.84	5.97	6.38	6.76	6.19	5.87	6.11	6.23	526
Lat 3 to 4 Lon 37 to 38	6.49	6.9	6.74	6.01	6.05	5.88	6.09	6.46	6.97	6.24	5.86	6.15	6.31	645
Lat 3 to 4 Lon 38 to 39	6.39	6.85	6.49	5.6	5.47	5.24	5.37	5.78	6.26	5.65	5.41	5.9	5.86	835
Lat 3 to 4 Lon 39 to 40	6.4	6.81	6.34	5.23	4.91	4.32	4.32	4.82	5.48	4.97	5.08	5.79	5.36	902
Lat 3 to 4 Lon 40 to 41	6.52	6.98	6.41	5.19	4.95	4.26	4.23	4.76	5.58	4.84	4.87	5.77	5.35	636
Lat 3 to 4 Lon 41 to 42	6.54	6.98	6.57	5.46	5.25	4.68	4.65	5.15	5.82	5.09	5.05	5.88	5.58	419
Lat 2 to 3 Lon 34 to 35	6.23	6.56	6.3	5.8	5.65	5.47	5.44	5.86	6.44	6.02	5.72	6.01	5.95	1242
Lat 2 to 3 Lon 35 to 36	6.23	6.67	6.44	5.94	5.84	5.57	5.55	6	6.59	6.17	5.71	5.93	6.04	803
Lat 2 to 3 Lon 36 to 37	6.18	6.54	6.49	6.1	5.96	5.7	5.8	6.21	6.71	6.26	5.66	5.78	6.11	674
Lat 2 to 3 Lon 37 to 38	6.13	6.62	6.49	5.96	5.84	5.55	5.86	6.2	6.79	6.14	5.54	5.67	6.06	562
Lat 2 to 3 Lon 38 to 39	6.23	6.73	6.39	5.66	5.89	5.64	5.8	6.18	6.68	5.99	5.27	5.58	5.99	511
Lat 2 to 3 Lon 39 to 40	6.3	6.73	6.12	5.28	5.3	4.98	4.98	5.35	5.95	5.29	4.84	5.43	5.53	434
Lat 2 to 3 Lon 40 to 41	6.41	6.8	6.23	5.3	5.12	4.59	4.55	4.97	5.67	5.01	4.78	5.56	5.41	411
Lat 1 to 2 Lon 34 to 35	6.15	6.51	6.31	5.93	5.69	5.53	5.43	5.79	6.34	6.02	5.69	5.93	5.93	1515
Lat 1 to 2 Lon 35 to 36	6.2	6.67	6.44	5.94	5.76	5.38	5.21	5.55	6.34	5.97	5.54	5.88	5.9	1436
Lat 1 to 2 Lon 36 to 37	6.49	6.98	6.68	6.2	6.2	5.94	5.89	6.26	6.9	6.29	5.65	6.05	6.28	1179
Lat 1 to 2 Lon 37 to 38	6.3	6.85	6.58	6.02	5.99	5.68	5.72	6.11	6.83	6.21	5.47	5.74	6.12	912
Lat 1 to 2 Lon 38 to 39	6.07	6.67	6.39	5.89	6	5.78	5.89	6.27	6.84	6.28	5.39	5.46	6.07	361
Lat 1 to 2 Lon 39 to 40	6.02	6.44	6.11	5.68	5.87	5.58	5.63	5.97	6.39	5.88	5.12	5.3	5.82	261
Lat 1 to 2 Lon 40 to 41	6.11	6.51	6.17	5.62	5.46	5.01	5.03	5.38	5.87	5.48	5.08	5.43	5.59	194
Lat 0 to 1 Lon 34 to 35	6.24	6.58	6.39	5.86	5.6	5.39	5.25	5.6	6.14	5.97	5.7	6.02	5.89	1465
Lat 0 to 1 Lon 35 to 36	6.24	6.71	6.59	5.94	5.68	5.33	5.09	5.33	6.19	5.97	5.62	6.05	5.89	1848
Lat 0 to 1 Lon 36 to 37	6.48	7	6.73	6.16	6.11	5.82	5.66	6	6.78	6.22	5.58	5.99	6.2	1694
Lat 0 to 1 Lon 37 to 38	6.47	7.05	6.71	6.18	6.07	5.75	5.72	6.08	6.86	6.24	5.45	5.86	6.19	1327
Lat 0 to 1 Lon 38 to 39	6.07	6.69	6.45	6	6.12	5.72	5.86	6.25	6.86	6.36	5.39	5.48	6.1	504
Lat 0 to 1 Lon 39 to 40	5.78	6.22	6.15	5.9	5.9	5.6	5.7	6.04	6.5	6.17	5.39	5.34	5.88	225
North Avg.	**6.26**	**6.69**	**6.39**	**5.76**	**5.69**	**5.38**	**5.39**	**5.79**	**6.37**	**5.84**	**5.43**	**5.79**	**5.89**	**819**

Monthly Averaged Insolation Incident on Horizontal Surface ($kWh/m^2/day$)

Data : 1983 to 2005 (22-year Average)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation (m)
Lat 0 to -1 Lon 34 to 35	6.42	6.78	6.64	6.2	6.03	5.86	5.81	6.26	6.53	6.21	5.99	6.28	6.24	1346
Lat 0 to -1 Lon 35 to 36	6.19	6.68	6.46	5.74	5.5	5.36	5.24	5.58	6.08	5.79	5.42	5.9	5.82	2151
Lat 0 to -1 Lon 36 to 37	6.21	6.72	6.43	5.66	5.61	5.32	5.16	5.48	6.19	5.7	5.14	5.74	5.77	2287
Lat 0 to -1 Lon 37 to 38	6.06	6.69	6.25	5.52	5.24	4.76	4.66	4.91	5.81	5.5	4.88	5.46	5.47	1502
Lat 0 to -1 Lon 38 to 39	5.9	6.58	6.27	5.87	5.56	4.91	4.9	5.24	6.22	6.13	5.31	5.43	5.68	558
Lat 0 to -1 Lon 39 to 40	5.53	6.05	6.02	5.76	5.48	5.09	5.24	5.57	6.15	6.07	5.36	5.25	5.62	221
Lat 0 to -1 Lon 40 to 41	5.69	6.13	6.03	5.74	5.31	4.92	5.03	5.33	5.77	5.79	5.48	5.38	5.54	130
Lat -1 to -2 Lon 34 to 35	6.12	6.51	6.42	5.98	5.83	5.76	5.74	6.06	6.37	6.26	5.8	5.95	6.06	1449
Lat -1 to -2 Lon 35 to 36	6.1	6.58	6.49	5.95	5.69	5.53	5.48	5.81	6.3	6.08	5.6	5.82	5.94	1886
Lat -1 to -2 Lon 36 to 37	6.42	6.86	6.66	5.83	5.36	5.11	5.23	5.55	6.37	6.13	5.59	6.06	5.92	1490
Lat -1 to -2 Lon 37 to 38	6.41	6.94	6.41	5.58	4.95	4.37	4.26	4.55	5.72	5.77	5.23	5.81	5.49	1332
Lat -1 to -2 Lon 38 to 39	5.83	6.46	6.14	5.68	5.18	4.58	4.61	4.94	5.87	5.96	5.31	5.49	5.49	630
Lat -1 to -2 Lon 39 to 40	5.44	5.94	5.98	5.69	5.16	4.76	4.84	5.13	5.77	5.93	5.44	5.32	5.44	180
Lat -1 to -2 Lon 40 to 41	5.54	5.94	5.92	5.61	5.03	4.68	4.8	5.15	5.62	5.71	5.51	5.39	5.4	68
Lat -1 to -2 Lon 41 to 42	5.69	6.13	6.02	5.41	4.84	4.58	4.87	5.28	5.65	5.64	5.35	5.36	5.39	17
Lat -2 to -3 Lon 36 to 37	6.42	6.84	6.51	5.82	5.38	5.27	5.47	5.79	6.43	6.28	5.69	5.97	5.98	1285
Lat -2 to -3 Lon 37 to 38	6.29	6.77	6.32	5.55	4.91	4.5	4.54	4.86	5.88	5.99	5.5	5.77	5.56	1256
Lat -2 to -3 Lon 38 to 39	5.98	6.52	6.17	5.66	5.01	4.55	4.59	4.94	5.86	6.05	5.48	5.62	5.53	554
Lat -2 to -3 Lon 39 to 40	5.55	6.02	6	5.67	4.99	4.68	4.75	5.01	5.68	5.9	5.56	5.44	5.43	173
Lat -2 to -3 Lon 40 to 41	5.55	5.96	5.95	5.47	4.79	4.57	4.72	5.16	5.7	5.8	5.54	5.41	5.38	24
Lat -3 to -4 Lon 37 to 38	6.2	6.55	6.02	5.24	4.55	4.26	4.44	4.88	5.79	5.98	5.58	5.74	5.43	1198
Lat -3 to -4 Lon 38 to 39	6.18	6.57	6.04	5.32	4.59	4.32	4.37	4.7	5.58	5.85	5.57	5.79	5.39	695
Lat -3 to -4 Lon 39 to 40	5.71	6.2	5.95	5.43	4.75	4.55	4.61	4.87	5.51	5.76	5.55	5.54	5.36	188
Lat -3 to -4 Lon 40 to 41	6.24	6.57	6.51	5.6	4.8	4.75	4.91	5.63	6.3	6.4	6.27	6.15	5.83	1
Lat -4 to -5 Lon 38 to 39	6.08	6.43	5.92	5.15	4.32	4.16	4.28	4.63	5.46	5.75	5.65	5.73	5.29	632
Lat -4 to -5 Lon 39 to 40	5.8	6.07	5.7	5.15	4.58	4.49	4.58	4.86	5.46	5.56	5.55	5.63	5.28	54
South Avg	**5.98**	**6.44**	**6.20**	**5.63**	**5.13**	**4.83**	**4.89**	**5.24**	**5.93**	**5.92**	**5.51**	**5.67**	**5.61**	**820**
Country Avg.	**6.12**	**6.56**	**6.30**	**5.70**	**5.41**	**5.11**	**5.14**	**5.51**	**6.15**	**5.88**	**5.47**	**5.73**	**5.75**	**819**

Source : NASA (http://eosweb.larc.nasa.gov/)
Lat : Latitude
Lon : Longitude
' - ' : South hemisphere

Guideline for Solar PV in Schools

February 2015

Ministry of Energy and Petroleum

Table of Contents

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List of Terms and Abbreviations

Abbreviation	Description
AC	Alternating Current
CC	Charge Controller
CRT	Cathode Ray Tube
DC	Direct Current
DECs	District Environmental Committee
EIA/EA	Environmental Impact Assessment/ Environmental Audit
EIA-TAC	Environmental Impact Assessment Technical Advisory Committee
EMCA	Environmental Management and Coordination Act
FPEF	Free Primary Education Fund
HH	Household
HPEF	Health Sector Service Fund
JET	JICA Expert Team
JICA	Japan International Cooperation Agency
KSh.	Kenya Shilling
LED	Light Emitting Diode
LPG	Liquefied Petroleum Gas
MC	Management Committee
MOE&P	Ministry of Energy and Petroleum
MoH	Ministry of Health
NASA	National Aeronautics and Space Administration, USA
NEMA	National Environment Management Authority
O&M	Operation and Maintenance
OPD	Out Patient Department
PbCb	Lead Calcium
PbSb	Lead Antimony
PCS	Power Conditioners
PECs	Provincial Environmental Committee
PP	Power Package
PV	Photovoltaic
PVC	Polyvinyl Chloride
REA	Rural Electrification Authority
SEA	Strategic Environmental Assessment
TOR	Terms of Reference
WHO	World Health Organization
USEPA	United States Environmental Protection Agency

List of Electrical Terminology

Unit	Description
Ah (Ampere-hour)	Unit of electric charge
V (Volt)	Unit of voltage
kV (kilovolt)	1,000 volts
W (Watt)	Unit of electric power
kW (kilowatt)	1,000 W
Wh (Watt-hour)	Unit of energy
kWh (kilowatt-hour)	1,000 Wh
MWh (Megawatt-hour)	1,000 kWh
Wp (Watt-peak)	Unit of PV output
kWp (kilowatt-peak)	1,000 Wp
MWp (Megawatt-peak)	1,000 kWp

EXECUTIVE SUMMARY

1. Background

Japan International Cooperation Agency (JICA) implemented the "Project for Establishment of Rural Electrification Model using Renewable Energy in Kenya" in 2012-2015. The project has two main components; (i) pilot projects for solar PV systems, and (ii) technical assistance for wind, small hydro, and biomass/biogas. This Guideline for Solar PV Generation is prepared within the scope of the project by a Working Group (WG) of JICA Expert Team of Nippon Koei Co., Ltd /KRI in cooperation with Rural Electrification Authority (REA) in Kenya.

2. Objective of the Guideline

The pilot projects for solar PV systems consist of four sites of Lot 1 installed in Narok and Kajiado County and six sites of Lot 2 conducted in Samburu County. On the basis of the lessons learnt from the installation of Lot 1 and Lot 2 solar PV systems, and also of the inspection of existing PV systems, necessities for appropriate design procedure of solar PV system were found. Therefore, the WG prepared "Guideline for Solar PV System for Public Institutions (Health Institutions and Schools)".

3. Structure of the Guideline

The main subjects included in the Guideline of Solar PV system are as follows.

(1) Main Text

"CHAPTER 1 INTRODUCTION" summarizes objectives and contents of each Chapter.
"CHAPTER 2 SOLAR PV SYSTEM" is designed as a technical resource for people interested in learning how to design stand - alone PV systems. The main objective of this chapter is to impart the ability to successfully deal with the many aspects of PV system design. It is also designed to integrate a range of skills required to specify the appropriate electrical components for the system, and select them from a wide variety of products and manufacturers.

The purpose of the "CHAPTER 3 O&M AND MANAGEMENT" is that REA, MoH and MoEST enhance their knowledge on the appropriate and effective action of sustainable PV system, strengthen their attitude towards action and give detail elements of practice. This section of the guideline can be used to ensure that all stakeholders make up an effective management system, in terms of physical and O&M matters, for electrification of dispensaries and primary schools in the non-electrified areas using solar PV systems. It also can be used to ensure that the facility users can enjoy the power generated by installed PV systems for as long as the lifetime of solar panels (20 years). The section covers all solar PV systems that REA installed and will install.

The purpose of the "CHAPTER 4 FINANCIAL SYSTEM" is to facilitate all the executing agencies, facility owners, concerned ministries and stakeholders to prepare and provide the necessary funding for O&M and replacement of equipment for the solar PV systems for the long run. This chapter includes the introduction of the financial model to provide methodology to estimate the required public funding from the government budget as well as the commercial revenue of each facility.

"CHAPTER 5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS" describes the systems of environmental managements, reviews of relevant EIA reports and issuances of environmental licenses. Environmental and social impacts caused by solar PV projects on small scales are limited because solar PV is an inherently silent technology.

(2) Solar PV Operation Manual

The Solar PV manual is prepared for distribution to end users, to make them understand about the installed solar PV system. In addition, the manual can be referred whenever O&M is required.

The manual contains basics of standalone PV system technology, installed systems at public facilities and information of charging system. The manual was developed with many illustrations for easier understanding by local system operators. The developed manual is attached at Annex 1.

For the operation of charging services, an operator needs to understand not only the technical part of the system but also the method of management and financial recording of the system. For this, the management and financial parts are also developed and included in the same manual.

CHAPTER 1 INTRODUCTION

1.1 Objective

(1) Background

Japan International Cooperation Agency is implementing the "Project for Establishment of Rural Electrification Model using Renewable Energy in Kenya" in 2012-2015. The project has two main components; establishment of electrification model for public facilities, dispensaries and public primary (boarding) schools, using solar PV system and implementation of pilot projects , and technical assistance for wind, small hydro, and biomass/biogas. This guideline for electrification of public facilities by solar PV system is prepared within the scope of the aforementioned Project, and includes the lessons learnt from the pilot projects.

Strategic Plan 2013/2014-2017/2018 of Rural Electrification Authority (REA) , Third Draft, stipulates the new electrification strategy of Kenya is to electrify public facilities of second priority such as primary schools.

Solar PV system is a common method of electrification in remote, non electrified areas where abundant sunshine is available. It does not need construction of power plant, extension of electric line, and purchase of fuel. It consumes only sunshine for power generation. These are reason why not only Kenya but many countries with low electrification rate apply it for rural electrification.

On the other hand, solar PV system needs constant maintenance as same as other types of power plant and needs certain amount of O&M cost including replacement of equipments. It is not easy for users of the system to respond to all requirements to use the system till the end of life time of solar panels.

The problem is that the requirements for sustainable system use are not widely shared among system users in Kenya. In Kenya, REA, MOE&P and other organizations installed solar PV system at a lot of schools and dispensaries, but many of them have already lost their power generation capacity or stopped mainly due to lack of appropriate system management. This comprehensive guideline is therefore prepared in order that the users of all strata to use the solar PV system sustainably.

(2) Objective of the Guideline

The guideline is prepared for the sustainable implementation and O&M of solar PV system at public facilities: such as, dispensaries and public (boarding) primary schools. The intended readers of this guideline are government offices and facility staff members who will implement the solar PV system and use it. REA and Ministry of Energy and Petroleum (MOE&P) are principal government implementers while Ministry of Education, Science and Technology (MoEST) (both headquarters and county offices), are owners of public facilities having solar PV system. This guideline can be utilized for entire stages of electrification covering technical, managerial and financial fields: site survey, planning, basic design, preparation of specifications, procurement, construction supervision, O&M support, monitoring, and preparation of necessary budget.

(3) Components of the Guideline

The guideline consists of the following four sections:

Chapter 2	Technical Section
Chapter 3	O&M and Management Section
Chapter 4	Financial Section
Chapter 5	Section of Environmental and Social Considerations

1.2 Introduction to the Technical Section of the Guideline

The technical section of the guideline is designed as a technical resource for people interested in learning how to design stand - alone PV systems. This section is intended for use as a self – teaching aid and although it focuses on professionals who will be designing systems for clients; individuals interested in designing their own systems will also benefit from it.

The main objective of this section is to impart the ability to successfully deal with the many aspects of PV system design. The technical section seeks to develop skills not only in computation, but also in making the necessary judgments of when and where PV can be a viable solution to power needs. It is therefore also designed to integrate a range of skills required to specify the appropriate electrical components for the system, and select them from a wide variety of products and manufacturers.

Most of the time, system design involves some degree of compromise between competing and desirable qualities. There are many choices that have to be made including the types and sizes of equipment, and related components and accessories.

Many people assume that PV system design involves the use of sophisticated machines such as computers. However, the actual truth is that designing a solar power system involves a great deal of judgment before and after every calculation is made.

1.3 Introduction to the O&M and Management Section of the Guideline

The purpose of the management section of the guideline is that REA and MoEST enhance their knowledge on the appropriate and effective action of sustainable PV system, strengthen their attitude towards action and give detail elements of practice. This section of the guideline can be used to ensure that all stakeholders make up an effective management system, in terms of physical and O&M matters, for electrification of dispensaries and primary schools in the un-electrified areas using solar PV systems. It also can be used to ensure that the facility users can enjoy the power generated by installed PV systems for as long as the lifetime of solar panels (20 years). The section covers all solar PV systems that REA installed and will install.

1.4 Introduction to the Financial Section of the Guideline

The purpose of the financial section of the guideline is to facilitate all the executing agencies, facility owners, concerned ministries and stakeholders to prepare and provide the necessary funding for O&M and replacement of equipment for the solar PV systems for the long run.

This section includes the introduction of the financial model to provide methodology to estimate the required public funding from the government budget as well as the commercial revenue of each facility.

Besides REA and MOE&P, this financial section is expected to provide necessary information to other stakeholders, i.e. MoEST as well as their county offices, as owners of solar PV systems in dispensaries and primary schools. The section is also useful for those who are at primary schools as beneficiaries and local managers of the solar PV system in the rural areas.

1.5 Introduction to the Environmental and Social Considerations Section of the Guideline

The National Environment Management Authority (NEMA) is a practical official body responsible for managing environment, reviewing "EIA Project Reports" and "EIA Study Reports" and issuing Environment Licenses for development projects in Kenya. These systems of environmental managements, reviews of relevant EIA reports and issuances of environmental licenses are regulated by the most principal regulations as shown below.

- Environmental Management and Coordination Act of 1999 (EMCA)
- EIA/EA Regulations (Amendment) 2009.

Renewable energy projects including PV systems fall under "No. 10 Electrical Infrastructure" in the "Second Schedule" of EMCA. Therefore, all solar PV projects are naturally subject to the EIA procedures in Kenya.

Environmental and social impacts caused by solar PV projects on small scales (excluding mega solar PV projects) are limited because solar PV is an inherently silent technology. With regard to environmental and social considerations, therefore, general countermeasures including noise and vibration, solid waste, construction vehicle managements and so on are taken for such solar PV projects during construction stage.

During the operation stage, however, replacement of each component of the solar PV system will cause environmental issues which shall be managed by each solar PV project facility. Namely, the issues of "e-waste management" are prominent. Especially e-waste components such as used batteries, used fluorescent lamps and other used electrical appliances including solar PV panels, inverters, etc. are the core issues.

In Kenya, solid waste management issues shall be addressed in compliance with the following regulations and Guidelines

- EMCA 1999
- Environmental Management and Coordination (Waste Management) Regulations 2006
- Guidelines for E-Waste Management in Kenya 2010.

In order to make sure the solid waste management of such e-wastes from solar PV systems, an E-waste Manifest structure can be applied to the facilities and communities operating such systems.

As points to keep in mind, the act and regulations noted above are subject to some modification in accordance with the new constitution enactment 2010.

CHAPTER 2 SOLAR PV SYSTEM

2.1 Solar Irradiation

Solar irradiation data for the installation site is essential for the design of an adequate solar PV system. If there is ground measurement solar irradiation data, then it is recommended that this data is used as a reference in system design. Even if the measured data is for a very short period it will still be helpful for comparison with other data source. If the ground measurement data is not available then satellite data can also be used as reference data for system design. In order to understand the irradiation level at the site, satellite data can be downloaded from NASA website. The solar irradiation levels for Kenya are summarized below.

Kenya receives a large amount of solar irradiation over the year, in almost every part of the country. Even though the country lies on the equator, there is very little difference between the level of solar irradiation received in the Northern part of the country, and that received in the Southern part. If data is considered separately then the annual average solar irradiation is 5.89 kWh/day and 5.61 kWh/day for Northern and Southern hemisphere respectively, and the country's annual average is 5.7 kWh/day. The graphs below summarize the monthly and annual minimum, maximum, and average solar irradiation for the Northern and Southern hemispheres, and the country.

Monthly Minimum, Maximum and Average Solar Irradiation on Horizontal Surface of the Country that lies at Northern Hemisphere (kWh/day)

Data : 1983 to 2005 (22-year Average)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average	6.26	6.69	6.39	5.76	5.69	5.38	5.39	5.79	6.37	5.84	5.43	5.79	5.89
Minimum	5.27	5.76	5.75	5.18	5.19	4.63	4.79	5.27	5.71	5.27	4.63	5.08	5.21
Maximum	6.94	7.51	7.04	6.25	6.16	5.87	5.96	6.30	6.90	6.33	5.90	6.41	6.46

Source : NASA (http://eosweb.larc.nasa.gov/)

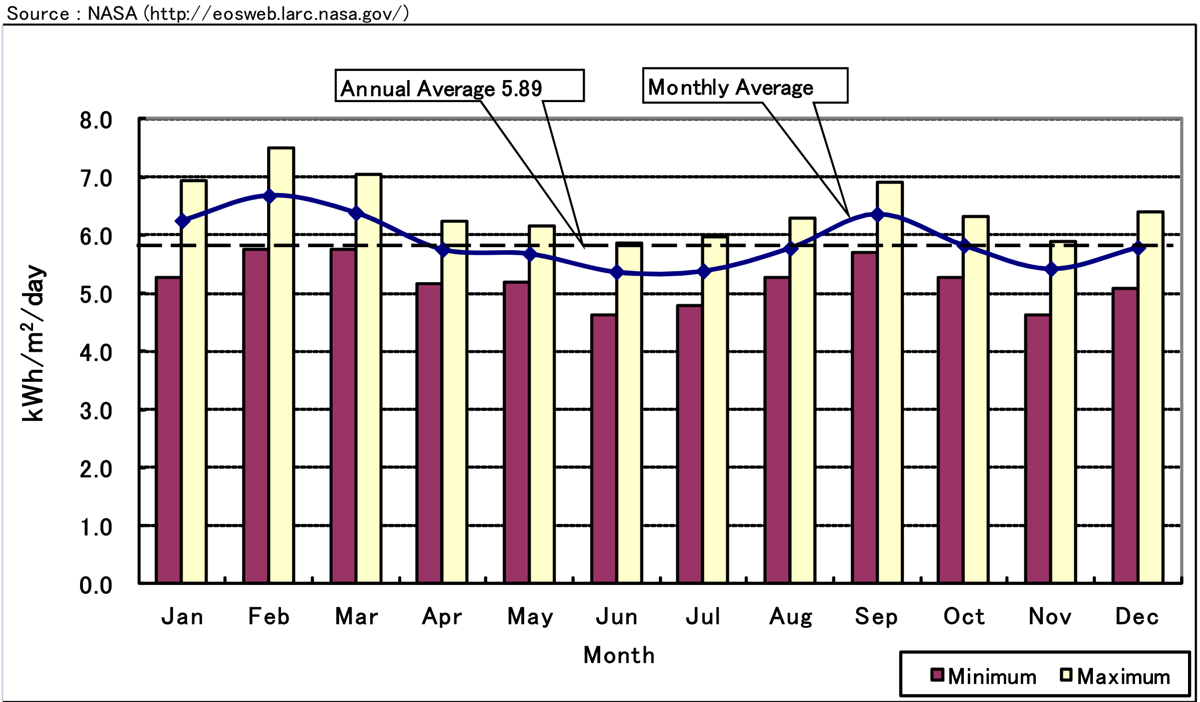

Figure 2.1.1 Solar Irradiation for Northern Hemisphere

The above figure shows that the monthly average is lower than the annual average of irradiation, for the months of May, June, July and November. However, for the months of April, August, October and December, the monthly averages are almost equal to the annual average. Further, for the months of January, February, March and September, the monthly averages are higher than the annual average.

Monthly Minimum Maximum and Averege Solar Irradiation on Horizontal Surface of the Country that lies at Southern Hemisphere (kWh/day)

Data : 1983 to 2005 (22-year Average)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average	5.98	6.44	6.20	5.63	5.13	4.83	4.89	5.24	5.93	5.92	5.51	5.67	5.61
Minimum	5.03	5.51	5.67	5.07	4.54	4.29	4.46	4.66	5.31	5.24	4.81	5.09	4.97
Maximum	6.67	7.25	6.70	6.11	5.69	5.36	5.48	5.84	6.49	6.48	6.02	6.22	6.19

Source : NASA (http://eosweb.larc.nasa.gov/)

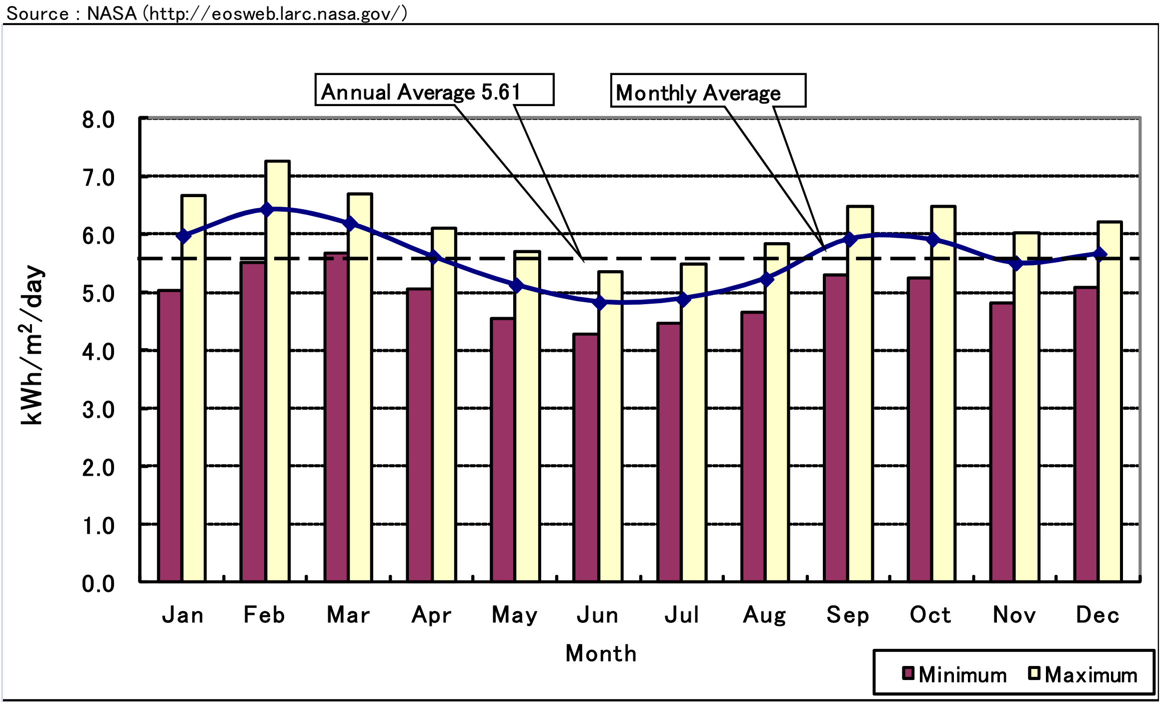

Figure 2.1.2 Solar Irradiation for Southern Hemisphere

The above figure shows that the monthly average is lower than the annual average irradiation for the months of May, June, July and August. However, for the months of April, November and December, the monthly averages are almost equal to the annual average. Further, for the months of January, February, March, September and October, the monthly averages are higher than the annual average.

A comparison of the above data for the Northern and Southern hemispheres shows that the Southern part of the country receives lower solar irradiation than the Northern part for the months of April to August. In the month of November, the Northern hemisphere receives slightly higher solar irradiation than the Southern hemisphere. However, for the remaining months the Southern hemisphere receives slightly higher solar irradiation. There is some variation in the average monthly solar irradiation between the Northern and Southern parts of the country, mainly for the months of April to August. The largest variations in solar irradiation between the Northern and Southern hemispheres are in the months of May and August, at around 0.56 kWh/day and 0.55 kWh/day respectively.

Country Monthly Minimum, Maximum and Average Solar Irradiation on Horizontal Surface (kWh/day)

Data : 1983 to 2005 (22-year Average)

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average
Average	6.1	6.6	6.3	5.7	5.4	5.1	5.1	5.5	6.1	5.9	5.5	5.7	5.7
Minimum	5.1	5.6	5.7	5.1	4.9	4.5	4.6	5.0	5.5	5.3	4.7	5.1	5.1
Maximum	6.8	7.4	6.9	6.2	5.9	5.6	5.7	6.1	6.7	6.4	6.0	6.3	6.3

Source : NASA (http://eosweb.larc.nasa.gov/)

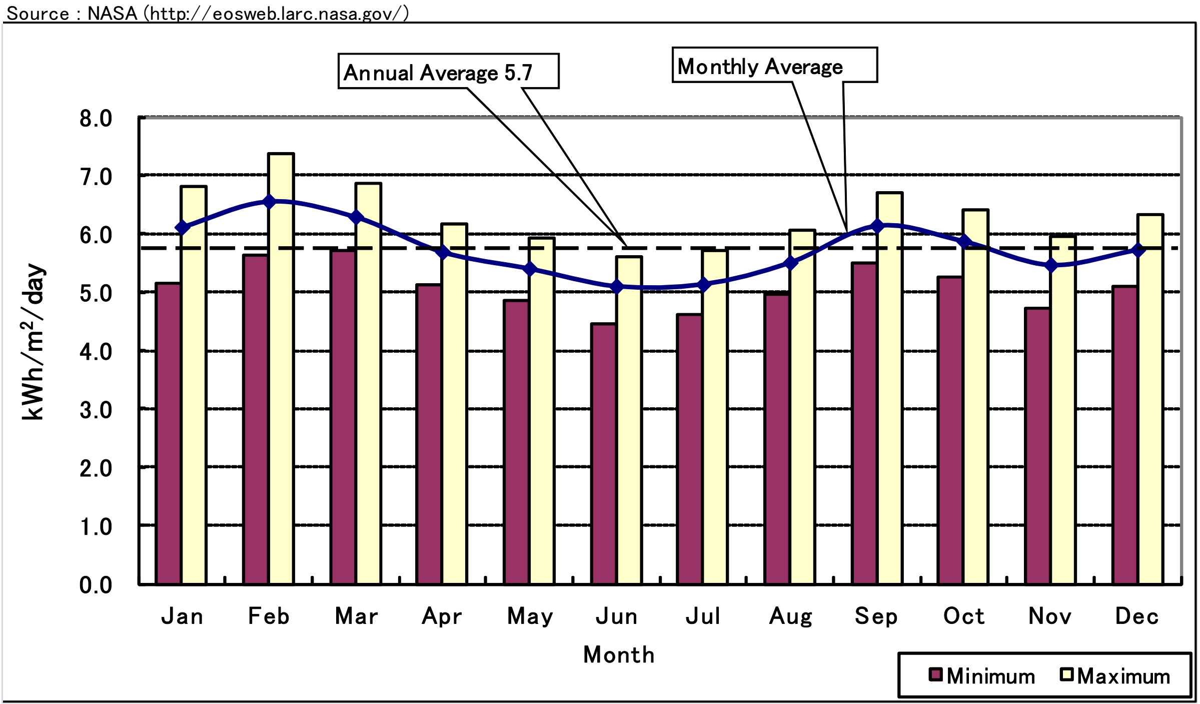

Figure 2.1.3 Solar Irradiation for Kenya

The above graph shows that the monthly average irradiation level is lower than the annual average for the months of May to August and November. However, their monthly and annual averages are almost equal for April, October and December. Further, for the months of January to March and September, the monthly averages are higher than the annual average for the whole country.

The detailed solar irradiation data for the country is attached in Annex 4 of this guideline. The data has been downloaded from NASA website http://eosweb.larc.nasa.gov/. The data provided is based on specific values of latitude and longitude.

2.2 System Components

It is important to understand the fundamental concepts of each component in order to design the solar Photovoltaic (PV) system. Each key word described below includes the basic points that need to be understood and applied as best practices for system design to ensure the system is adequate.

2.2.1 Solar PV cell/module

(1) Characteristics of PV module

The generation of voltage from light is referred to as "Photovoltaic" and often abbreviated as "PV". The common term for a PV cell/module is "solar cell/module".

A solar cell is just a converter which receives light energy and changes it into electrical energy. Therefore, sun light acts as a fuel to generate electricity from PV cell/module. A number of solar cells arranged in a closed circuit (series and parallel) for the purpose of securing a defined output is called a PV module. These products (PV modules) are available to users, from the commercial market. A number of PV modules arranged and installed (series and parallel) for the purpose of generating electrical output is called a PV array.

The PV module produces but does not store any energy. Therefore, when the light source is not available or is removed, there is no electrical output from the PV module. If electricity is required when there is no light source (typically the sun), some form of energy storage is necessary. To meet this requirement, a storage unit (commonly battery) is included in the system.

1) PV module I-V Curve terminology

Solar PV power generation is influenced by natural conditions, namely solar intensity and ambient temperature at that instance. Therefore, it is very essential to understand the effect of these conditions on the system design and performance. Figure 2.2.1 summarizes the output current and voltage of the PV module respective to the solar irradiance.

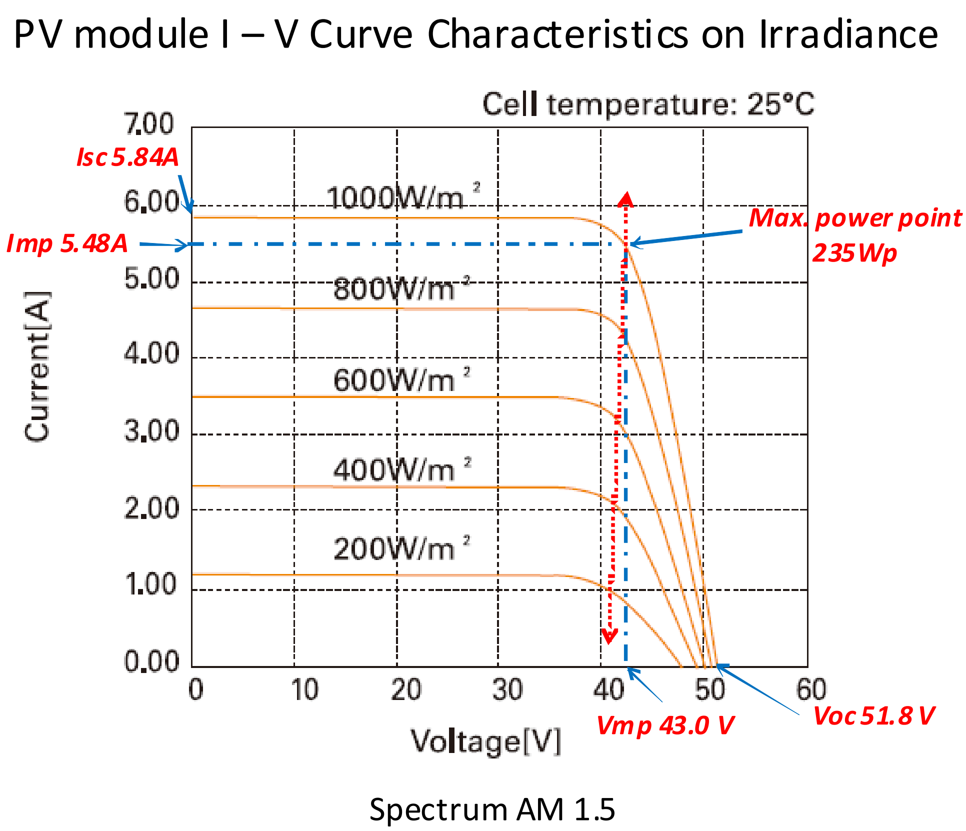

Figure 2.2.1 Example of PV Module I-V Curve – Effect of Irradiance on PV Module Characteristics

The above figure (I-V curve) shows that as the irradiance level increases, the output current of the PV module increases, while the output voltage remains almost the same (very little increase). Although the output voltage increases only slightly, the output power (voltage x current) increases significantly due to the increase in current generated. It can therefore be considered that the output current of the PV module is directly influenced by solar intensity, and output power varies according to the solar intensity mainly due to change in output current.

Figure 2.2.2 summarizes the output voltage of the PV module respective to the module temperature.

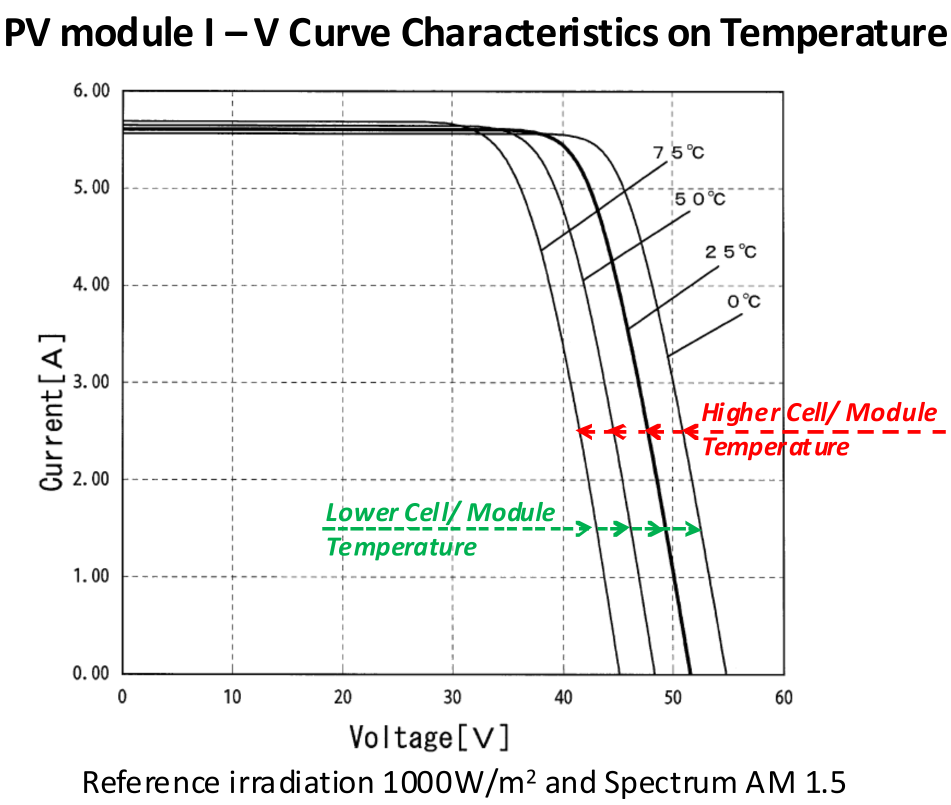

Figure 2.2.2 Example of PV Module I-V Curve – Effect of Temperature on PV Module Characteristics

The above figure (I-V Curve) shows that as PV cell/module temperature increases, the output voltage decreases, while there is very little increase in output current which is almost negligible. It can therefore be considered that the output voltage of the PV module is directly influenced by the operating temperature of PV module, and the output power varies accordingly mainly due to change in output voltage. Therefore, it is very essential to consider this factor at the time of system design.

It is clear that increase in temperature greatly influences the output voltage, which subsequently directly affects the output power (voltage x current). Different types of PV modules assembled from different types of PV cells are available in the commercial market. The response of each type of PV module to temperature therefore varies, depending on the material selected to manufacture it.

Table 2.2.1 summarizes the range of reduction in current and voltage due to increase in the operating temperature of the PV cell/module.

Table 2.2.1 Power Reduction Range of PV Cell/module due to Temperature Rise

PV Cell/module Type	% /°C reduction
Crystal silicon	-0.3 ~ -0.5
CIS	-0.2 ~ -0.4
a-Si	Almost to "0"

Note: Even though a PV cell is crystal silicon, various manufactures may use different technologies in the same crystal silicon cell and controls/reduces voltage drops even when PV cell/module temperature rises. For details refer to manufacturers' literature.

The calculation method to determine the power generation by the installed PV module/array considering the influence of temperature is summarized in section 2.3, and a detailed example of an actual installation is described in section 2.4.

2) PV module connections

There are many types of PV modules available to end users, from the commercial market. Amongst the various types, crystalline PV modules are the most common.

The capacity of the system is totally dependent on load demand and solar intensity at the particular site. To get the design output voltage (e.g. 12 V, 24 V, 48 V or higher) and required energy from an installed solar PV system; PV modules are either wired together or connected individually from the installation area to the installed control units and storage batteries.

Depending on the required system voltage and power, PV modules are connected in series and parallel. Therefore, if more than one PV module is used in the system then they are connected either in series or in parallel. The PV modules connected in series or in parallel have the same characteristics as connected dry cell batteries. It's possible to connect a number of PV modules in series and/or parallel to get the desired design voltage and current.

(i) Series connection

When two PV modules are connected in series, the output voltage doubles. When three PV modules are connected in series, the output voltage triples. Hence, whenever the number of series connections is increased, the output voltage increases proportionally with respect to the number of connected PV modules. It is possible to connect PV modules in a number of series connections to get the required voltage output while current output remains unchanged.

The figure below summarizes series connection of PV modules.

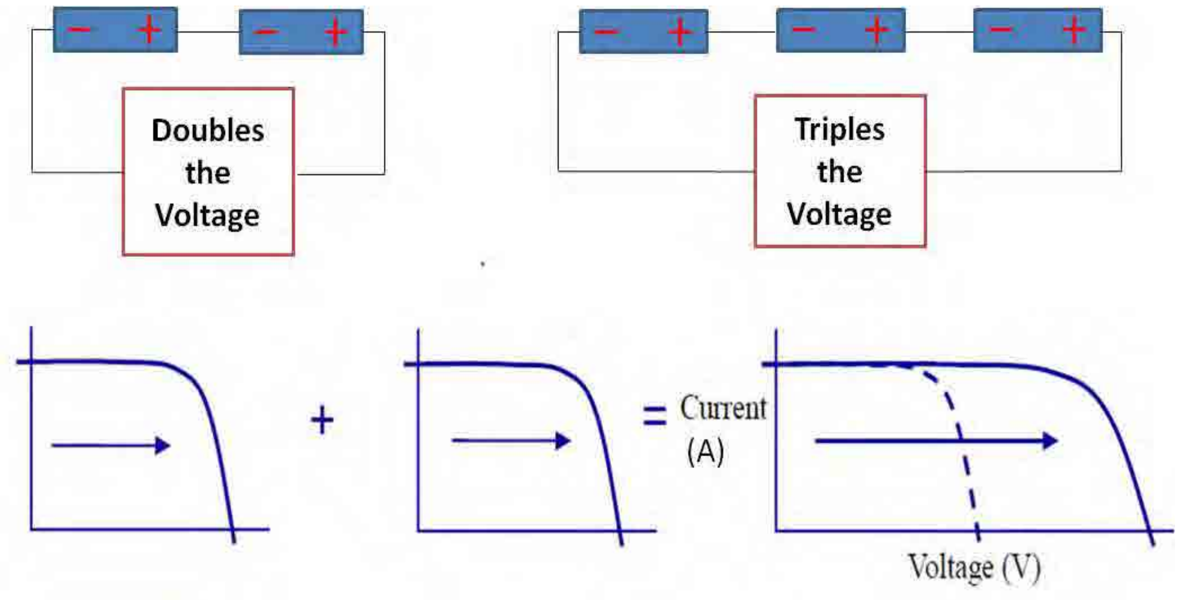

Figure 2.2.3 Example of PV Modules connected in Series

(ii) Parallel connection

When two PV modules are connected in parallel, the current output doubles. When three PV modules are connected in parallel, the current output triples. Hence, whenever the number of parallel connections of PV modules is increased, the current output will increase proportionally with respect to the number of connected PV modules. It is possible to connect PV modules in a number of parallel connections to get the required current output, while voltage output remains unchanged.

Figure 2.2.4 summarizes parallel connection of PV modules.

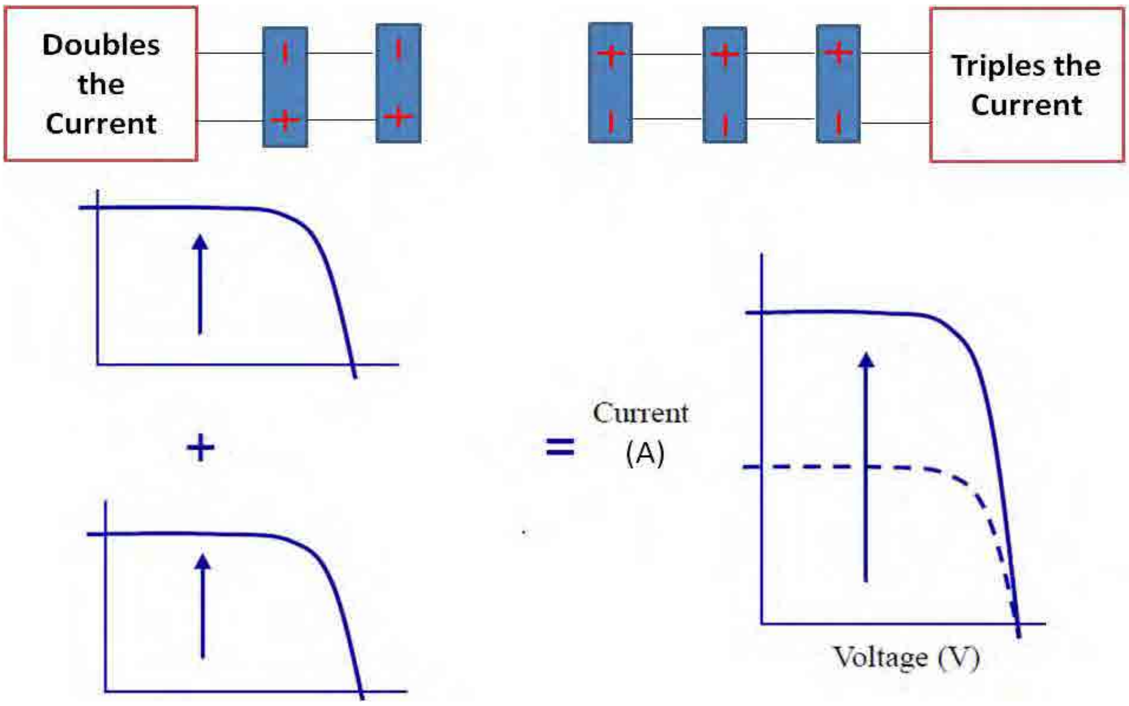

Figure 2.2.4 Example of PV Modules connected in Parallel

In the system, the number of series and parallel connections is determined by the design system voltage and required power for the loads. In some cases, input ratings of selected equipment for the system also restrict the total capacity and number of PV modules connected in series and parallel.

To decide the number of series and parallel connections of PV modules in a system, it is also necessary to consider technical specifications, such as the availability of components/equipment as per design, voltage and current bearing capacity of the equipment, workability, O&M, financial support and so on.

In the actual installation, the designed PV system capacity may need to be adjusted due to the availability of equipment, space for installation, demand and so on.

2.2.2 Batteries

Most PV systems use batteries to store the energy converted by the solar modules during the daylight hours. The converted energy is stored in the battery as chemical energy for use during the night or on bad weather days. The system's battery works like a water storage tank and as an intermediate between the power that might be available at any moment from the PV array and the power that the load might need to draw at any time. If the loads need more power than the installed PV array can produce at that time, then the storage battery discharges to supply the difference. During the night or on bad weather days when the PV array does not produce power, the batteries must discharge and fully supply the power that is required by the loads. During the daylight hours, if the loads do not consume all possible generation from the installed PV array, then the unused generation goes into recharging the installed storage battery.

(1) Purpose of Batteries in PV systems

In PV systems, the most important yet most poorly understood component is the battery. It is very difficult to have a perfect type of battery for all remote PV systems. There are many factors that influence the choice and performance of batteries in a PV system.

- The most important function of the batteries in a PV system is to allow the loads to be operated even when there is no generation of power. This occurs each night, on cloudy day and during bad weather days. To cover these instances of low or no power generation, a PV system is described as having “Autonomy”. This is the ability of the system to operate by itself without any energy input from the PV array.

- The purpose of the batteries in a PV system is to level the wide fluctuations in voltage that can be produced by the installed PV array. A load may operate only during the day, and days of autonomy may not be needed, or it may not be necessary to cover any surge current. However, direct coupling to the load may expose the system to voltages that might be too high or too low for proper operation. Ultimately the equipment may break due to the wide range of voltage fluctuation. Batteries operate within a smaller range of voltage than the PV array and can hold the voltage point of the system within a more acceptable range.
- Another important function of batteries in PV systems is to supply the level of current that may be demanded by the load, which is higher than the installed PV array can produce. The current output of the PV array is limited and directly influenced by solar intensity. The designed capacity of the PV array may be large enough to meet the total energy demand over the day, but may not be large enough to meet a large momentary demand at any particular time of the day. Hence, the battery can act as a buffer, supplying large currents to the load for short periods and being slowly charged by the installed PV array during daylight.

(2) Typical Construction of lead acid batteries

A variety of batteries are available in the market, for the choice of users. For PV systems, lead acid batteries are the most commonly used because they are cheaper compared to others on an ampere-hour basis, and are available in a wide range of capacities.

One of the main parameters to distinguish batteries is their ability to “cycle”. The cycle involves discharge and then charge of the battery. The type of batteries used in a PV system can be cycled, but it is important to understand how deeply and how many times the battery can cycle before permanent loss of capacity occurs.

There are also many different types of batteries, even for the general classification of batteries commonly used in PV systems. Some important components of battery construction are mentioned below. Here, the types of batteries commonly used for PV systems are considered.

In lead acid batteries, the grid is made of lead or alloys such as lead-antimony (PbSb) or lead-calcium (PbCa). The lead-calcium grid alloy is used in shallow cycling or flat type batteries, as this chemistry reduces gassing and requires less water maintenance. Lead-antimony is typically used in deep cycle batteries as this chemistry can efficiently recover from deep discharge on a regular basis.

The thickness of the grid also affects the cycle depth of the battery. In automotive starting type batteries, many thin plates are used, which provide more surface area for contact. A larger surface area means that it is possible for large current to flow in an instance, which is required for starting engines. However, the thin plate means that the discharge cannot be sustained for a long time.

Thick plates are used for more deep cycling applications such as power for forklifts, golf carts, electric vehicles and in PV systems. The thick plate allows deep discharge for a long period of time, while still preventing transmission to the grid. For this reason, good adhesion is maintained and the battery has a long lifespan as a result. Due to the thick plates, thick plate batteries are heavier than thin plate type for the same ampere-hours.

(3) Battery Trade-off

When deciding on the batteries for the PV system, either shallow cycle or deep cycle batteries are selected. Designers and system owners are forced to deal with the financial decision to “pay now or pay later” which means to either;

i) Pay less initially using shallow cycle type batteries and get a short lifespan (1-2 years).
ii) Pay more initially for deep cycle type batteries and get a longer lifespan (4 - 7 years).

(4) Series and Parallel Connection of Batteries

Most of the time, questions arise on how many batteries can be connected in series and parallel. If the requirement is a large in capacity, 2 V batteries are normally used in the system. For example, in telecommunication systems, the number of days of autonomy is higher and large capacity batteries are required to ensure reliable power supply without interruption. In this case, if the battery capacity is designed with normal 12 V batteries, then series connection of batteries may be reduced to adopt the design system voltage. However, to secure the required Ampere-hours, a large number of batteries are connected in parallel. This means that a number of batteries are connected in parallel to secure the required capacity for reliable power supply. However, in parallel connection the batteries are connected externally and charging and discharging of all the batteries may not work equally. This may affect reliability of power supply to the equipment, which will directly hamper services to the public. Hence, in telecommunication systems or other systems where a large battery capacity is required, 2 V batteries are used. To make 12 V systems, 6 nos. of 2 V batteries are connected in series, 12 nos. to make 24 V and 24 nos. to make 48 V. This means that every battery needs to react to charge or discharge.

From the above, it is clear that when 12 volt batteries are used in parallel connection, the batteries are connected externally to have a large capacity (Amp-hour). This means that when connected externally, if the number of parallel connections becomes large, then some of the batteries may not be charged or discharge properly, and they may finally collapse. Therefore, when a large battery capacity is required, it is recommended to increase the DC system voltage in order to decrease the parallel connections and required battery capacity (Amp-hour). If batteries are connected in series, then they are connected internally and all batteries need to charge and discharge in order to run the system. Hence, it is not recommended to have more than 4 or 5 batteries (12 V mono block type) in series connection too, because the internal resistance increases and heat will be generated, ultimately affecting the battery life. If a large battery capacity (Amp-hour) is required in the system, then 2 V batteries are the best option.

2.2.3 Charge Controller (Regulator)

In a PV system, modules are highly reliable and virtually maintenance free. But in most cases, PV module/array alone does not solve the customer’s demand. Therefore, PV modules are connected with batteries to supply power 24 hours a day. When batteries are included in the system, additional equipment are required to protect the system and control against overcharge and over-discharge.

(1) Purpose of using Charge Controller (CC)

The Charge Controller (CC) is an important component of a PV system with storage battery. The most important function of the CC is;

i) To prevent Overcharge

When there is sunlight, current from PV array will flow into the battery. This current is proportional to the irradiance at that time, whether the battery needs to be charged or not. If the battery is almost full, it will overcharge. The voltage will rise and gassing will begin, causing the electrolyte to be lost, internal heating to occur and battery life to be reduced. If left uncontrolled, the battery could lose almost all its electrolyte and be permanently damaged, which means that supply to the load will fail and it will not be possible to use appliances.

The charge controller prevents excessive charging of the battery by interrupting the current flow from the PV array into the battery. If the loads drive the battery voltage down, then the charge controller will sense this shift and reconnect the PV array to the circuit to supply power.

ii) To prevent Over-discharge

If the loads are left in ON position for too long, the battery can be over discharged. The reaction of lead and lead dioxide will continue and approach the lead grid material, weakening the bond. This can result in greater resistance and heat generation, and accelerate the loss of lifetime. Some shallow cycle type batteries are very difficult to recharge once they have been severely discharged, especially with slow charge rates typical of remote PV systems. If batteries are too deeply discharged, the voltage falls below the operating range of the loads, and it is not possible to use the appliances.

Over-discharge protection is built into the charge controller. If the battery voltage falls to a low level, the built in protection unit will disconnect the load, preventing further battery discharge. The PV array can gradually recharge the battery to some intermediate value, and the protection unit will reconnect automatically to the circuit. This process also gives feedback to the users as to the limits of their system use.

iii) To provide information to users

PV systems operate quietly and without much intrusion on the users. Some form of feedback of the system status is essential to users, so that they can understand the operation status of the system and specifically the battery status. The information can be communicated via LED light that can show the status of the battery at different stage, or a digital readout of battery voltage. Users must also be given guidelines to interpret the information received from the system, such as the color of LED lamp changing at each stage or the voltage reading. From this information, the users should be able to begin demand side management of energy uses to prevent the battery from over-discharge which may lead to system fall down.

2.2.4 Inverter (DC/AC)

The PV array generates DC current and voltage. The battery also works on DC current and voltage. If AC power is required for the loads then an inverter is required to convert DC to AC. Commonly available inverters can convert DC power to single or three phases, 50/60 Hz and AC voltage. The main characteristics of the inverter is output power and surge power.

(1) Output power and Surge power

<u>Output power</u>

An inverter is capable of providing output power depending on its ability to dissipate the heat generated within the inverter. Its rated output power is generally the power level it can maintain for a long period of time. An inverter can supply larger output power than its nominal rating for a short period of time, before it overheats and shuts off. Good inverters can supply output power above their nominal ratings for a few minutes, allowing large loads such as large power tools and pump motors to operate.

However, there is no standard period of time acceptable by all manufactures for inverter output rating. There is a trend for manufacturers to rate their inverters on a continuous basis indicating the power that the inverter could supply for many hours. This is a conservative and safe rating method. In most cases, inverters do not operate at their full rated output level for 24 hours a day, but rather for a few hours or minutes as required.

Some manufactures rate their product output for 30 minutes while others rate for 15 minutes. The problem in this situation is that the system designer will have the burden of establishing the exact method of output rating to make a fair comparison. Therefore, instead of reading a single power value, it is better to find a chart or graph that describes the output as time increases.

<u>Surge Power</u>

In actual practice the output power of the inverter can exceed the nominal rating for a few minutes. This is often referred to as the “surge capability” of the inverter. The surge power may be defined as the power that the inverter can output for less than a second to start a large inductive (motor) loads. Therefore, if there is an inductive load in the system, then it is necessary to consider and select an inverter that is capable of coping with the surge power of the inductive load in addition to other non-inductive loads that may run at the same time.

The surge power of an inverter is not a single fixed value, but varies with the amount of time. A good inverter can typically output more than 200% of its nominal power for a few seconds. Some low cost inverters cannot output more than 130% of their output for a short time. These would have limited surge capability and would not be useful for systems where an inductive load exists.

i) Inverter efficiency

An Inverter consumes some power itself. This adds to the load that the PV array must operate, and the inverter should therefore be as efficient as possible. The efficiency may depend on the nature of the load. Pure resistive loads may operate the inverter at a higher efficiency than inductive loads that absorb the power differently.

The inverter efficiency is not a fixed value, but varies depending on the amount of power being generated by the inverter. A curve of efficiency versus output power is the best way to determine how the inverter will perform under different conditions. It is very difficult or almost impossible to predetermine exactly what the power demand on the inverter will be at any moment. It is therefore necessary to estimate the power levels at which the system will operate and determine the average inverter efficiency from a curve.

ii) Output waveform

The waveform of the inverter output is an important factor in matching with loads. The waveform describes the way the current and voltage vary over time. There are three general classes of waveforms:

<u>Square wave</u>

Generally, the most inexpensive inverters are square wave types. In this technology the input DC power is chopped and boosted in voltage, with little filtering or modulation of output. The resulting output contains many unwanted harmonics, or waves of various frequencies that fight each other. The effect of these unwanted waveforms is harmonic distortion. The square wave inverters cannot surge significantly. Their efficiencies can be as low as 50 to 60% and they have little output voltage regulation. However, these inverters may be useful for small inductive loads or resistive loads.

<u>Modified square wave or modified sine wave</u>

Another type of inverter produces a modified square wave output. This type of inverter is also referred to as modified sine wave. The waveform more closely resembles a square wave, with delay through zero. The total harmonic distortion is significantly lower than that of a square wave type inverter. This type of inverter can surge over 200% above the continuous power, and has good voltage regulation. Efficiencies greater than 90% are common. This type of inverter is quite popular in remote home systems and can operate a wide variety of common appliances and electronic loads. However, there are reported problems with operating specific loads such as laser printers, microwave ovens, small electronic clocks and so on. It is necessary to check with the manufacturer whether any incompatibility with planned loads for installation has been reported.

<u>Sine wave</u>

This kind of inverter produces nearly sine wave output, and may involve extensive and carefully tuned filtering of digital synthesis. The efficiency of this type of inverter is more than 90%. In general, it is best to choose a sine wave inverter and supply a sine wave output to the AC loads. By choosing this type, very little or no problems will occur with respect to harmonic distortions or inadequate peak voltages.

2.3 System Designing (Sizing)

The purpose of PV system sizing is to calculate the capacity of PV array and batteries needed to reliably operate the load throughout the year. Here, a simple method for calculating PV array capacity and batteries are presented. It is necessary to keep in mind that there are decisions that require judgments on the part of designing.

To install a solar PV system which serves its purpose, the base parameters for system design need to be defined and established. Parameters are very critical points for design and it is very important to choose the correct values to get reliable output, not only to get required capacity but also to select the most suitable components/equipment for smooth operation and long lifespan of the system.

2.3.1 PV Array Capacity Sizing

The PV array is sized to meet the load on a daily basis, based on the site, area or regional weather conditions. The PV array will replenish the battery during subsequent days of country average irradiation. The PV array and battery are NOT sized based on how quickly the battery be recharged after a few days of bad weather conditions in which the irradiation level is lower than the average. If sizing is based on this, then the result will be a large PV array, most of which is not needed or used during most of the year. To determine the minimum size of PV array required for the installation, the following equation is applied.

PV Array capacity (Acap) = Total load (demand) / H_A x K' ……………….. (i)

Where,

H_A: Country minimum annual average Solar Irradiation (kWh/day) = 5.1 kWh/day

Depending on the type of system and importance, the selected value of solar irradiation may vary. Some may choose the minimum solar irradiation value while others may chose the maximum. However, in most cases, either the country average or minimum average is taken into account. Here, minimum average solar irradiation is used because:

a) The minimum average value is not very different from the average value
b) For basic design, the site is not specified and the system may be installed in any part of the country.

For higher accuracy, it is recommended to use site data if it is available. If it is not available, it is recommended to measure and collect data for the area where the installation is planned.

K' : Design coefficient factors (K_{HD} x K_{PD} x K_{PM} x K_{PA} x K_{PIX} x η_{INV} x η_{BA} x η_{CC} x K_{PT})

K_{HD}: Annual irradiation deviation = 0.97 (universal constant)

K_{PD}: PV module degrading = 0.9 (Range 0.9 to 0.95)

This depends on the manufacturer, and it is necessary to get the actual value from the specification sheet or to confirm with the manufacturer.

K_{PM}: PV array load matching = 0.97 (Range 0.9 to 0.98)

This depends on the design and load type.

K_{PA}: PV array circuit correction = 0.98 (Range 0.95 to 0.98)

The larger the PV array capacity or the higher the number of PV strings, the higher the loss.

K_{PIX}: PV array inclined angle and axis correction = 0.96 (Range 0.9 to 1.0)

If the installation is as per designed orientation and inclination angle, then this can be neglected (can be 1).

η_{INV}: Inverter efficiency = 0.9 (Range 0.9 to .95)

Depends on the manufacturer and type

η_{BA}: Battery charging loss = 0.95 (Range 0.9 to 0.95)

The charging loss is taken to PV array side because this will occur only during charging, and to avoid adding power to the battery.

η_{CC}: Charge Controller consumption = 0.99 (Range 0.97 to 0.99)

Depending on the type of CC and PV array capacity, it may not be necessary to consider this factor.

In case of crystalline silicon type PV cell/module there is a reduction in power generation when PV cell/module operating temperature rises. The loss of power may be critical in a system supplying power for demand load. Therefore, it is very important to consider the effect of temperature when designing solar PV systems. The equation below is used to calculate power losses as the cell/module operating temperature increases.

K_{PT} (Reduction due to the temperature rise) = $1 + \alpha_{Pmax} \times (T_m - 25)/100$ --------(ii)

Where,

α_{Pmax}: [PV Cell/Module Temperature coefficient (- %/°C)]

T_m (PV Cell/Module temperature °C) = $T_{av} + \Delta T$

T_{av}: (Ambient temperature °C)

Δ T: (Temperature rise on PV cell/module °C)

Temperature rise (ΔT) depends on the specific position of the installation. For example, the temperatures at various locations are:

a) Ground installation with some height for wind flow: 18°C
b) Installation on roof with some gap between module and roof for wind flow: 22°C
c) Roof integrated installation: 28°C

A roof integrated installation is where the PV module/array is installed on the roof itself without establishing an air gap underneath between the module/array and the roof for wind flow.

The value of ΔT is provided to understand how the distance between the installation surface and PV array affects the temperature rise of PV cell/module in different types of installations, to facilitate system design. This may vary from site to site and by country. To find the exact value; system installation, experiments, and data recording and analysis are required.

For example, if an installation on the roof with some space for wind to flow is considered, then from the above 'Equation (ii)' and value of reduction of power generation (α_{Pmax} = -0.4), the actual power generation when ambient temperature rises to 32°C will be,

$K_{PT} = 1 + \alpha_{Pmax} \times (T_m - 25)/100 = 1 + (-0.4) \times \{(32+22)-25\}/100 = 0.89$ (89%)

Note: To determine the accurate value of temperature coefficient (α_{Pmax}) of each PV module type, it's recommended to refer to the specification sheet or confirm with the manufacturer.

Therefore if a 120 W PV module is selected for installation, then generation at 32°C ambient temperature will be 106.8 W (PV rating 120 x Reduction 0.89).

Hence, in the above 'Equation (i)', by adding reduction value of power generation from 'Equation (ii)' the total design coefficient (K') correction factor to determining PV installation capacity will be 0.6.

Now, by inputting the values of demand load and solar irradiation in the equation, the required PV array capacity can be determined.

'Equation (i)' can be used to determine the size of the PV array with storage battery, supplying power. In the case of a DC system there is no need to include inverter efficiency correction factor. However, in an AC system it is necessary to include inverter efficiency correction factor irrespective of the DC system voltage.

2.3.2 Battery Designing (Sizing)

The job of the battery is to supply energy to the loads when the solar irradiation is lower than designed and installed PV array cannot generate enough power to meet the demand. Batteries therefore also need to supply power when there is no sun, such as during the night. It's necessary to size the battery bank to operate the loads during a long sequence of low solar irradiation days. During a low solar irradiation day, the PV array cannot supply all the required power to charge and to replace what the load draws from battery. Therefore, the battery ends up being discharged at the end of the day. If the following day does not have enough solar irradiation, then the battery will continue discharging to operate the system. This process can continue until the battery is discharged to a point where it may become damaged. Therefore, in design, it is necessary to build battery capacity for an adequate number of days of charge, so that the battery operates the loads autonomously, meaning without any energy input from PV array. These days of reserve are referred to as “days of autonomy". The importance of reliable power to the facility and the economic situation greatly influence the days of autonomy of the system.

As in PV capacity sizing, the coefficients (correction factors) are very important for sizing battery capacity. The size of the battery bank can be determined using the following equation:

Battery Capacity (B_{CAP}) = A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC} ---------------- (iii)

Where,

A_{DY}: Days of Autonomy (Number of Days of reserved energy) = 3 (3 to 7) days

The value is highly influenced by the importance of reliable power supply requirements and the weather pattern at the installation site. If the weather conditions at the site/area are bad or a high degree of reliability is required, then it is necessary to have more days of autonomy.

D_{LD}: Daily load (kWh/day) = As per requirement

In some cases, the load may only be available in AC (kWh/day). In order to get the necessary battery capacity (Amp-hour), the required capacity (kWh) at DC side is first calculated and sized for the design days of autonomy, and this value is divided by the adopted DC system voltage.

B_{DD}: Battery Maximum ‘Depth Of Discharge (DOD)’ = 80%

In the case of a deep cycle tubular type battery, it's possible to discharge up to 80% in maximum by the end of the days of autonomy. If a shallow cycle type is used, then it shall not be discharged by more than 50% by the end of the days of autonomy. For a sealed type deep cycle battery, it is recommended to maintain a maximum of only 70%, by the end of the days of autonomy.

η_{INV}: Inverter efficiency = 0.9 (Range 0.9 to 0.95)

This depends on the type and manufacturer. If the product has already been decided, it is recommended to use the product value, considering the average operating load demand.

η_{CE}: Battery discharging efficiency = 0.95 (Range 0.9 to 0.95)

The battery has self - discharge, and a low self - discharge type of battery should be selected. The battery needs to supply power even when solar irradiation is low or the sun is not there during the night. When reserved energy is discharged from the battery, there is some internal heat generation which leads to some power loss. This should be considered when sizing the battery capacity.

η_{CC}: Charge Controller consumption = 0.99 (Range 0.97 to 0.99)

Depending on the type of CC and size of the PV array, it may not be necessary to consider this factor. If the battery is connected directly to the inverter, or there are no DC loads in the system, then this value can be neglected (can be 1). If the type of CC to be used has already been decided, then it's recommended to use the value that is provided by the manufacturer.

From the above ‘Equation (iii)’,it can calculate the required battery capacity for the decided days of autonomy.

If three days of autonomy are decided, then the calculated capacity is for 72 hours (3 days x 24 hours). Another factor that needs to be considered when sizing the battery is that battery capacity increases as discharge rate decreases. Typically manufacturers list the battery capacity at a standard rate of 8, 10 or 20 hours of discharge. But in PV systems, depending on the days of autonomy decided, the discharge rate becomes slower than standard rate. That is, 72 hours of discharge for three days of autonomy.

The average rate of discharge for a PV system can be determined using the equation provided below.

Avg. Rate of Discharge (hour) = Days of autonomy x 24 hours

After determining the average rate of discharge for the PV system, compare that rate with battery capacity at standard rate, for the same battery. The capacity at the standard rate will be less because the battery is being discharged much faster than at PV system discharge rate. To compare and decide the required battery capacity, it is recommended to refer to the specification sheet or confirm with the manufacturer.

The equation for the Rate factor is the ratio of the two rates of discharge, and indicates how much more capacity will be gained at calculated average slow rate.

Rate factor = Capacity at PV system rate/Capacity at manufacturer's standard rate

If it is not possible to get detailed information from the manufacturer when sizing the battery, a rough "rule of thumb" can be used for the initial stage. The rough Rate factor is 1.2 (for shorter days of autonomy) to 1.3 (for more than 3days of autonomy). In other words, it can be considered that about 20% to 30% additional capacity may be gained at an expected discharge rate lower than the manufacturer's standard rating. This is just a rough method of calculating capacity on low discharge rate.

To determine the number of storage batteries to be connected in parallel and series for the system:

a) The basic method of calculation to determine the number of batteries to be connected in parallel is to divide the required capacity (Amp-hour) by the selected battery capacity (Amp-hour).
b) To determine the number of batteries to be connected in series, the DC system voltage should be divided by the nominal battery voltage.

2.3.3 Voltage Drop

The voltage drop is a critical point in the system to supply power or charge the battery to bring it to full charge state. There are two types of voltage drops in solar PV systems.

These are:

(1) The voltage drop at generation point due to the temperature rise of PV cell/module

When there is temperature rise in PV cell/module (especially in crystal silicon type) there is decrease in power generation mainly due to the voltage drop as explained in section 2.3.3, PV cell/module I-V curve, effect of temperature on PV characteristics. To calculate the possible voltage drop due to temperature rise in PV cell/module, hence power generation output at different temperatures, 'Equation (ii)' is used.

That is,

K_{PT} (Reduction due to the temperature rise) = $1 + \alpha_{Vmax} \times (T_m - 25)/100$ --------(ii)

Where,

α_{Vmax}: [PV Cell/Module Temperature coefficient for voltage (– %/°C)] = – 0.3 to – 0.4

For the actual value, refer to the specification sheet or confirm with the manufacturer. The multi-crystalline silicon type of PV cell/module has higher voltage drop than single-crystalline silicon type.

T_m (PV Cell/Module temperature °C) = $T_{av} + \Delta T$

T_{av}: (Ambient temperature °C)

ΔT: (Temperature rise on PV cell/module °C)

The value of ΔT is as explained in the section on PV array capacity sizing.

From the above equation, if α_{Vmp} is – 0.4, then the correction factor for the voltage generation when ambient temperature is 32°C is 0.89.

(2) Voltage drop along the cable section

In actual system operation, the charging voltage of charge controller (CC) is influenced by battery voltage at that time. Charging current gradually decreases as charging voltage gradually increases up to full charge state. However, even when there is some drop in voltage across the cable, it is necessary to understand the correct size of cable to supply voltage to the loads and to charge the batteries.

To calculate the voltage drops across the cable of each section, the following equation is applied:

$$e = 35.6 \times L \times I / 1{,}000 \times A \quad \text{--------------- (iv)}$$

Where,

e: Voltage drop across the cable (V)
A: Cross section area of the cable (mm^2)
L: Length of the cable (m)
I: Rated Current (A) flow

The above equation holds for copper conductors, when phase conductors of the circuit are in equilibrium and cable conductance is 97%.

2.3.4 Inverter

To select the inverter it is necessary to understand the peak demand. If an inductive load is in the system, it is recommended to choose a type of inverter which can withstand higher surge power for a long time. It is also necessary to understand that if peak demand supply is longer, then the inverter may become heated. Further, if the ambient temperate is high then it will negatively affect the operating efficiency of the inverter. If the inverter is highly heated during operation, its efficiency decreases drastically and could be as low as 50%. To avoid this, if the loads are non-inductive, it is recommended to select an inverter by multiplying required inverter capacity by 1.3 (minimum). Further, if inductive loads (depending on size) are included in the system, then it is recommended to multiply the required inverter capacity by 1.5 (minimum) if the inductive load is considered to be small in capacity.

Inverter Capacity (W) = Peak load demand (W) x 1.5

2.3.5 Charge Controller (CC)

To establish the system, one of the main points is to select the correct size of CC for the system. This requires that the DC system voltage and current flow from the installed PV array are understood correctly. Having determined the installation capacity of the PV array, the rated current (Imp) of PV array at reference solar radiation (1,000 Wh/m^2) should be multiplied by 1.5 to get the installation size of the CC for the system.

CC size (Amp) = Current rating (Imp) of PV array x 1.5

To decide the DC system voltage, it is necessary to consider not only the battery capacity with series and parallel connections, but also the required cable size, viability of required components/equipment, reliability, durability and workability, etc.

2.4 Determining PV System Capacity for Public Institutions

To decide the capacity of the PV system for facilities in the public institutions, it is necessary to understand the power demand of each facility. Hence, by using the equations described in section 2.3, the required capacity of the PV system and storage battery can be determined.

For the calculation of required power supply in public schools, the demand is divided into three categories as described below.

- PV system for lighting
- PV system for charging services
- PV system for laptop system

2.4.1 PV System for Lighting

For lighting, it is assumed that a PV system is installed in each building separately. To determine the capacity of each system, the points mentioned below are considered.

- In general, public schools consist of a number of buildings constructed separately to serve the various requirements and there is some distance between these buildings.

- The load patterns are different for each building.
- With security reasons, PV modules are considered to be installed on the buildings' roofs.
- The existing roof structure may not be strong enough to hold a large PV array on the roof. In addition, it is necessary to consider the appropriate location of the installation on the roof to avoid shadows throughout the year.
- Avoiding complicated house wirings in an attempt to connect all buildings to one system.
- Avoiding concurrent blackouts in all facilities/buildings caused by system failure, by installing a separate system for each building,
- To optimize the replacement cost of equipment, especially storage battery, install a small scale PV system in each building.

From the demand load pattern of each facility in the institution such as class room, teacher's room, dormitory, staff quarter, office room, dining hall and so on, the model for lighting is divided into three different Power Packages (PPs). If demand is rather high compared to the summarized demand range, then it is recommended to separate loads and install more than one system to serve the purpose. In addition, it is necessary to conduct demand side management by each facility whenever required. The table below shows the designed Power Package (PP) for lighting systems for public schools.

Table 2.4.1 Assumed PPs for Lighting Purpose according to the Demand

Power Package (PP) Type	PP0	PP1	PP2
Daily load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Days of autonomy (days)	3	3	3

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If demand matches an assumed PP as shown in the above table, then PV array capacity is calculated using the equation described in section 2.3.

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'

From the above equation, the required PV array capacity for each type of PP can be determined as shown below.

i) In case of power demand up to 350 Wh/day (PP0),

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 0.35 /5.1 x 0.6 = 0.114 kW = 114 W

As a 114 W PV module is not available, the nearest capacity which may be a 120 W PV module. In this case, the actual PV installation capacity will be 120 W.

ii) In case of power demand up to 700 Wh/day (PP1),

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 0.7 /5.1 x 0.6 = 0.228 kW = 228 W

If 120 W PV modules are used, then actual PV installation capacity will be 240 W.

iii) In case of power demand up to 1,400 Wh/day (PP2),

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 1.4 /5.1 x 0.6 = 0.458 kW = 458 W

If 120 W PV modules are used, then actual installation capacity will be 480 W.

The table below summarizes the results of above calculations of PV capacity based on designed Power Packages (PPs).

Table 2.4.2 Summarized Results of PV Capacity according to the PPs

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
County min. average solar irradiation (kWh/day)	5.1	5.1	5.1
Total system design factor	0.6	0.6	0.6
Calculated min. required PV array capacity (W)	114	228	458
Actual/Adjusted PV array installation capacity (W)	120	240	480

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2.4.2 Battery Designing (Sizing)

As in the PV capacity sizing, the coefficients (correction factors) are very important for battery sizing. To determine the size of battery for the aforementioned power packages, the following equation that is described in section 2.3 is used.

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / DC System voltage

Where,

A_{DY}: Days of Autonomy (Number of Days of reservation) = 3 days

D_{LD}: Daily load (AC) = Total demand (Wh/day)

B_{DD}: Battery Maximum 'Depth Of Discharge (DOD)' = 80%

η_{INV}: Inverter efficiency = 0.9

η_{CE}: Battery discharging efficiency = 0.95

η_{CC}: Charge Controller consumption = 1

(Here, it is assumed that battery is connected directly to inverter.)

Now,

i) In case of daily load demand up to 350 Wh/day (PP0)

When,

DC system voltage: DC 12 V
Load demand: 350 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 12
= (3 x 350 / 0.8 x 0.9 x 0.95 x 1) /12
= (1,050 / 0.684) / 12 = 127.9 Ah

If Rate factor is 1.3, then minimum required battery capacity is 98.4 Ah (127.9 / 1.3). As this capacity is not available, it requires upward adjustment. If 100 Ah at 20°C (charging rate) is used then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / Battery voltage
= 12/12 = 1 nos.

ii) In case of daily load demand up to 700 Wh/day (PP1)

When,

a) DC system voltage: DC 12 V

Load demand: 700 Wh/day (AC)
Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 12
= (3 x 700 / 0.8 x 0.9 x 0.95 x 1) / 12 = (2,100 / 0.684)/12
= 255.9 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 196.8 Ah. As this size is not available, it requires upward adjustment. If 200 Ah at 20°C is used, then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / Battery voltage
= 12 / 12 = 1 nos.

b) DC system voltage: DC 24 V

Load demand: 700 Wh/day (AC)

Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 24
= (3 x 700 / 0.8 x 0.9 x 0.95 x 1) / 24
= (2,100 / 0.684) / 24 = 127.9 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 98.4 Ah. As this size is not available, it requires upward adjustment. If 100 Ah at 20°C is used then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / Battery voltage
= 24 / 12 = 2 nos.

iii) In case of daily load demand up to 1,400 Wh/day (PP2)

When,

a) DC system voltage: DC 12 V

Load demand: 1,400 Wh/day (AC)

Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 12
= (3 x 1,400 / 0.8 x 0.9 x 0.95 x 1) / 12
= (4,200 / 0.684) / 12 = 511.7 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 393.6 Ah. As this size is not available, it requires upward adjustment. If 400 Ah (100 Ah x 4 nos. or 200 Ah x 2 nos.) at 20°C is used, then days of autonomy will be slightly more than 3 days.

As mentioned in section 2.3 above, if a large number of batteries are connected in parallel, then charge/discharge and equalizing charge may not be effective. Over the time of operation, some of the batteries may not charge and discharge well.

If 100 Ah battery is used in the system,

Batteries in parallel = Required battery capacity / Ah of each battery
= 400 Ah / 100 Ah = 4 nos.

If 200 Ah battery is used in the system,

Batteries in parallel = Required battery capacity / Ah of each battery
= 400 Ah / 200 Ah = 2 nos.

The required number of batteries in series = DC system voltage / Battery voltage
= 12 / 12 = 1 nos.

b) DC system voltage: DC 24 V

Load demand: 1,400 Wh/day (AC)

Days of Autonomy: 3 days

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 24

= (3 x 1,400 / 0.8 x 0.9 x 0.95 x 1) / 24
= (4,200 / 0.684) = 255.8 Ah

If Rate factor is 1.3, then battery capacity at 20°C will be around 196.8 Ah. As this size is not available, it requires upward adjustment. If 200 Ah at 20°C is used, then days of autonomy will be slightly more than 3 days.

The required number of batteries in series = DC system voltage / battery voltage
= 24 / 12 = 2 nos.

The recommended capacities of PV array and batteries are summarized in the table below.

Table 2.4.3 Recommended PV Array and Battery Capacities for Installation

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Country min. average solar irradiation (kWh/day)	5.1	5.1	5.1
Total system design factor	0.6	0.6	0.6
Calculated min. required PV array capacity (W)	114	228	458
Recommended PV capacity (W) for installation	120	240	480
Recommended DC system voltage (V)	12	24	24
Days of autonomy (days) taken for calculation	3	3	3
Recommended Storage battery capacity (Ah)	100	100	200
Required Battery Quantity (Nos.)	1	2	2

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2.4.3 Voltage Drop

The Voltage drop is a critical point in the system, to supply power or charge the battery. In the system, there are two types of voltage drops as described in section 2.3.

These are:

(1) The voltage drop at generation due to temperature rise of PV cell/module.

For calculation, the following equation described in section 2.3 is applied.

K_{PT} (Reduction in voltage generation) = 1 + α_{Vmax} x (T_m - 25)/100 = 0.89
Where,
α_{Vmp} [PV Cell/Module Temp coefficient for voltage (– %/°C)] = – 0.4
T_m (PV Cell/Module temperature °C) = T_{av} + ΔT = 52°C
T_{av} (Ambient temperature °C) = 32°C
Δ T (Temperature rise on PV cell/module °C) = 22°C

If 120 W module is used in the system, then the output is as follows:

Voltage at maximum power point (V_{mp}) = 17.49 V
Current at maximum power point (I_{mp}) = 6.86 V

Therefore, voltage generation at 52°C = V_{mp} x K_{PT} = 17.49 x 0.89 = 15.6 V

(2) Voltage drop along the cable section.

To calculate the voltage drop at each cable section, the following equation described in section 2.3 is applied.

e = 35.6 x L x I / 1,000 x A
Where,
e: Voltage drop across the cable (V)
A: Cross section area of the cable (mm^2)
L: Length of the cable (m)

I: Rated Current (A) flow

The equation shown above holds when the cable conductor is copper, phase conductors of the circuit are in equilibrium and cable conductance is 97%.

When selecting the cable size for the system, in addition to the voltage drops mentioned above in (1) and (2), it is necessary to consider required minimum voltage for equalizing charge. Most Charge Controllers (CCs) need minimum 15 V input from PV array for equalizing charge. Depending on the manufacturer, some may need more or less than 15 V, and this also depends on the type of battery (flooded, sealed or gel). Considering this, even with voltage drops in generation and cable sections, there should be at minimum 15 V supply to the CC.

In the case of 24 or 48 volt systems, the required minimum voltage up to the input terminal of CC is 30 and 60 (15 x 2 and 15 x 4) volts respectively.

Furthermore, most PV modules come with attached cable of 4 mm^2 in size and around 1 meter in length. This also needs to be considered when calculating voltage drops.

For the voltage drop calculation here, a 120 W module is used for reference. Therefore, voltage drop in the system up to the end of the attached cable to the PV module will be:

$e = 35.6 \times L \times I / 1{,}000 \times A = 35.6 \times 1 \times 6.86 / 1{,}000 \times 4 = 0.06$ V

When,

e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 4 mm^2

L (Length of the cable) = 1 meter

I (Rated Current flow) = 6.86 Amp

Hence, if operating temperature of PV module is 52°C, then voltage up to the end of attached cable (4 mm^2) will be 15.54 V.

That is,

Voltage generation by PV array at 52°C (a) – Voltage drop up to the end of attached cable of PV module (0.06 V).

15.6 V – 0.06 V = 15.54 V

Now, from the end of attached cable to CC input terminal, the cable size should be such that the voltage drop shall not be more than 0.5 V irrespective of the cable length, in order to ensure input voltage is over 15 V.

To calculate voltage drop of the cable, it is assumed that current flow is maximum at that time. If the above values are applied to the Power Packages (PPs) mentioned in preceding sections, then the results are as follows:

(1) In case of PP0 (Demand load up to 350 Wh/day)

System voltage (V) = 12 V DC

Generated voltage by PV up to the end of attached cable: 15.54 V

PV panels in parallel (no.) = 1 (120 Watt)

Then, using the equation for voltage drop below:

$e = 35.6 \times L \times I / 1{,}000 \times A = 35.6 \times 10 \times 6.86 / 1{,}000 \times 10 = 0.24$ V

When,

e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for the calculation)

L (Length of the cable) = 10 meters (assumed maximum length)

I (Rated Current flow) = 6.86 Amp

From the above calculation, in the case of PP0, the possible voltage at input terminal of CC will be 15.3 V (15.54 V – 0.24 V).

In addition to the voltage drops mentioned above for the cable section from PV to CC, there is another cable section from CC to battery. This is also a very important factor in bringing the battery to full charge state. In this CC to battery section, the connection cable shall be as short as possible and assumed to be 3 meters (maximum). Further, the voltage drop of this cable section shall be as small as possible, and 0.1 V at most. Considering these points, the required cable size for the section will be calculated as below.

A = 35.6 x L x I / 1,000 x e = 35.6 x 3 x 6.86 / 1,000 x 0.1 = 7.33 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) =? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp

From the above calculation, to restrict voltage to 0.1 V when cable length is 3 meters, the minimum required cable size is 7.33 mm^2. As this size is not available, the nearest possible size to avoid more than 0.1 V drop will be 10 mm^2.

(2) In case of PP1 (Demand load up to 700 Wh/day)

i) When System voltage is 12 V DC

Generated voltage by PV up to end of attached cable: 15.54 V
PV panels in parallel (no.) = 2 (120 W x 2 nos.)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 2) / 1,000 x 10 = 0.49 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 mm^2 (assumed for the calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, in the case of PP1 (DC 12V), the voltage at input terminal of CC will be 15.05 V.

As in PP0, voltage drop of the cable section from CC to battery shall be as small as possible and 0.1 V at most. The required cable size for the section will be as follows:

A = 35.6 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 2) / 1,000 x 0.1 = 14.65 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) =? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, to restrict voltage drop to 0.1 V when cable length is 3 meters, the minimum required cable size is 14.65 mm^2. As this size is not available, the nearest possible size to avoid more than 0.1 V drop will be 16 mm^2.

ii) When System voltage (V) = 24 V DC

Generated voltage by PV up to end of attached cable: 31.08 V (15.64 V x 2 in Series)
PV panels in parallel (no.) = 1 (120 W x 2 in Series)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x 6.86 / 1,000 x 10 = 0.24 V
When,
e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp

From the above calculation, in the case of PP1 (DC 24 V), the possible voltage at input terminal of CC will be 30.8 V (31.08 V – 0.24 V).

As in PP0, voltage drop of the cable section from CC to battery shall be 0.1 V at most. The required cable size for the section will be as follows:

A = 35.6 x L x I / 1,000 x e = 35.6 x 3 x 6.86 / 1,000 x 0.1 = 7.33 mm^2.
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) = ? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp

From the above calculation, to restrict voltage drop to 0.1 V, the minimum required cable size is 7.33 mm^2. As this size is not available, the nearest possible size will be 10 mm^2.

(3) In case of PP2 (Demand load up to 1,400 Wh/day)

i) When System voltage (V) = 12 V DC

Generated voltage by PV up to end of attached cable: 15.64 V
PV panels in parallel (no.) = 4 (120 W x 4 nos.)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 4) / 1,000 x 10 = 0.98 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp x 4 PV modules

From the above calculation, in the case of PP2 (DC 12 V), the voltage at input terminal of CC is 14.56 V. Here, due to the high voltage drop, the remaining voltage is less than the required voltage of 15 V. In order to minimize the voltage drop, a larger cable size is required for this section. From the above calculations, to ensure the voltage at input terminal of CC is more than 15 V, the required minimum cable size will be more than 20 mm^2. As this size is not available, the nearest cable size will be 25 mm^2.

Even though large cable sizes are available in the market, small equipment cannot adopt larger cable sizes as their performance of workability becomes very poor.

As in other PPs, voltage drop of the cable section from CC to battery also needs to be considered. This means that here, very large cable sizes may also be required to ensure a maximum voltage drop of 0.1 V. The required cable size for the section will be as follows:

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 4) / 1,000 x 0.1 = 29.31 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) =? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp x 4 PV modules

From the above calculation, to restrict voltage drop to 0.1 V, the minimum required cable size will be 29.31 mm^2. As this size is not available, the nearest possible size will be 35 mm^2.

From the above results, it can be considered that as PV system capacity becomes larger, it becomes less practical to design the system on DC 12 V. Where DC 12 V is not practical, it is recommended to design the system in higher voltage such as DC 24 V or DC 48 V depending on PV capacity.

ii) When System voltage (V) = 24 V DC

Generated voltage by PV up to end of attached cable: 31.08 V (15.64 V x 2 in Series)
PV panels in parallel & series (no.) = 2P & 2S (120 W x 4 nos.)

Then, using the equation for voltage drop below:

e = 35.6 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 2) / 1,000 x 10 = 0.49 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp x 2 parallel

From the above calculation, in the case of PP2 (DC 24 V), the possible voltage at input terminal of CC is 30.59 V.

As in other PPs, voltage drop of the cable section from CC to battery shall be 0.1 V at most. The required cable size for the section will be as follows:

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 2) / 1,000 x 0.1 = 14.65 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) = ? mm^2
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 6.86 Amp x 2

From the above calculation, to restrict voltage drop in this section to 0.1 V, the minimum required cable size is 14.65 mm^2. As this size is not available, the nearest possible size to avoid more than 0.1 V drop will be 16 mm^2.

The table below shows the results of the calculation of cable size for each section, when the designed PPs are adopted.

Table 2.4.4 Recommended Cable Size for each Section

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Minimum required PV array capacity (W)	114	228	458
PV module rating taken for calculation (W)	120	120	120
PV array Current rating (I_{mp})	6.86	6.86	13.72
Recommended PV array capacity (W)	120	240	480
Recommended DC system voltage (V)	12	24	24
Cable size (mm^2) for PV to CC (L=10m)	10	10	10
Cable size (mm^2) for CC to Battery (L=3m)	10	16	16

Prepared by JET

The above table shows that from the calculations, the cable size for the section from CC to battery is 10 mm^2 for a PP0 type system and 16 mm^2 for PP1 and PP2 systems. To standardize, it is recommended to use 16 mm^2 cables for this section for all PPs. The cable for the section from CC to battery shall be of a flexible type.

The table below summarizes the total system configuration of the respective PPs.

Table 2.4.5 Summary of System Configurations for PPs

Power Package (PP) Type	PP0	PP1	PP2
Load demand (Wh/day)	Up to 350	350 to 700	700 to 1,400
Country min. average solar irradiation (kWh/day)	5.1	5.1	5.1
Total system design factor	0.6	0.6	0.6
Calculated min. required PV array capacity (W)	114	228	458
Recommended PV capacity (W) for installation	120	240	480
Recommended DC system voltage (V)	12	24	24
Days of autonomy (days) taken for calculation	3	3	3
Recommended Storage battery capacity (Ah)	100	100	200
Required Battery quantity (Nos.)	1	2	2
Recommended Cable size (mm^2) for the section PV to CC (L = 10 m)	10	10	10
Recommended Cable size (mm^2) for section CC to Battery (L = 3 m)	16	16	16
Recommended Charge Controller (CC) Capacity (I)	15	15	30
Recommended Inverter Capacity (Watt)	300	500	700

Prepared by JET

2.4.4 PV System for Charging Services

The charging service is considered to provide power for charging mobile phones, lanterns and hair clippers for community residents at a small fee. When charging services are provided at public schools where other PV systems are installed, the income generated can be used as financial support for the replacement of consumable equipment such as lamps, fuses, distilled water for refilling battery and so on.

The assumed utilization pattern of the charging service is as shown in the table below.

Table 2.4.6 Assumed Utilization Pattern of Charging Service

Item	Quantity	Watt (AC)	Use (hr/day)	Total Demand (Wh/day)
Mobile phone	35	2	3	210
Lantern (LED)	20	3	5	300
Hair clipper	1	20	3	60
In house light (LED)	1	5	4	20
Security light	1	10	11	110
Total				700

Prepared by JET

The total demand shown in the above table is applied to determine the PV array capacity, using the equation mentioned in section 2.3. For reference, the methods of calculation to determine PV array capacity, storage battery and voltage drop are those in section 2.4.1. The summarized results are as shown below.

(1) PV array sizing for demand load of 700 Wh/day (charging service)

The method of determining PV array size for the charging system is the same as for other systems. From the calculation, the required PV array capacity is as shown below.

PV Array capacity (Acap) = Total load (demand) / H_A x K'
= 0.7 /5.1 x 0.6 = 0.228 kW = 228 W

If, 120 W PV module is used, then total PV array capacity for the system will be 240 W (120 W x 2).

(2) Battery sizing for demand load of 700 Wh/day (charging service)

In the charging system, charging is done during the day. This means that the main tasks of the battery are to stabilize the voltage and to provide power when the installed PV array is not able to supply power at that moment or when a higher current is required for some time which cannot be maintained by the installed PV array capacity. Furthermore, by reducing the battery capacity to a minimum, the initial cost of system and replacements cost can be reduced. Considering the aforementioned points:

When,

System voltage: DC 12 V

If Days of Autonomy (A_{DY}): 1 day,

Then,

Battery Capacity (B_{CAP}) $= (A_{DY} \text{ x } D_{LD} / B_{DD} \text{ x } \eta_{INV} \text{ x } \eta_{CE} \text{ x } \eta_{CC})$ / DC System voltage

= (1 x 700 / 0.8 x 0.9 x 0.95 x 1) / 12

= (700 / 0.684) / 12 = 85.3 Ah

From the calculation, the required storage battery capacity is 85.3 Ah. As this size is not available, it requires upward adjustment. The nearest available capacity is 100 Ah at 20°C. If the installation site has bad weather, then it is recommended to increase the battery capacity from 100 Ah to 200 Ah.

(3) Determining the cable size for demand load of 700 Wh/day (charging service)

System voltage (V) = 12 V DC

Generated voltage by PV up to end of attached cable: 15.54 V

PV panels in parallel (no.) = 2 (120 Watt x 2 nos.)

Then, using the equation for voltage drop below:

e = 36.5 x L x I / 1,000 x A = 35.6 x 10 x (6.86 x 2) / 1,000 x 10 = 0.49 V

When,

e (Voltage drop across the cable) = ? (V)

A (Cross section area of the cable) = 10 mm^2 (assumed for calculation)

L (Length of the cable) = 10 meters (assumed maximum length)

I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, in the case of DC 12 V system for charging service, the possible voltage at input terminal of CC is 15.05 V.

For the section from CC to battery restricting voltage drop to 0.1 V, the required cable size is as shown below.

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x (6.86 x 2) / 1,000 x 0.1 = 14.65 mm^2

When,

e (Voltage drop across the cable) = 0.1 V

A (Cross section area of the cable) = ? mm^2

L (Length of the cable) = 3 meters (maximum length)

I (Rated Current flow) = 6.86 Amp x 2 PV modules

From the above calculation, the minimum required cable size is 14.65 mm^2. As this size is not available, the nearest possible size will be 16 mm^2.

Table 2.4.7 System Capacity for Charging Service

Items	Value
Load demand (Wh/day)	700
County minimum average solar irradiation (kWh/day)	5.1
Total system design factor	0.6
Calculated minimum required PV array capacity (W)	228
Capacity of each PV module (W)	120
DC system voltage (V)	12
Adjusted PV array capacity (W) for installation	240
Storage battery capacity (Ah)	100
Required Battery quantity (Nos.)	1
Recommended Cable size (mm^2) for section PV to CC (L = 10 m)	10
Recommended Cable size (mm^2) for section CC to Battery (L = 3)	16
Recommended Capacity of CC	30
Recommended Capacity (min.) of Inverter (W)	300

Prepared by JET

If demand for charging increases in the future, it is recommended to install an additional system to serve the demand.

2.4.5 PV System for Laptop system

To determine the PV array capacity for laptop system, it's necessary to understand utilization hours and power consumption by the equipment. Based on the information provided by MoEST, the PV system for laptop use is designed as shown below.

The table below summarizes the estimated power demand of laptop system.

Table 2.4.8 Assumed Utilization Pattern of Laptop Use

Item	Quantity (nos.)	Watt (AC)	Use (hr/day)	Peak Demand (kW)	Total Demand (kWh/day)
Laptop for students	50	25	3	1.25	3.75
Computer for teacher (Administration)	1	50	3	0.05	0.15
Projector	1	230	1	0.23	0.23
Laser printer	1	600	1	0.60	0.60
Total		905		2.13	4.73

Prepared by JET

As shown in the above table, the total demand is 4.73 kWh/day and peak demand is 2.13 kW. Based on the estimated power demand, the calculation methods to determine the capacity of PV array, storage battery, inverter, charge controller and cable size are as described in section 2.3.

If demand is as shown in the above table, then the following equation described in section 2.3 is used to determine the required PV array capacity.

PV Array capacity (A_{cap}) = Total load (demand) / H_A x K'
= 4.73 / 5.1 x 0.6 = 1.55 kW

If 120 W PV module is selected for installation, then in order to meet the above installation capacity, 12.9 numbers of PV modules are required. This quantity is rounded up to 13 numbers of PV modules. As the quantity of PV modules is an odd number, the DC system voltage will be 12 V only.

From the above section, it is clear that if the system is designed on DC 12 V, then the cable size for each section will be very large. It may therefore be impossible to procure equipment like CC and inverter in the required sizes. Further, there may also be a problem in charging and discharging of batteries. It is therefore recommended to design the system in higher DC system voltage.

The table below summarizes the PV capacity according to the DC system voltage.

Table 2.4.9 Summary of PV Capacity Respective to DC System Voltage

Items	24 V System	48 V System
Load demand (kWh/day)	4.73	4.73
Country min. average solar irradiation (kWh/day)	5.1	5.1
Total system design factor	0.6	0.6
Calculated min. required PV array capacity (kW)	1.55	1.55
Chosen PV module type (W)	120	120
Rounded up PV module (If 120 W is used) quantity	13	13
Required quantity to adopt system voltage (Nos.)	14	16
PV array Capacity (kW) due to adopted quantity	1.68	1.92

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Battery Designing (Sizing)

For storage battery sizing, characteristics of power consumption patterns are considered to decide days of autonomy. That is;

a) In schools, laptops are used during the day's hours of week days only.
b) The main functions of the battery is to stabilize voltage and to supply power when the PV array does not meet the demand at that particular operational time.
c) The battery maintains an ideal state over the weekends and long vacations.
d) The replacement cost of storage batteries needs to be as low as possible.

As mentioned in section 2.3 above, if a large number of batteries are connected in parallel, then charge/discharge and equalizing charge may not be effective. Therefore, over the time of operation, some of the batteries may not charge and discharge effectively. In the long run, this may affect the lifespan of the system. Therefore, in this case, the calculation for DC 12 V system is excluded.

The method of battery sizing is the same as for other systems. To determine the size of the battery for DC 24 V and DC 48 V systems, the following equation is used.

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / DC System voltage

i) In case of DC 24 V System

Load demand: 4,730 Wh/day (AC)

Days of Autonomy: 1 day

Then,

Battery Capacity (B_{CAP}) = (A_{DY} x D_{LD} / B_{DD} x η_{INV} x η_{CE} x η_{CC}) / 24
= (1 x 4,730 / 0.8 x 0.9 x 0.95 x 1) / 24
= (4,730 / 0.684) / 24 = 288.13 Ah

From the above calculation, the required minimum battery capacity is 288.13 Ah. As this size is not available, it requires upward adjustment. If 300 Ah (100 Ah x 3 nos.) at 20°C is used, then days of autonomy will be slightly more than that assumed for the calculation. If 600 Ah (200 Ah x 3 nos.) at 20°C (charging rate) is used, then days of autonomy will be more than 2 days.

If 100 Ah is used in the system,

Batteries in parallel = Required battery capacity / Ah of each battery
= 300 Ah / 100 Ah = 3 nos.

If 200 Ah is used in the system,

Batteries in Parallel = Required battery capacity / Ah of each battery
= 600 Ah / 200 Ah = 3 nos.

The required number of battery in series = DC system voltage / Battery voltage
= 24 / 12 = 2 nos.

From the above calculations, when either a 100 Ah or 200 Ah battery is chosen for the system, the required number of batteries will be 6 (2 Series x 3 Parallel).

ii) In case of DC 48 V System

DC system voltage: DC 48 V
Load demand: 4,730 Wh/day (AC)
Days of Autonomy: 1 day

Then,

Battery Capacity (B_{CAP}) $= (A_{DY} \text{ x } D_{LD} / B_{DD} \text{ x } \eta_{INV} \text{ x } \eta_{CE} \text{ x } \eta_{CC})$ / DC System voltage
= (1 x 4,730 / 0.8 x 0.9 x 0.95 x 1) / 48
= (4,730 / 0.684) / 48 = 144.1 Ah

From the above calculation, the required minimum battery capacity is 144.1 Ah. As this size is not available, it requires upward adjustment. If 200 Ah at 20°C (charging rate) is used, then days of autonomy will be slightly more than 1 day.

The required number of batteries in series = DC system voltage / battery voltage
= 48 / 12 = 4 nos.

From the above calculation, the required number of batteries in the system is 4 (in Series).

The results of calculations to determine the battery capacities are shown in the table below, which summarizes the recommended capacities of PV array and batteries for installation.

Table 2.4.10 Recommended Capacity of PV Array and Batteries for Installation

Items	24 V System	48 V System
Load demand (kWh/day)	4.73	4.73
Country min. average solar irradiation (kWh/day)	5.1	5.1
Total system design factor	0.6	0.6
Calculated min. required PV array capacity (kW)	1.55	1.55
Chosen PV module type (W)	120	120
Rounded up PV module (If 120 W is used) quantity	13	13
Required quantity to adopt system voltage (Nos.)	14	16
Adjusted PV array Capacity (kW)	1.68	1.92
Days of Autonomy taken for calculation	1	1
Calculated required Battery capacity (Ah)	288.13	144.1
Adjusted Battery capacity (Ah)	300	200
Required Battery quantity (Nos.) to adopt voltage	6	4

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Voltage drop

The calculation methods to determine the voltage drop at the generation side due to temperature rise of PV cell/module, and cable size are the same as in section 2.3.

(1) To Determining the Cable Size for Laptop System

i) When System voltage (V) = 24 V DC

Generated voltage by PV up to end of attached cable = 31.08 V (15.54 V x 2)
Total PV system capacity = 1.68 kW (120 W x 14 nos., 2 Series x 7 Parallel)
PV Sub-array (nos.) = 7
No. of PV circuits (strings) from PV to Junction Box (JB) = 7 Circuits

From the equation, the voltage drop of each string (circuits) for the section from PV to JB will be as shown below.

e = 36.5 x L x I / 1,000 x A = 35.6 x 10 x 6.86 / 1,000 x 10 = 0.24 V
When,

e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 (mm^2)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp (each string)

Voltage drops of each string up to the input terminal of diode (with heat sink) are 30.84 V (31.08 V – 0.24 V)

There are also some voltage drops at diode, which vary depending on the diode type and material. For details, refer to the specifications sheet or confirm with the manufacturer. Here, for calculation it is assumed that a silicon diode is used and the voltage drop for this particular type of diode is 0.7 V. Here, a diode will be connected after each string (seven circuits).

Hence,

Total voltage drop of each string from PV to JB (with diode) = 0.94 V (0.24 + 0.7)

Now,

The seven strings (circuits) are combined together at JB to connect CC. Therefore, to ensure a minimum of 30 V at input terminal of CC, the possible voltage drop in this section (JB to CC) are 0.14 V (31.08 V – 30 V – 0.94 V).

Hence, from the voltage drop calculation, the required cable size is as shown below.

A = 36.5 x L x I / 1,000 x e = 35.6 x 2 x 48.02 / 1,000 x 0.14 = 24.42 mm^2
When,
e (Voltage drop across the cable) = 0.14 (V) (to secure 30 V)
A (Cross section area of the cable) = ? (mm^2)
L (Length of the cable) = 2 meters (assumed maximum length)
I (Rated Current flow) = 48.02 A (6.86 Amp x 7 strings combined together)

In the case of DC 24 V system, when PV module operating temperature is 52°C and current flow is maximum, then to ensure a minimum of 30 V up to the input terminal of CC, the required cable size for the sections are:

a) PV to JB = 10 mm^2 (each string)
b) JB to CC = 25 mm^2 (Cable size 24.42 mm^2 is not available)

For the section from CC to battery, voltage drop shall not be more than 0.1 V. To restrict the voltage drop, the required cable size for the section will be as shown below.

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x 48.02 / 1,000 x 0.1 = 51.29 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) = ? (mm^2)
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 48.02 Amp (6.86 Amp x 7 Sub-array)

From the above calculation, to restrict voltage drop in this section to 0.1 V when cable length is 3 meters, the minimum required cable size is 51.29 mm^2. As this size is not available, the nearest size is 70 mm^2. However, this large cable size is not practical, for connection to CC.

ii) When System voltage (V) = 48 V DC

Generated voltage by PV up to end of attached cable = 62.16 V (15.54 V x 4)
Total PV system capacity = 1.92 kW (120 W x 16 nos., 4 Series x 4 Parallel)
PV Sub-array (nos.) = 4
No. of PV circuits (strings) from PV to Junction Box (JB) = 4 Circuits

From the equation, the voltage at each string (circuits) from the section from PV to JB will be as shown below.

e = 36.5 x L x I / 1,000 x A = 35.6 x 10 x 6.86 / 1,000 x 10 = 0.24 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 (mm^2)
L (Length of the cable) = 10 meters (assumed maximum length)
I (Rated Current flow) = 6.86 Amp (each string)

After the voltage drops of each string, the input voltage to the JB from PV sub-array is 61.92 V (62.16 V – 0.24 V)

Here, all 4 strings (circuits) connect after diode at JB and combined single string will connect CC. As in the above calculation, if voltage drop at diode is 0.7 V,

Then,

Total voltage drop from PV to JB (with diode) = 0.94 V (0.24 V + 0.7 V)

Now,

To ensure a minimum of 60 V at input terminal of CC, the possible voltage drop in this section (JB to CC) is 1.22 V (62.16 V – 60 V – 0.94 V).

Hence, from the calculation if 10 mm^2 size cable is used, then voltage drop in this section is,

e = 36.5 x L x I / 1,000 x A = 35.6 x 2 x 27.44 / 1,000 x 10 = 0.19 V
When,
e (Voltage drop across the cable) = ? (V)
A (Cross section area of the cable) = 10 mm^2
L (Length of the cable) = 2 meters (assumed maximum length)
I (Rated Current flow) = 27.44 A (6.86 Amp x 4 Sub-array)

In the case of DC 48 V system, when PV module operating temperature is 52°C and current flow is maximum, then to ensure a minimum of 60 V up to the input terminal of CC, the required cable sizes for the sections are:

a) PV to JB = 10 mm^2
b) JB to CC = 10 mm^2

For the section from CC to battery, voltage drop shall be 0.1 V at most. To restrict the voltage drop, the required cable size for the section is:

A = 36.5 x L x I / 1,000 x e = 35.6 x 3 x 27.44 / 1,000 x 0.1 = 29.31 mm^2
When,
e (Voltage drop across the cable) = 0.1 V
A (Cross section area of the cable) = ? (mm^2)
L (Length of the cable) = 3 meters (maximum length)
I (Rated Current flow) = 27.44 Amp (6.86 Amp x 4 Sub-array)

From the above calculation, to restrict voltage drop in this section to 0.1 V when cable length is 3 meters, the minimum required cable size is 29.31 mm^2. As this size is not available, the nearest size is 35 mm^2.

The table below summarizes the total system configurations for laptop system.

Table 2.4.11 Summary of Laptop System

Items	24 V System	48 V System
Load demand (kWh/day)	4.73	4.73
Country min. average solar irradiation (kWh/day)	5.1	5.1
Total system design factor	0.6	0.6
Calculated min. required PV array capacity (kW)	1.55	1.55
Chosen PV module type (W)	120	120
Rounded up PV module (If 120 W is used) quantity	13	13
Required quantity to adopt system voltage (Nos.)	14	16
Adjusted PV array Capacity (kW)	1.68	1.92
Days of Autonomy taken for calculation	1	1
Calculated required Battery capacity (Ah)	288.13	144.1
Adjusted Battery capacity (Ah)	300	200
Required Battery quantity (Nos.)	6	4
Recommended Cable size (mm^2) for section PV to JB (L = 10 m)	10	10
Recommended Cable size (mm^2) for section JB to CC (L = 2)	25	10
Recommended Cable size (mm^2) for section CC to Battery (L = 3)	70	35
Recommended Charge Controller (CC) Capacity (I)	70	40
Recommended Inverter Capacity (kW)	3.0	3.0

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From the above table, even though there are differences in actual practice of use pattern, if the system is designed at DC 48 V, then the adjusted PV array can still supply power smoothly in the long run without any problem.

The above table shows that the adjusted PV array capacity at DC 48 V becomes 1,920 W. As the PV array capacity is slightly higher than required capacity due to connection arrangements, the same installation capacity can supply power for higher demand of up to 5.8 kWh/day.

In actual installation, the capacity of the PV array differs from the calculated required minimum size of the PV array due to series and parallel connection of PV modules in order to adopt the pertinent DC system voltage and ensure market availability of the product.

2.5 Installation

In existing or ongoing installations, once the contract between the owner and supplier/contractor is finalized, procurement and installation of the system should be undertaken. This includes other works such as verification of installed materials and equipment against the tender/contract document, supervision during installation and required rectification works which are additional responsibilities of the supplier/contractor.

As soon as the contract with the owner is finalized, the supplier/contractor should proceed with the installation works. For this the supplier/contractor makes a contract with the technicians on the basis of volume and type of works to be carried out and decides the time line of installation. Once the contract of work is made with the technicians, the supplier/contractor delivers the materials to the site and technicians start the installation works. If only the process stipulated in the contract for installation works is considered, the installation may look satisfactory. However, there are some important points that are not included either before or during installation works, or after completion of works that are directly related to the life of the system and installation quality. That is,

(1) After the service contract between the owner (requester) and supplier/contractor is finalized, the requested type of work is not explained in detail to the supplier/contractor, or the supplier/contractor does not go through the tender document to understand the required type of installation work properly.

(2) To understand the required installation work at the site or to plan for the installation work, the supplier/contractor normally does not visit the actual installation site before participating in bidding, after getting the work offer, or before contracting technicians for installation works. Hence, the supplier/contractor is not able to prepare shop drawings for the system installation plan or explain the required type of installation work to the technicians at the site. The supplier/contractor only adheres to the quantities or

measurements stated in the tender document, which cannot be exactly the same in the case of mass installation. This means that, for example, if the wiring route or installation position of a component or equipment requires adjustment, then such a small issue will affect the whole installation and material management.

(3) Sometimes, the basic rules of house wiring are not understood or are neglected by the technicians. For example:
- Naked (non insulated) wire of one of the three (3) cores of Vinyl Insulated Flat cable is used either as negative wire or as returned wire from lamp to ON/OFF switch.
- Earth rod is not grounded properly. In some cases, if it cannot go down smoothly, then instead of shifting grounding position the remaining portion is bent or cut off.

(4) The installation materials are not handled carefully. Hence, even cracked or partly broken switches, sockets, lamp holders, cable turfs, etc., are installed.

(5) In some cases, all holes for mounting equipment are not used, which means the equipment may fall off at any time during system operation.

(6) Due to forceful work or unmatched use of tools, threads of terminal screws are broken or slip.

(7) PV module/array is installed on the roof without considering the inclination angle and orientation (direction) of the installation. Therefore, power generation differs drastically from the designed value (causing a mismatch with design use pattern).

(8) In case of connecting storage battery , even though there is more than one battery in the system (12 V), more than two (2) wires are connected at the same terminal.

(9) The positioning of equipment is not adequately considered during installation. Hence, DC and AC wires/cables cross over each other or the same cable turf is used for both power supply systems.

(10) Cross check during the installation or inspection after installation by the supplier/contractor is not common practice. Hence, the supplier/contractor is not sure of the actual status of the installed system, and commissioning may even be carried out by owner.

Considering all the above points, in order to avoid confusion and ensure smooth operation and good quality of work, the following points are recommended as countermeasures:

(1) The owner shall conduct inspection of procured materials, verifying against the contract document before materials are dispatched to the site.

(2) The installation materials and equipment shall be checked and confirmed before dispatching to the site, by both the technicians and supplier/contractor.

(3) The operation of equipment like inverter, CC, etc., needs to be confirmed and recorded before dispatching to the site.

(4) For transportation, materials and equipment shall be packed well to avoid any damages while transporting.

(5) The responsible engineer/personnel on behalf of the supplier/contractor shall accompany the technicians to guide the installation work, and shall explain the required work in detail to the technicians at the site. If there is more than one group/team of technicians for installation work, then the responsible engineer shall guide the installation work and explain the required work in detail to each group.

(6) During installation, the responsible engineer/personnel on behalf of supplier shall visit the installation site to cross check and confirm the ongoing installation work. At the time of each inspection, the record of the inspection with pictures shall be kept to confirm guided /requested work. The record – inspection sheet shall be prepared in such a way that the counting of materials shall also be verified at the same time.

(7) After technicians finalize any installation work, internal inspection by the supplier/contractor is essential. The record of installed materials and equipment shall be verified against the agreed contract. The final internal inspection shall be confirmed and documented in a record sheet of installation materials verification, operation status of

each component/equipment and operation status of the integrated system. The final internal inspection sheet shall be signed by the system inspector and responsible engineer/personnel on behalf of the supplier/contractor. The signed internal inspection record sheet shall be submitted at the time of commissioning as a base for commissioning and as a record of system installation work and operation status of the installed system.

(8) To finalize the system installation work, additional required documents such as installed materials list, as built drawings, manual, pictures showing the site before, during and after installation, etc., should be provided by the supplier/ contractor.

(9) There should be some form of penalty if there are drastic differences between the submitted internal inspection record sheet and actual installation at the site.

Besides the above recommended countermeasures, there are other recommendations for installation as described below.

(1) In most cases the installation areas for equipment are not smooth or flat. To fix equipment, a wooden plank shall be fixed first and equipment shall be fixed on the wooden plank.

(2) The equipment shall be covered or placed inside boxes with proper ventilation to avoid any direct contact.

(3) There should be some extra length of wire at each terminal connection point to avoid any tension either to the terminal or wire/cable.

(4) For grounding, a minimum of 50 cm by 50 cm hole shall be made below ground level and earth rod shall be grounded.

(5) Outdoor type cable shall be used to connect PV array to isolator. To offer protection and prevent cables from touching the metal roof, flexible conduct shall be used.

(6) Indoor type flexible cable shall be used to connect CC to Battery.

(7) The minimum capacity of isolator shall be 1.5 times the Current at maximum power point (Imp) of PV array.

(8) The minimum size of fuse or DC breaker installed between CC and battery shall be 1.3 times the maximum output current rating of CC, and shall be installed as close to the battery as possible.

(9) The minimum size of fuse or DC breaker installed between battery and inverter shall be 1.5 times the maximum input current rating of inverter, and shall be installed as close to the battery as possible.

(10) The best inclination angle for installation of the PV array is 0 to 5 degrees. Considering the rainy season months, position of the sun at that time, dust deposit on the modules, etc., it is recommended to incline the PV array at a minimum of 10 to 15 degree facing north.

2.6 Procurement

Procurement occurs after the distribution of the tender documents by the owner and their submission by the bidders. In some cases, the time provided between these two stages is rather short and bidders therefore submit their offer based on company catalogues, information available on the internet, or on past experience, without gathering current information. For the bidding documents, the required information to be attached is either a copy of the bidder's catalogue or information downloaded from the internet. Rarely, there may be cases where a guarantee letter of equipment supply from the manufacturer should be attached. At the time of finalizing the contract between the owner and supplier/contractor, the provided procurement period cannot be guaranteed to be sufficient. Due to the limitation on procurement period, the installation work may become patchwork in some cases.

Besides the aforementioned complicated problems, in most cases there is no practice of asking and addressing questions related to the tender documents, between the owner and bidders before submitting the bidding offer. For example, even if the supplier/contractor finds it more practical to change the system configuration or it is not possible to purchase some of the components, these kinds of discussions to solve the problem are not held before submitting the bidding offer. Instead, the changed component/equipment or system configuration is directly attached and submitted in the bidding offer. Hence, the installation work is not understood fully or clearly unless bidding is opened and evaluation is made.

Considering the above points and in order to simplify the resulting complications, the following points are recommended:

(1) At least one month should be given from the date of distribution of tender documents to submission.
(2) After distribution of tender documents, if there are any doubts or need for clarification from the bidders', or if a supplier thinks of a better technical option than that proposed by the owner, etc., a question and answer session of 7 (seven) days after distribution of document shall be scheduled, to clarify the recommendations from the bidder and requirements from the owner. Any questions or recommendations for change shall be submitted in writing. Responses to these queries shall be given in writing and shall be disclosed to all participants without disclosing the company name of the inquirer. If any amendment of clauses is made, then it shall be provided in writing to all participants.
(3) Once the contract is awarded to the bidder, a period of 3 (three) months shall be scheduled for procurement. If the supplier/contractor suggests a shorter period for procurement, then the suggestion shall be discussed and agreed between the parties.
(4) The maximum limit of installation dates and commissioning period shall be decided during the contracting process for the installation work. If these need to be changed, then at least one month's advance notice with justification shall be submitted by the supplier/contractor.
(5) The inspection of procurement shall be done before dispatching materials to the site, to confirm and verify the products and quantities against the contract document.
(6) Before dispatching the procured equipment, the supplier/contractor shall conduct operation tests of equipment in the presence of responsible person(s) representing the owner.

2.7 System Operation and Maintenance

In PV systems, generation is DC power while utilization is AC power. For trouble shooting, it is necessary to understand first how the system operates. Figure 2.7.1 summarizes the system power flow.

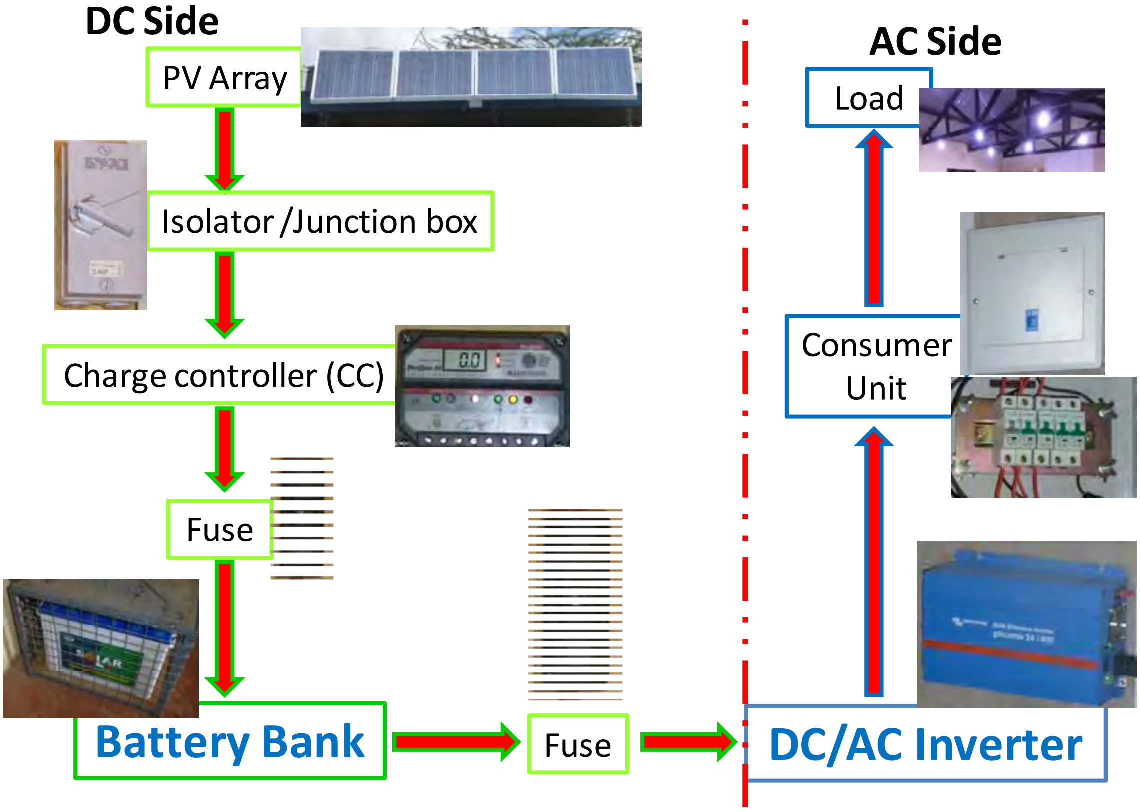

Figure 2.7.1 PV System Operation Power Flow

From the above figure, it can be considered that irrespective of PV capacity or DC system voltage during daylight hours, PV array converts the received light energy to DC electric energy, which flows to battery passing through isolator, charge controller and fuse sequentially. When load is turned on, the energy stored by the battery or generated from PV array will flow to inverter. The inverter converts DC power to AC power and supplies power to load via consumer unit.

Failure and trouble shooting

If the system is not working, then trouble shooting is required to find and resolve the problem. To troubleshoot:

(1) Turn off the isolator and measure the open circuit voltage (V_{oc}) of PV array at input terminal of isolator.

(2) The measured value of Voc of PV array will be:

i) If DC system voltage is 12 V, then the measured value will be within the range of V_{oc} of PV module at STC ± 10%.

ii) If DC system is 24 V, then the measured value will be within the range of V_{oc} (1st module + 2nd module) at STC ± 10%.

iii) If DC system is 48 V, then the measured value will be within the range of V_{oc} (accumulated Voc of 1st to 4th module) at STC ± 10%.

The V_{oc} may be different from the stated value depending on PV cell/module temperature at that time. For further details, refer to the technical specification of the installed PV module. Keep a record of the measured value of Voc.

iv) If V_{oc} of PV array is out of range, then measure V_{oc} of each module separately and keep a record of measurements.

v) If V_{oc} of module is out of range, then measure short circuit current (I_{sc}) of that module. The Isc will depend on the intensity of solar insolation at that time (I_{sc} at STC x intensity of solar insolation at that time). If there is no current flow, then PV module is not generating power. It is therefore necessary to change the damaged PV module. Keep a record of measurements.

Note: Only trained personnel shall conduct the measurement works. To measure I_{sc}, it is necessary to use suitable equipment such as a circuit tester that can measure current or clamp meter.

While conducting measurement works, it is necessary to concentrate and be cautious to avoid any hazards which may cause accidents. Now,

Conformation at DC side:

- ✓ If PV modules are found to be working well, then make a jumper at isolator (isolator must be at OFF position) from input terminal to output terminal and measure voltage. If there is charging voltage, then isolator is not working. In this case, change the isolator. Keep a record of measurements and the work that is carried out.
- ✓ If isolator is working, then measure PV input voltage at input terminal of charge controller. Measure voltage at battery connection terminal of CC and charging current to battery. To measure, isolator must be at ON position. Keep a record of measurements. If there is current flow, then the problem is not at CC.
- ✓ If there is no current flow toward battery, check the fuse installed between CC and battery. If fuse is blown, then change the fuse. The fuse may blow due to the effect of lightning, short circuit, rush current and so on. Before removing fuse, make sure that isolator is at OFF position. Never remove fuse without turning isolator OFF first. To turn isolator ON fuse must be inserted.
- ✓ If fuse installed between CC and Battery is normal, then check installed fuse between battery and inverter. Before removing fuse, make sure that the inverter is at OFF position. If fuse is blown then replace the fuse.
- ✓ If fuse installed between battery and inverter is normal, then measure DC input voltage and current.

Conformation at AC side:

- ✓ If measured DC voltage at input terminal of inverter is normal (nearby battery voltage then turn ON the inverter and measure AC output voltage and output frequency of inverter.
- ✓ If inverter is operating normally, measure AC voltage and frequency at input terminal of main breaker of consumer unit. Confirm the position (ON/OFF) of breakers at consumer unit. The breakers may turn OFF due to short circuit, overload or breakdown of used loads and so on. If breaker is at OFF position, then first check the circuit to find the problem. To turn ON the breaker first push lever towards OFF position and turn to ON position. The breaker must maintain an OFF position as long as the problem is not solved.
- ✓ Confirm the tightness at every terminal of component/equipment.

Important points to note are:

i) If operation is interrupted due to any faults, the faults must be cleared first before system operation is resumed

ii) Confirm the operation status of system at CC (digital display/LED indicator).

iii) Only authorized person should carry out the trouble shooting.

The PV system does not have any moving parts. However, for smooth system operation regular inspection of system is essential. To understand actual operation status, record keeping and timely checkups of the system are very important and recommended.

For reference, the recommended points for regular inspection and confirmation are:

a) Level of battery liquid and refilling (at least once a month)

b) Visual status of PV array and its structure
c) Permanent shadows over each PV module
e) Visual status of equipment
f) Abnormal noise from equipment
g) Bad smell or odour such as burnt wire/cable or paint on equipment
h) Temperature of room where system is installed.
i) Entry of any insects into installed component/equipment (at least once a week)
j) Working status of CC and Inverter regularly, and also after every lightning strike nearby site.
k) Dust deposit on equipment and cleaning if required
l) Record keeping of every inspection in detail

Depending on the type of cleaning work, the system may need to be stopped before proceedingwiththe work. Make sure that there is no electrical hazard while cleaning, at the time of inspection and when undertaking maintenance works.

To ensure years of smooth operation of the system:

i) Daily record keeping of system operation status is essential.
ii) Timely discussions among the stakeholders are recommended, to ensure they understand the system operation status.
iii) Periodic checks and replacement of individual components are essential, as recommended by the manufacturer or as per requirement.

2.8 Existing PV System and Grid Connection

In grid connected application, there are two main types of systems.

(1) Grid connected centralized system

A grid connected centralized system functions as its name suggests; centralized power generation and supply. The power generated and supplied by the system is not associated with a particular electricity consumer. Generally, such systems are directly connected to an existing distribution/transmission line, or a dedicated line is established to connect the system to an existing grid sub-station. Hence, such systems are installed in rather large capacity.

(2) Grid connected distributed system

A number of customers are connected to the grid for electricity supply. The PV system is generally integrated into the customer's premises, often on the demand side of the energy meter. For the installation, the capacity of the PV system is dependent on the available open space, financial situation, and rules and regulations of the government, utility company and related authorities. The installation site will also vary and can be residential, public and commercial buildings, as well as hilly slopes, waste lands and so on.

In general, the PV system capacity is not a determining factor for the installation area, in most parts of the world. However, a 1 MW PV system on a roof top may be large by PV standards for distribution systems.

From the above, it can be considered that where a PV system exists and a distribution grid is extended after some time, it is possible to connect the PV powered facility to the grid with some simple modifications or replacement of some equipment.

The connection type and method may vary depending on the existing PV system capacity, demand and best match for the particular system. The possible types of connections for the PV system to work together with the extended grid are as follows:

a) Reverse flow type connection

Prior to PV system installation and grid integration, the rules and regulations for grid connection need to be established. In reverse flow type of connection, there are two options.

i) Without storage battery bank

In this type of connection, when there is excess power generated by the PV system compared to the demand, the excess power will flow to the grid. Further, if the grid system fails to supply power within the stated standard or a sudden power supply interruption occurs, grid interconnecting Power Conditioners (PCS) will stop and disconnect the grid until grid supply resumes or operates within the stated operation condition, for safety reasons. Hence, when there is no grid supply this system cannot work.

ii) With storage battery bank

In this type of connection, when there is excess power generated by the PV system compared to the demand, then the excess power will flow to the grid. Further, if the grid system fails to supply power within the stated standard or a sudden power supply interruption occurs, grid interconnecting PCS will disconnect the grid. However, the system will continue operating by supplying power from the storage battery, and the PCS will reconnect the grid when grid supply resumes or operates within the stated operation condition. When the battery is discharged, it will be charged by the PV system in daylight hours. In case of bad weather days or at night, the battery will be charged by grid power supply.

b) Non reverse flow type

As the name suggests, the system works together with the grid but does not supply power to the grid. Hence, whether there is grid connection or not, the system can also work as an off grid system. However, in order to operate as an off grid system it requires storage battery to supply power when grid supply is not available and to absorb the large surge of PV array voltage. Generally this type of system can be divided as follows:

(i) Using Inverter charger

At existing PV systems installation sites where the facility is connected to the grid, a standalone type Inverter will be replaced by an Inverter charger type inverter in order to adopt the PV system to work together with grid supply. By replacing this equipment, the system will work with PV charging the storage battery and also supplying power to the load in the day time regardless of whether the grid supply is available or not. If grid supply is not available then power will be supplied from the PV system and if grid supply is available power will be supplied directly from grid. If the battery is discharged, it will then be charged in daylight hours by the PV system, and at night time by grid supply. Therefore, days of autonomy can be reduced to a minimum, which means that battery capacity will be small and replacement costs will be low. Furthermore, as the battery discharge level becomes shallow, the battery life will be extended.

(ii) Using change over switch

This type of system will be most cost effective if the existing PV system is small, and power demand of the facility is low and mostly occurs in daylight hours. In this type of system, the power supply can be selected, by adding change over switch before input terminal of main breaker of existing consumer unit. The change over switch can be either manual or automatic. Hence, if load demand is high or the weather is consistently bad the system can be changed to grid supply. If grid supply is affected or power requirement is mostly in daylight hours, then the system can be changed to PV supply. By avoiding long hours of use or high supply at night from the PV system, it will be possible to control deep discharge of the battery to get longer life.

CHAPTER 3 O&M AND MANAGEMENT

3.1 Purpose of the Section for Management of Solar PV Systems at Primary Schools

The purpose of the management section of the guideline is that REA and MoEST enhance their knowledge on the appropriate and effective actions of sustainable PV system, enhance their attitude towards the actions and give detail elements of practice. This section can be used to ensure that all stakeholders make up an effective management system, in terms of physical and O&M matters, for electrification of primary schools in the un-electrified areas using solar PV systems. It also can be used to ensure that the facility users can enjoy the power generated by installed PV systems for as long as the lifetime of solar panels (20 years). This section of the guideline covers all solar PV systems that REA has installed and will install.

3.2 Basis of Operation and Maintenance System

3.2.1 Implementation of Pilot Projects

This guideline was prepared based on the implementation of and lessons learnt from the pilot projects implemented at ten public facilities by the JICA expert team (JET). It aims at examining feasibility and applicability of solar PV systems, in the technical, financial, social and institutional points of view, to the public facilities located in remote, un-electrified area. The target facilities are divided into Lot 1 and Lot 2. The list of the target facilities is as in Table 3.2.1.

Table 3.2.1 List of the Target Facilities of the Pilot Projects

Lot	Facility	Facility Type	County	Period
1	Ilkilnyeti	Dispensary	Kajiado	May 2013 - October 2014
	Iltumtum	Primary Boarding School	Narok	
	Olkinyei	Dispensary	Narok	
	Olemoncho	Primary Boarding School	Narok	
2	Tuum	Primary School	Samburu	January 2014 - October 2014
	South Horr	Dispensary	Samburu	
	Illaut	Primary School	Samburu	
	Latakweny	Dispensary	Samburu	
	Marti	Primary School	Samburu	
	Angata Nanyokei	Dispensary	Samburu	

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3.2.2 Lessons Learnt from Pilot Projects regarding O&M (including Financial Management)

One of the important points to consider from the challenges faced was to strengthen the capacity of the facility management committee (MC) for O&M, and to manage and run the charging service. It was expected that the facilities would collect sufficient proceeds and use it for daily O&M and replacement of equipment.

The lessons learnt from implementation of the pilot projects are summarized as follows.

(1) Capacity of MC is often not adequate for stable management of solar PV systems. It is a structural problem for the end management body of public facilities all over Kenya.

- MC members are villagers living in the neighbourhood and are usually busy with their normal duties. Therefore, it is not easy for them to contribute their time to the PV system management frequently.
- Basic capacity of MC is low both in human and institutional aspects because members live in remote areas where public and private investment have rarely been made up to now and they are not accustomed to reporting and calculating.
- MC members are not accustomed to managerial issues because they hardly received adequate training on the organization management.
- MC members are not permanent, the knowledge that JET trained was not transferred to new members when members were replaced.

Therefore, REA and MoEST shall continue to strengthen capacity of MC.

(2) Charging service did not earn as much income as was expected, but it generates income to a certain extent. It is a scarce fund source that MC can use to meet their immediate needs.

- Market size is small. Population and population density are generally small in the service zone of the facility and economic power of the target area is the lowest in Kenya.
- The sales from phone charging service are low. There are already a lot of competitors of mobile phone charging where the mobile phone network has reached while there are very few numbers of mobile phones where the network has not reached.
- Other services such as hair clipping are more profitable though the number of customers is still small. The more important finding is that it was impossible to repair the hair clippers in adjacent town.
- However, each facility gains some proceeds and MC can use it for their urgent O&M needs such as broken bulbs and distilled water.
- The proceeds from charging service are not enough for replacement of equipment.

Therefore, REA and MoEST shall consider the proceeds from charging service as an important fund for self-reliant management of solar PV system. They shall also supervise MCs to improve their O&M and management capacity.

3.2.3 Analysis of Charging Service

This is the analysis of charging service using the above mentioned lessons in Samburu County. The proceeds from charging service are estimated using the matrix of the number of households within a 5 km radius of the facility and the type of communities (dispersed or concentrated). These indicators explain the market size and also the existence of competitors[1]. Sales from charging service are identified for each category of matrix made by the indicators. As electrification of public facilities using solar PV system targets remote areas, less developed counties, data of Lot 2 (Samburu County) is appropriate and applicable. The data shows that facilities located in or near concentrated core have the potential to earn more than KSh 1,000 per month in the moderate case (average). If the network becomes available, even communities located in dispersed areas have potential to earn more than now with the "Blue Ocean" effect. Hair clipping is an important service for the MC.

[1] One lesson learnt from the pilot project is that competitors (private charging service providers) generally exist in the communities whose population size is bigger and that have core area of commercial use.

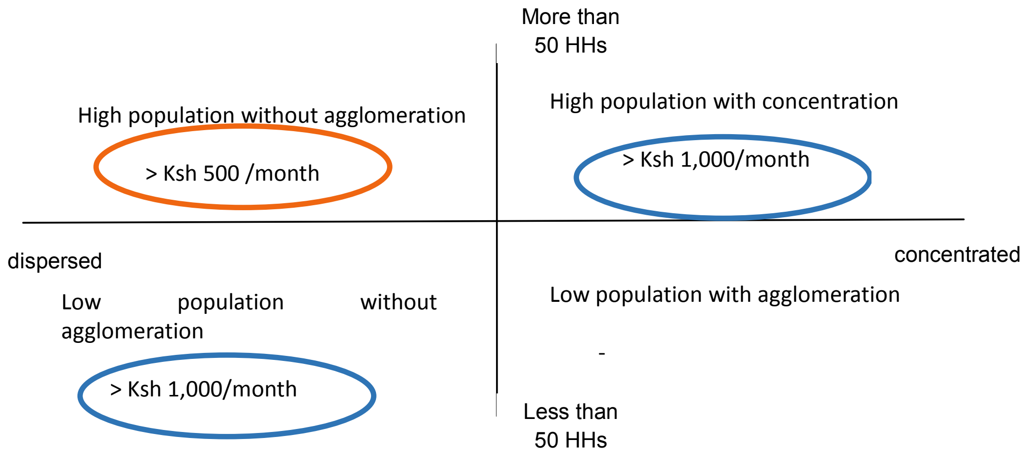


Figure 3.2.1 Sales of Charging Service in Lot 2 Sites by Type (Moderate Case)

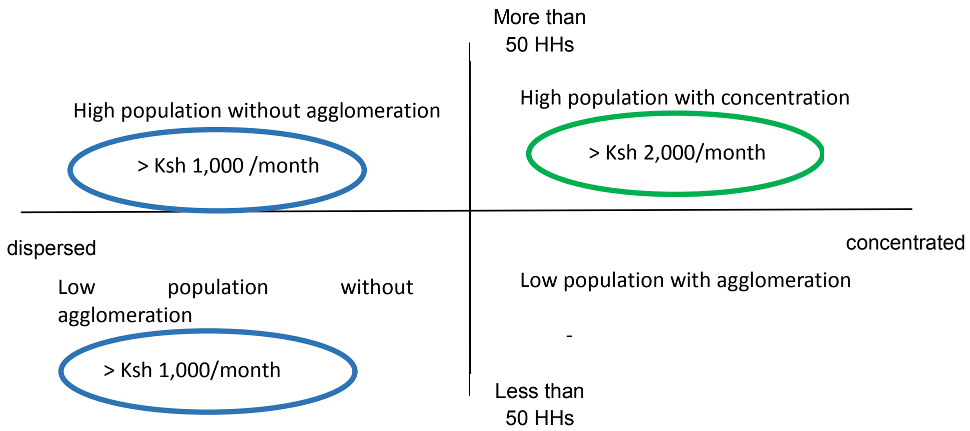


Figure 3.2.2 Sales of Charging Service in Lot 2 Sites by Type (Optimal Case)

3.2.4 Positioning of the Charging Service in the O&M Model

Charging service is an important tool of sustainable system use at the facility level. Income from the service is used by the MC exclusively to pay for immediate needs of system O&M (e.g., repair of clipper, replacement of broken bulbs) and daily administration cost (e.g. distilled water, bulbs, transportation) in order that MCs can use the solar PV system without deep dependence on the fixed annual budget such as HSSF and FPEF. Thus, from users' point of view, charging service activity gives MCs not only free funds but also an opportunity of strengthening their activities and capacity in social development. With this independent financial source, MCs can deal with troubles more effectively and enhance their experience and skills in fund management and small business.

As mentioned above, however, the proceeds from charging service are not enough for replacement of equipment but MC can use them for daily O&M if the social and economic condition meets the need So what is the condition? It is analyzed and presented in the next section.

REA and MoEST shall consider the proceeds from charging service as an important fund for self-reliant management of solar PV system. They shall also supervise MCs to enhance their O&M and management capacity. As the capacity of MC is not adequate, REA and MoEST shall continue to develop capacity of MC. This income source will supplement the budget for O&M and replacement of equipment coming from MoEST and will support the socialization of MCs in the remote areas in Kenya.

3.2.5 Application of the Charging Service in the Model

(1) Minimal Conditions for the Charging Service

The first or minimal condition for the applicable charging service is that income from charging service be above the initial investment, that is, construction cost of charging kit consisting of solar PV system for charging service and charging hut. The second condition is that the revenue covers both initial investment of the charging service kit and daily O&M cost; in this case target facility gets benefit for covering O&M cost and further its MC gets opportunity for their future social development; MoEST gets benefit because they can reduce the budget for O&M of the solar PV system; and also REA gets benefit because the system they installs have fund for O&M to a certain extent.

The estimated amount of initial investment (installation of charging kit) and O&M of the charging service using the data from bidding document and the financial model is monthly proceeds shall be at least Ksh 1,120. Charging service of a facility does not generate loss if the proceeds from charging service are moderate case (Figure 3.2.1). It must be noted that payment for initial cost is NOT required to the facility but the JICA expert applied it to examine if REA invested only for waste or for meaningful social development.

Next question is what condition is needed to earn this income? Bargaining power of customers and intensity of competitive rivalry both seriously affect the proceeds of the charging service but also risk of substitutes and new entrants should not be underestimated. Public facilities will get favourable proceeds if these threats from these factors are low.

Then, what approach is feasible and applicable to this situation? As customers go to charge their phone as their wants that meet particular customer's particular needs, which is difficult for public facilities. One strategy is to coexist with these rivals and substitutes and the second is start earlier than rivals to catch the customer's needs and make them customer's wants.

Thus, by referring to the result of the pilot project in Lot 2 sites, the minimal conditions of potential facilities for charging service are identified and proposed as follows:

a. Mobile phone network will come soon; and,
b. Starting charging service before private service providers and M-Kopa come to the neighbourhood.
c. A facility inside or very near to an agglomeration of houses;
d. More than 50 households in five kilometres radius;

Note that these conditions or criteria are external one because internal conditions, such as coherency of MC and cleanness of financial matter, are difficult to find instantly by observation. REA and relevant ministries shall survey these factors when they start planning and before detailed design of electrification by solar PV system with charging service.

(2) Procedure of selection of potential target facilities

REA and MoEST shall survey candidate dispensaries using these four criteria to identify the potential dispensaries for starting charging service. As the number of candidate dispensaries is large, the first screening must be simple and possible to implement in Nairobi. Thus, we start with abovementioned condition c., then advance to d., to a. through b.

<Step 1>

REA and MoEST officers prepare a list of candidate list of non-electrified dispensaries with their location name. (identification of the candidate facilities and their location)

<Step 2>

REA and MoEST officers identify the area that (i) the mobile phone networks have already covered, (ii) it will cover in a few years, or (iii) it has plan of installation in recent years. The most favourable area is (ii). REA and MoEST will do this survey by communicating with mobile phone service providers, i.e. Safaricom, Airtel or Orange. After they find the potential area of mobile phone net work, they check the name of areas with the list of candidate facilities to choose potential ones being inside the area (ii). (selection of the candidate facilities located in the area where mobile phone network comes soon)

<Step 3>

REA and MoEST officers check if M-Kopa service has reached the area candidate facilities by communicating with service providers, such as M-Kopa Kenya Ltd. (selection of the candidate facilities without or with small number of competitors)

<Step 4>

After screening at Step 2 and Step 3, REA and MoEST officers move to the sub-county capitals. They examine if candidate facilities are located in and adjacent to the core (small trade centre) or not by interviewing sub-county officers who knows facilities well and choose facilities having core. (selection of the candidate facilities with potential customers)

<Step 5>

REA and MoEST officers go down to the candidate facilities to check the size of the surrounding communities: +50 within 5km radius. (selection of the target facilities with potential customers)

<Step 6>

REA and MoEST officers start baseline survey of the finally selected site as instructed in this Guideline. They use the result of the survey for designing and stakeholder meetings.

3.3 O&M Model

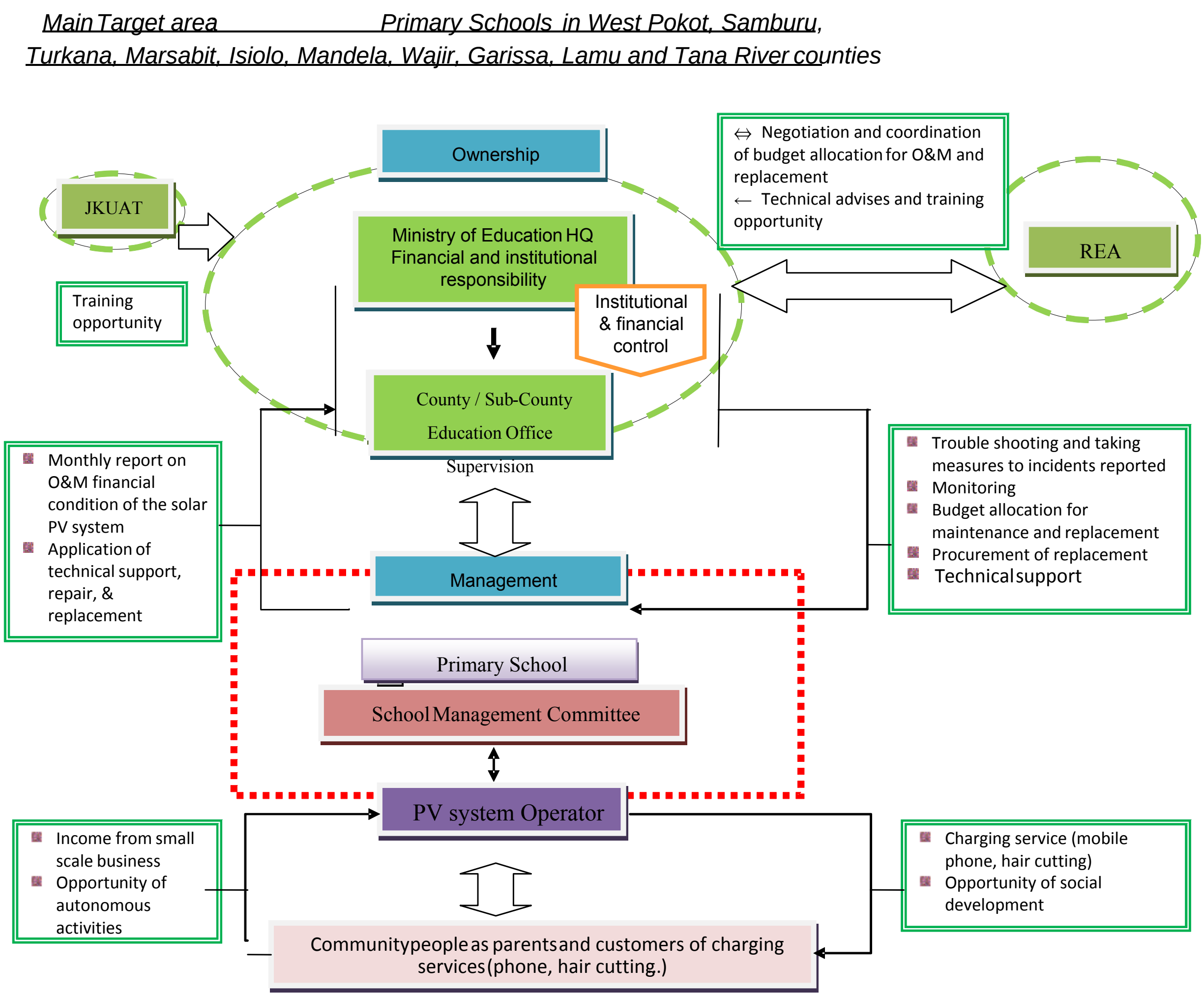
3.3.1 Stakeholders

There are various stakeholders for the electrification of public facilities using solar PV system.

a) Target facilities as responsible institution for daily O&M
b) School management committee members as management body
c) Community people of the surrounding communities as facility users and potential customers of the charging service
d) County and sub-county offices of MoEST as the owner and supervisor of the solar PV system
e) Headquarters of MoEST as advisors to the ministry county offices[2]
f) REA as project implementer, system installer and technical advisor
g) Chiefs and/or assistant chiefs of the concerned locations/sub-locations as local authority

Each stakeholder plays different roles for the sustainable use of solar PV system. JET prepared O&M model that explains role demarcation of all stakeholders including REA and MoEST for the electrification using solar PV system (refer to Figure 3.3.1)

[2] The role of the ministry headquarter should be revised when the MOU is signed.



Prepared by JET

Figure 3.3.1 O&M Model for Electrification of Primary Schools

3.3.2 Ownership and Responsibility

Figure 3.3.1, Table 3.3.1 and Table 3.3.2 show important tasks of REA, MoEST, MCs, etc. at each time stage. MOE&P is in charge of making policy and strategy of electrification of public facilities using solar PV system while REA is in charge of implementation. REA has responsibility for installation of solar PV systems while MoEST has both ownership and responsibility for system management for sustainable system use.

Table 3.3.1 Roles of Key Stakeholders

Institution	Responsibility
REA	• REA installs solar PV system in un-electrified primary schools using the technical model prepared by the JICA Project. • REA gives technical and managerial advices to owners of solar PV systems on the O&M.
MOEST	• MoEST is the owner of the solar PV systems as the system is a component of assets of facilities under their supervision. • County offices of MoEST do direct supervision of system use.

Institution	Responsibility
Staff members of the public facility	• Facility staff members and management committees are in charge of O&M management. They do operation, maintenance, charging service and reporting.
MOE&P	• Provision of an enabling energy policy framework • Timely disbursement of funds regarding renewable energy • Timely submission of budgets to the Treasury • Sourcing for additional funds[3]

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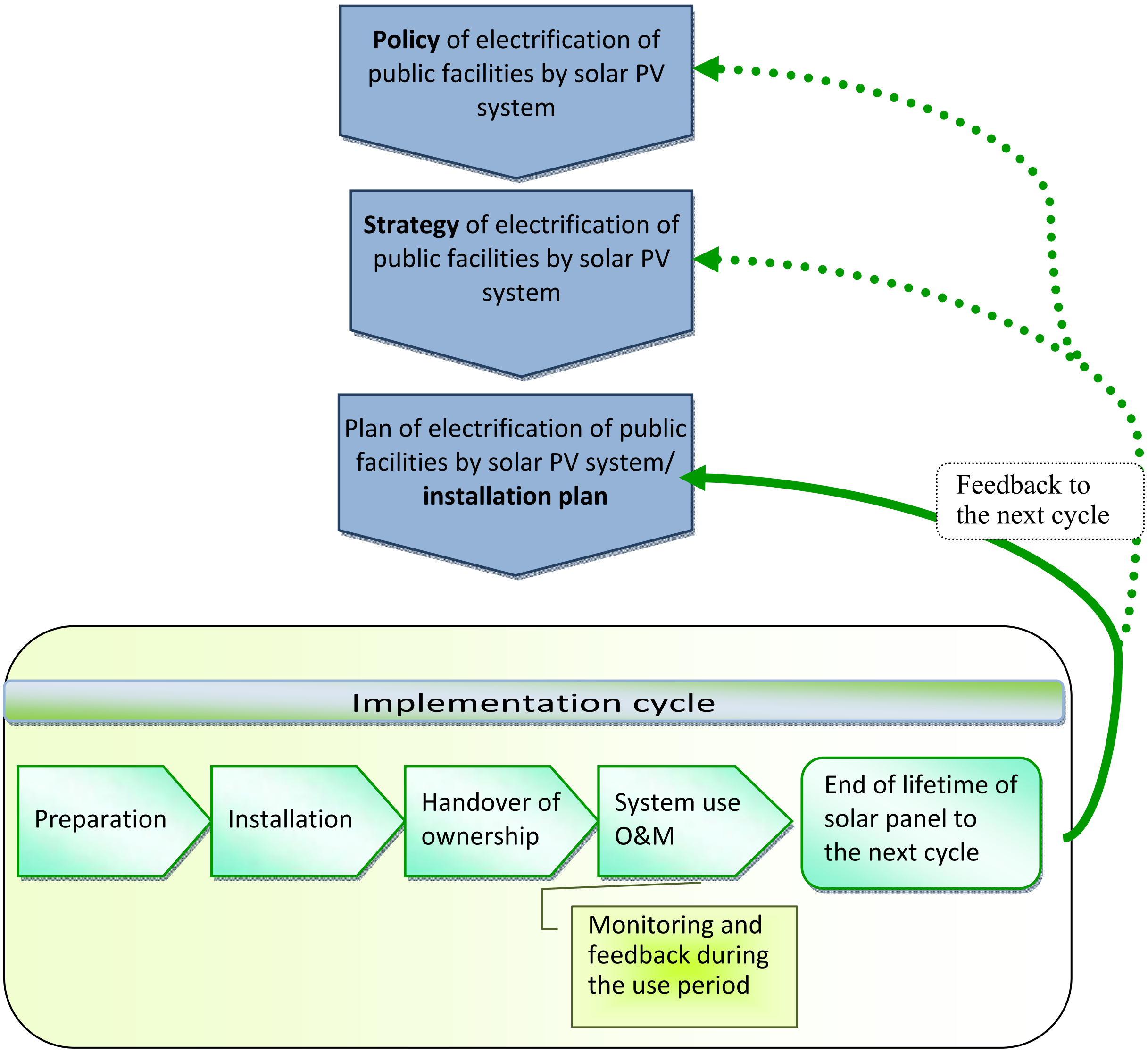

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Figure 3.3.2 Project Cycle of Electrification of Public Facilities by the Solar PV System

Project is the most concrete and final stage of the governmental implementation for development. Generally the proponent implements a project in accordance with the plan and/or program, and a plan is made based on the strategy of the sector or region. The highest level is government policy that defines the nationwide direction of the sector.

[3] REA's expectation to MOE&P in Rural Electrification Authority (REA). (2013). *Strategic Master Plan 2013/2014-2017/2018, Third Draft*.

A project has cycles during its lifetime. It does not finish when the project proponent (project owner) constructs or installs facilities or equipment but the project owner and system owner shall continue periodical monitoring of the system and management and give feedback of the monitoring result to the management organization. Additionally, overall result of evaluation and lessons from the implementation shall be utilized in policies, strategies and planning of next generation.

Table 3.3.2 Tasks of Key Stakeholders at each Project Stage

Time stage	Institution	Tasks
Project planning	REA	a) monitors and collects data of nationwide electrification condition of public facilities b) makes implementation plan c) makes budget for implementation or finding fund source d) budget appropriation and execution of initial investment
Preparation	REA	a) executes baseline survey to collect basic social and economic conditions of neighbourhood community as well as the condition of the target facility b) applies the result for designing the system and O&M structure c) holds stakeholders meetings with concerned government officers and target facilities
	MoEST	a) provides information of un-electrified primary schools to REA for selection of targets and designing b) shares information on the electrification plan with REA c) starts budgeting for equipment replacement d) gets technical staff trained
	Facility MC	a) provides information of actual situation of the facility and social and economic condition of neighbourhood community b) shares information of electrification by solar PV among MC members as well as with community people
	Others	<JKUAT> a) gives technical training to MoEST officers
Installation of PV system	REA	a) makes design of each facility using the data of baseline survey b) prepares bidding document including an article stipulating technical training to system users by contractor c) selects the contractor d) holds stakeholders meeting with concerned government officers on the project details and O&M cost after handover e) holds stakeholders meetings with facility staff members and MC members about the details of PV system and installation schedule f) supervises installation activities by the contractor and conducts inspection g) holds stakeholders meeting together with MoEST officers and facility MC to explain necessary O&M system and charging service h) gives accounting training to MC members i) confirms responsibility of MoEST for O&M and financing to maintain the PV system during the life time of solar panels and signs MOU j) hands over the ownership of solar PV system to MoEST after the signature on MOU
	MoEST	a) understands the details of electrification of primary schools by solar PV system b) nominates an officer at county offices to manage the electricity use c) makes annual budget for O&M (especially equipment

Time stage	Institution	Tasks
		replacement) and submits it to the Treasury d) (gets technical staff trained)
	Facility & MC members	a) attend stakeholders meetings b) share the information of electrification by solar PV and charging service among members and inform it to neighbourhood communities c) select an operator from employees of the facility d) formulate a by-law regarding the O&M of the PV system and management of charging service (including service time, unit price) e) receive technical training given by contractor and financial training given by REA
Handover of ownership to MoEST	REA	a) concludes the MOU with MoEST that stipulates responsibility of MoEST for supervision of O&M and budget for replacement of equipment b) holds stakeholders meeting at the facility to ensure the responsibility of MC for daily O&M and charging service c) gives technical and managerial advices to MoEST
	MoEST (county)	a) concludes the MOU with REA that stipulates responsibility of MoEST for supervision of O&M and preparation of budget for replacement of equipment b) appoints one or two officers at county level to support MCs in O&M and management
	Facility & MC members	a) confirm the tasks of chairperson, secretary, treasurer and operator for the O&M and charging service
Use of solar PV system	REA	a) gives technical advices to MoEST b) collects market price of batteries, inverters and charge controllers and inform it to MoEST in order for the ministry to make budget for replacement
	MoEST (county)	a) examines monthly report submitted by facilities to understand the condition of solar PV system and charging service b) dispatches technical officer to each facility to check the condition of solar PV system and takes action if he/she finds problems c) takes action if the system has trouble by calling mechanics d) makes budget for replacement of batteries, inverters and charge controllers according to the cash flow model in the guideline e) purchases and replaces batteries, inverters and charge controllers with new ones at the end of lifetime of each equipment
	Facility & MC members	a) conduct O&M as trained b) provide charging service as trained and advertise it to the neighbourhood community c) make monthly O&M report to submit to the county MoEST office d) include the financial status of the charging service into the facility monthly report and submit it to the county MoEST office e) take action when the system has trouble f) treat e-wastes as stipulated in the Kenyan regulation when the lifetime of electric devices and equipment ends
End of lifetime of solar panels	REA	a) prepares a new electrification plan to ensure electricity to the concerned facilities b) makes budget

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3.4 Tasks of REA

3.4.1 Project Planning Stage

REA shall make the implementation plan for electrification of particular public facilities by solar PV system. For this, they shall continuously monitor the nationwide electrification situation of public facilities and collect the latest electrification data. They set the criteria for selection of priority facilities.

After selection of the target facilities, REA shall start making budget estimate for implementation and request to the government. If there is a fund from other institutions or donors, REA starts getting approval to use it. REA also needs to prepare a plan of operation.

3.4.2 Preparation Stage

(1) Execution of |Baseline Survey

The purpose of the baseline survey is to collect basic social and economic conditions of neighbourhood community as well as the condition of the target facility. REA shall apply the result to design the system and O&M structure. Social and economic condition of neighbourhood community is the basis of managerial and financial capability at facility level, and is also used for the feasibility study of the charging service. REA staff members in the special field of social development or subcontractor in this field goes to the site and conducts interview survey using the questionnaire sheet.

An example of the questionnaire is attached in Annex 2-2.

(2) Information sharing with Relevant Local Government

REA shall meet relevant local government officers, that is, county MoEST officers, at least once before planning. It aims at reducing information gap between them at the beginning. Both sides exchange information and reach agreement regarding electrification of public facilities by solar PV system. REA explains technical specification of electrification by solar PV system, financial plan and O&M model as well as implementation schedule. County officers explain the current condition of target facilities and both sides to reach agreement on installation and demarcation of responsibilities.

(3) Stakeholders meeting with facility and management committee

To raise awareness of facility staff and MC members and strengthen their attitude toward solar PV system management, REA, together with officers of county MoEST, should have stakeholders meeting before the implementation and before commencement of system use. REA staff visit facilities and meet stakeholders of the target facility. The key participants are members of school management committee (MC) and head teacher (secretary of MC), local authority (chief, assistant chief), elders and normal inhabitants of neighbourhood communities.

The main topics of the first meeting are:

- System design
- Role demarcation, especially roles of MC (refer to the O&M model)
- Agreement from stakeholders about the responsibility for O&M and management of solar PV system
- Installation schedule including trainings

The most important matter is that the stakeholders understand their role as being in charge of O&M management. They do operation, maintenance, charging service and reporting. Also they conduct charging service to generate income for daily expenditure for the solar PV system management.

REA also explains the activities that MC should do prior to the commencement of system use. MC shall prepare the following:

- By-law formulation prescribing rules of solar PV use and protection, which is a written regulation of power provision, service, service time, unit charging price, person in charge of service attendant etc.
- Fixing of tariff for charging business
- Selection of operator and determination of his/her salary

3.4.3 Installation Stage

(1) Designing

See the technical section of the guideline

(2) Bidding

See the technical section of the guideline

(3) Selection of Contractor

See the technical section of the guideline

(4) Stakeholders Meeting (1st)

a) Information sharing with officers of concerned government offices

This is the second information sharing meeting between REA and county officers of MoEST. It aims at confirming the responsibility of MoEST after handover, for the sustainable system management in terms of technical and financial preparation and supervision of the management by MC. It is expected that REA explains the MOU concerning the roles and responsibilities of REA and MoEST and both sides agree to it at this meeting.

b) Stakeholders meeting with target facilities (2nd)

REA, together with the county MoEST officers, hold the second stakeholders meeting just before the commencement of the system. It aims that the facility staff and MC members understand to take responsibility of daily system management, conduct charging service, and report to the county office. REA explains to them about these roles and responsibilities and also explains ways of solving technical troubles. REA also explains again the activities that MC should do prior to the commencement of system use and confirms if MC is ready to start management.

(5) Supervision of System Installation

See the technical section of the guideline

(6) Training

a) Technical training

As mentioned in the technical section of the guideline, suppliers that REA contracts with gives technical training to the facility staff members and MC members. They get from this training at least knowledge about the solar PV power generation and system structure, as well as the basic measures to deal with system troubles.

b) Financial training

As mentioned in the financial section of the guideline, REA staff (or subcontractor) gives financial training to the facility staff, MC members, and operator. The training aims that (i) MC and operator record daily income from charging service and expenditure for repair and purchase of small equipment, and (ii) they make monthly report of balance sheet to submit to the county MoEST office. The training includes procedure of service provision and money collection on daily basis, recording of sales, making daily report and monthly report.

3.4.4 Handover

(1) Conclusion of MOU

It is indispensable to clarify roles and undertakings on the electrification of primary schools by solar PV to ensure the sustainable use of the systems. Generally REA's duty is construction or installation of solar PV system and does not cover O&M and replacement after the handover to the owner (MoEST in this case). On the other hand, MoEST does not have enough experience in O&M and replacement of solar PV system equipment. Thus, it is indispensable that these stakeholders share information about it to demarcate roles and undertakings of each side as a prerequisite of handover. As of the end of November 2014, REA and HQs of MoEST are under discussion for such an MOU.

The important items prescribed in the draft MOU are that REA updates the list of un-electrified institutions, decide priority of electrification, designing, installation and monitoring. On the other hand, MoEST compiles un-electrified institutions to share with REA. MoEST facilitates the agreement between REA and county offices on the responsibilities, supports county offices in proper O&M including budget allocation, and introduces county offices to the available trainings.

(2) Stakeholders meeting with target facilities

REA, together with the county MoEST officers, hold the second stakeholders meeting just before the commencement of the system. It aims that the facility staff and MC members understand to take responsibility of daily system management, conduct charging service, and report to the county office. REA explains to them about these roles and responsibilities and also explains ways of solving technical troubles. REA also explains again the activities that MC should do prior to the commencement of system use and confirms if MC is ready to start management. REA also explains e-Waste management (refer to the section for environmental and social considerations).

3.4.5 Use Period

(1) Technical and Managerial Advices to MoEST

REA supports and gives advices to MoEST on the technical issues on O&M. It is obvious that the technically proper supervision and support as well as timely and appropriate budget disbursement for equipment replacement are indispensable for sustainable system use. The owner shall be capable for conducting these matters. As staff members of MoEST are not the experts of technical issues of solar PV system, REA shall mediate training opportunities. Technical staff from MoEST can get training on solar PV system prepared by JKUAT. In addition, REA shall give advices to MoEST about the specification of necessary equipment (batteries, inverters, charge controllers and so on) and market price of the year that REA uses for their installation project to facilitate budget making by the ministry.

(2) Monitoring of Use Condition

Periodical monitoring on the condition of solar PV system and the charging service shall be done by the county offices. In case technical advices are requested, REA will respond quickly.

(3) Update of Database of Electrified /Un-electrified Areas in Kenya

The situation of electrification and un-electrified public institutions changes swiftly in Kenya. REA shall periodically update the list of un-electrified area and institutions in collaboration with MOE&P, and MoEST. Without the latest information of this kind, REA will not make plans of electrification by solar PV system to new institutions. The data shall be shared among officers in REA and, if requested, disclosed to other stakeholders and donor organizations.

(4) Support to MoEST in Cost Estimate and Budget Making

REA shall support MoEST when the county offices prepare budget for replacement of main equipment by:

- advising and discussing with county offices for technical and financial issues of installed solar PV systems
- advising and discussing with county offices to assist their budget proposals for equipment replacement for installed solar PV, especially specification of the equipment, market price and information of supplier (latest cost information of equipment replacements of solar PV)

3.4.6 End of Life Time of Solar PV Panels

(1) Preparation for renewal of the whole system including PV panels

REA shall prepare new electrification plan for the target institutions. As the lifetime of PV panels is twenty years by standard, REA will prepare budget to replace them. The grid electricity line will be extended to many of the remote areas in 20 years and the number of un-electrified public facilities will be reduced. To make the electrification plan for the short term, REA shall update the list of un-electrified public facilities constantly.

3.5 County Offices of MoEST

County offices of MoEST are the administrators of schools and the owner of installed solar PV systems. Their main roles are to keep the system condition well and to prepare appropriate O&M budget for especially the equipment replacement expenditure.

3.5.1 Preparation Stage

(1) Information sharing with REA

a) Information of un-electrified schools (to REA)

County offices with support from Sub-county offices have the concrete data of un-electrified facilities.

b) Information of electrification plan (from REA)

REA informs the county offices of the implementation plan for solar PV system. County offices of MoEST shall supervise management committee in O&M and management of solar PV system. They start to make budget in support of the facility.

(2) Training of technical staff on solar PV system

There are several training courses on solar PV system at JKUAT. It is recommended to send technical officers and staff to the course so that they are equipped with basic knowledge and skills on this subject. After coming back from the training, these officers and staff will support facilities having solar PV system: they check the monthly O&M reports to check the condition of the solar PV systems and give advices and respond to the calls from facilities.

3.5.2 Installation Stage

(1) Establishment of management system for the solar PV system

MoEST together with REA hold stakeholders meetings in which they explain to the facility staff and management members on the necessity of establishment of a management system. They also explain the roles of the management body: it is expected that the school management will take responsibility for overall management of the PV system including O&M, purchase of distilled water, bulbs and other repair costs.

3.5.3 Handover

(1) Conclusion of MOU

Before official handover of the solar PV system from REA to MoEST, both organizations shall conclude on an MOU regarding the responsibilities of technical and financial administration.

3.5.4 Use Period

While REA continuously updates the list of un-electrified facilities, makes the implementation plan and installs solar PV systems to schools, MoEST shall collect information of these facilities, examine the O&M report and financial report submitted from the facilities having solar PV system to understand the current condition of the system and charging service business, and make budget for replacement and O&M costs that the facility cannot afford.

(1) Examination of monthly reports from primary schools

MoEST must supervise the O&M and management activities of the solar PV system installed at the facilities under their supervision in terms of technical and financial status. They understand the system condition by examining monthly O&M reports submitted by the facility, and check if the systems are in good condition and water level is constantly checked or not. They also understand the amount of money collected from charging service.

(2) Biannual site observation and monitoring

It is important that the installed solar PV system functions as long as their life time by proper operation and maintenance. The technical officers who got training on solar PV system visit the public facilities at least twice in a year. They check the condition of the power generation system and give instructions and advices to the management committee members and the operator at each site.

In addition to this site inspection, these officers monitor the O&M and financial reports attached to the regular monthly reports that facilities submit and understand system condition as well as financial state. If there are technical problems they give instructions and, in case of system failure or any large repairs, prepare the budget for repair and/or call the supplier. Refer to the example of monitoring sheet in Annex 2-2.

County officers shall also instruct facility staff and management committee members on the e-waste management (For details, refer to Chapter 5). The point is that facilities cannot dispose equipment such as batteries or bulbs after their lifetime comes to end but return to the certified companies. Practically, they request suppliers who bring new equipment to the facilities to take away these used ones. As the suppliers can sell the used equipment to certified companies, management committee can receive a certain amount of income from suppliers.

(3) Making annual budget for O&M and equipment replacement

County offices shall prepare the upcoming replacement of batteries, inverters, and charge controllers.

(a) They calculate the long-term cost projection of daily O&M and replacement of batteries, inverters and charge controllers for 20 years. This is the life time of solar PV panels in accordance with the implementation plan of the nationwide program (refer to the financial section of the guideline).

(b) They make budget proposals for equipment replacement for installed solar PV system and submit to the county treasury.

3.5.5 End of Life Time of Solar PV Panels

Before the lifetime of solar PV panels come to the end (after about twenty years after installation), county offices of MoEST shall discuss with REA about the future energy plan of the area and request the next cycle of electrification by solar PV system.

3.6 Headquarters of MoEST

After decentralization, ministry headquarters have become policy maker instead of policy implementer. Their roles are to collect electrification status of primary schools and inform the data to REA. They discuss with REA the countrywide plan of installation of solar PV system in the coming years. When the plan is approved, headquarters shall make cost estimates and cash flow for the O&M of the system and requests to the national treasury.

3.7 Public Facilities and Management Committees

Primary schools and their management committees have responsibility.

Each public facility equipped with solar PV system is responsible for daily O&M and reporting to the ministry through the county office. The responsible personnel are school teachers, staff and school management committee. They manage charging service, conduct O&M and financial management including cash management, recording of system condition and financial status, and report to the county office.

Responsibility & Roles

a) To operate and manage charging service
b) To manage O&M and financial management for daily works
c) To record daily activities
d) To prepare monthly reports on O&M and financial management to the county office of MoEST
e) To inform any problems to the county office

CHAPTER 4 FINANCIAL SYSTEM

4.1 Introduction

According to the experience of the pilot projects, the public funding for both initial and recurrent expenditure is absolutely imperative to ensure sustainable use of solar PV systems in public facilities of dispensaries in un-electrified rural areas. In addition to daily O&M expenses, solar PV systems normally require replacement expenditure for major equipment every five to seven years throughout the average system lifetime of 20 years. These costs greatly increase the required revenue from charging service and the deficit must be covered by the public funding.

The purpose of the financial section of the guideline is to facilitate all the executing agencies, facility owners, concerned stakeholders to prepare and provide the necessary funding for O&M and replacement of equipment for the solar PV systems for the long run.

These guidelines include the introduction of the financial model to provide methodology to estimate the required public funding from the government budget as well as the commercial revenue of each facility.

Besides REA and MOE&P, this financial section is expected to provide necessary information to other stakeholders, i.e. MoEST as well as their county offices, as owners of solar PV systems in dispensaries. The section is also useful for those who are at primary schools as beneficiaries and local managers of the solar PV system in the rural areas.

4.2 Roles and Responsibilities of Agencies and Stakeholders

Table 4.2.1 summarizes the roles and responsibilities of agencies and stakeholders in financial management of solar PV projects for primary schools.

Table 4.2.1 Roles and Responsibilities by Project Stage

Project Stage	Major Role	Agency or Stakeholder	Financial Management Task
Initial Investment	National-level Programming and Installment of Solar PV Systems	**REA**	- **Budget appropriation & execution for Initial Investment** - Monitoring and data collection of nationwide implementation
Operation & Maintenance (O&M)	Technical Assistance on O&M and replacements	**REA**	- **Technical assistance** on overall O&M and replacements including provision of cost reference and updated price data - Monitoring of nationwide operational status
	National-level Financial Management	**MoEST**	- National-level mid- and long-term projection for recurrent expenditure, especially replacement costs - **Ensure replacement cost budget is allocated** to responsible County Office
	County-level Financial Management	**County MoEST**	- **Budget appropriation for daily O&M and replacement cost** for each solar PV facility in the county - Project monitoring
	Facility-level Daily O&M and Financial Management of Solar PV System	**Primary School**	- **Daily O&M** of solar PV system - Reporting to County Office on the financial state - Commercial operation of charging service

Prepared by JET

4.3 Financial Model

The financial model is designed to provide preliminary cost estimation of initial and O&M costs as well as the revenue from charging service of the solar PV system for each project component that concerned stakeholders are responsible for. It also illustrates the methodology and information source that the concerned stakeholders should refer to when formulating their own budget proposal and planning upon implementation of a solar PV project.

The costs and revenue values in this section are estimates as of year 2014 based on the contract prices of the existing pilot projects. The values are all expressed in the 2014 constant price unless otherwise indicated. It should be noted that, since those values may change over time for many reasons, they are subject to further revision at the time of preparing each budget proposal or expenditure plan for solar PV projects. The revision should be based on the latest cost information to be collected by REA such as recent monitoring results of on-going projects, etc.

(1) Cost Components and Responsible Agency/Stakeholders

Cost components of a solar PV system consist of (i) initial cost, (ii) recurrent operation expenses, and (iii) replacement cost. Table 4.3.1 summarizes the major items and responsible agency/stakeholder for each component.

Table 4.3.1 Cost Components of Solar PV System

Cost Component		**Responsible Agency/ Stakeholder**	**Funding Source**
Initial Investment		**REA**	- REA Budget (and/or Donor finance)
Operation & Maintenance (O&M)	Recurrent Operation Expenses	**Primary School Management Committee**	- **Charging Service Revenue** - Operational Budget allocated by County MoEST (or School Management Committee)
	Replacement Cost - Battery - Charge Controller - Inverter	**County MoEST**	- County MoEST Budget

Prepared by JET

Initial investment will be borne by REA and the investment cost will be determined based on required PV system scale. The installed solar systems require daily operations and maintenance work by certain specific persons, i.e. operators at expense of primary schools along with other daily expenses which the management committee of each facility is primarily responsible for. The main system components i.e. batteries, inverters and charge controllers, are to be replaced at the end of each lifespan; i.e. batteries are to be replaced every five years, inverters/ charge controllers are to be replaced every seven years over the project lifetime of 20 years. It is envisaged that these replacement costs are borne by County MoEST budget for dispensaries.

(2) Charging Service Revenue

In order to support O&M cost required for sustainable use of solar PV systems, some of schools are to be equipped with the solar charging system for charging services of mobile phones, lanterns, etc. depending on the number of potential customers. The charging service is a revenue-generating operation that provides electricity for mobile phones and other devices at unit price of KSh. 20 (approx. US cent 24 as of November 2014) per time, for instance, for customers coming from communities nearby. The collected fee is saved for expenses of daily operation and consumables of the solar systems such as distilled water, stationery for accounting, transportation and so on. However, as seen in the sample cash flow projection prepared in Table 4.3.7 provided at the end of 4.3, it is projected that most part of the operational expenses will be far beyond the charging service revenue, even with funding allocation from the existing public budget for the facility operation. Such deficit from daily operation must be covered by additional budget allocation.

(3) Cost Estimation

Costs estimation of solar PV systems consists of three components: (i) estimation of PV system scale, (ii) initial cost estimation and (iii) O&M cost estimation.

Based on the information of the target facility, the required PV system scale (capacity and number of equipment) is estimated which determines factors to estimate initial and O&M costs. Necessity and size of charging service system should be determined by information on the surrounding area, demand among residents, mobile signal coverage, etc.

Figure 4.3.1 illustrates the conceptual flow of cost estimation for solar PV projects.

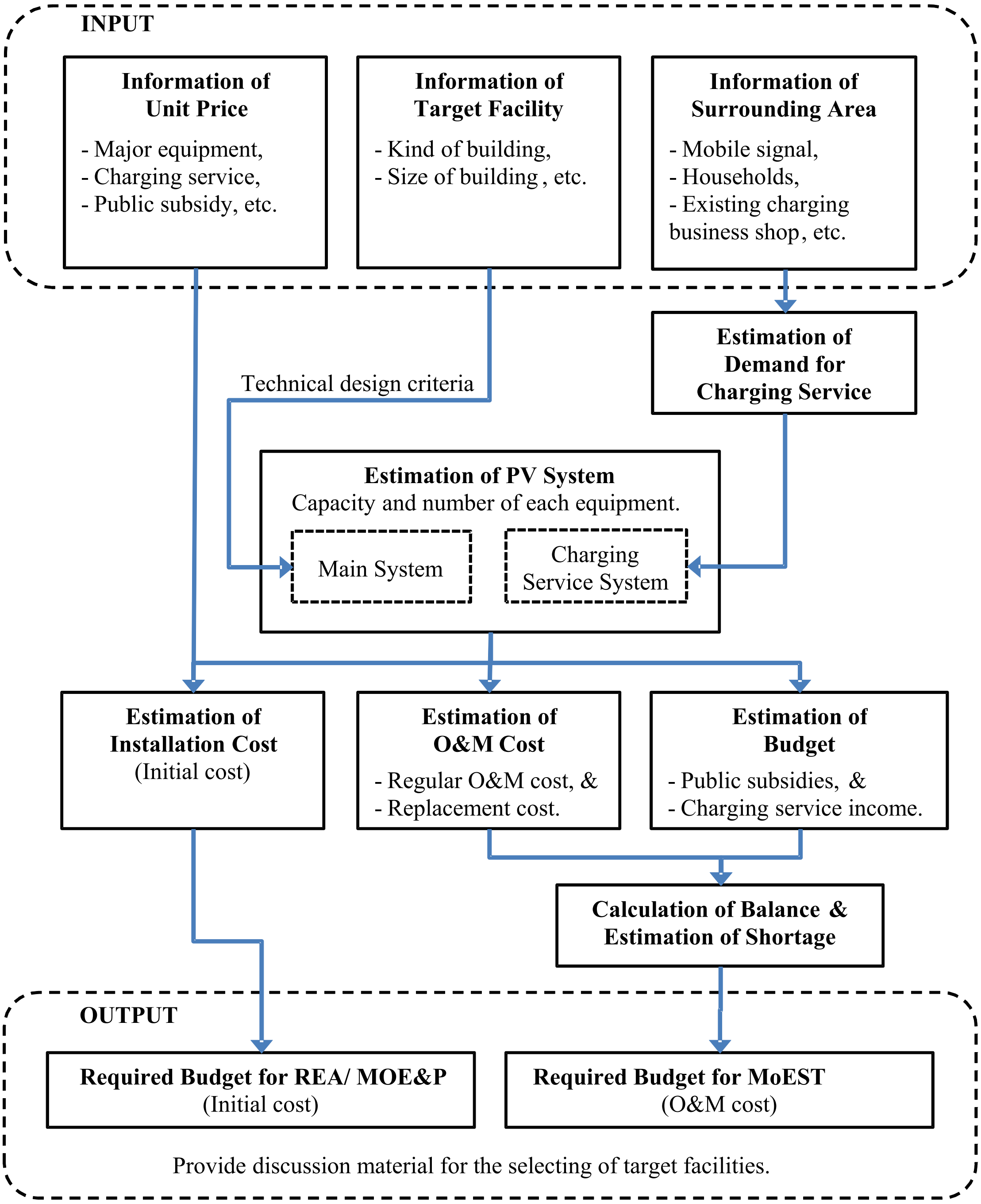

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Figure 4.3.1 Conceptual Diagram of Financial Model of PV Systems

a) PV System Scale [REA]

The PV system scale required for each facility depends on its electricity demand which is determined by number and type of rooms in its buildings. Once the demand is estimated, the suitable power package is chosen from lighting model (PP0, PP1 and PP2) and charging model.

Table 4.3.2 shows unit power demand by room type and Table 4.3.3 presents suitable power package by estimated power demand.

Table 4.3.2 Estimated Unit Power Demand of Primary School

No.	Room Type	Unit Power Demand (Wh/day)
Primary School		
S1.	Class room (each room 40 W x 4hrs)	160
S2.	Teacher room (Light: 160 Wh/day + Power Socket 300 Wh/day)	450
S3.	Dining Hall (Light 100 W x 4hrs + TV 100 W x 4hrs)	800
S4.	Dormitory (Light 80 W x 4hrs)	320
S5.	Store quarter (max. 2 rooms) + TV	600
S6.	Store	50
S7.	Security (10 W x 4nos. x11hrs) for each building	440

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Table 4.3.3 Suitable Power Package by Power Demand

No.	Unit Power Demand (Wh/day)	Power Package (cf. Table 4.3.4)
PD1	~ 350	PP0
PD2	~ 700	PP1
PD3	~ 1,400	PP2
PD4	~ 700	Charging Model

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Example: Power Package Selection for Primary School

One building in a primary school with one main room and one store room

- Power demand (P) = 500 Wh/day x 1 main room + 100 Wh/day x 1 store room
  = 600 Wh/day

Power package: 1 unit of PP1 (~ 700 Wh/day)

For charging model, unit power demand is estimated to be 700 Wh/day. This was assumed on the basis of number of 20 mobile phones and 20 LED lanterns each day. In general, one package of charging model would be sufficient to cover demand of mobile charging and other small power usages in a facility in rural area. In case that more customers are expected than the assumption, the number of charging models should be increased.

b) Initial Cost [REA]

The initial cost of PV system is estimated by the following formula:

$$P_{IC} = P_1 + P_2 + P_3 + P_4$$
$$P_2 = P_1 \times 0.25$$
$$P_3 = 130{,}000$$
$$P_4 = (P_1 + P_2 + P_3) \times 0.3$$

Where, P_{IC}: initial cost of PV system
P_1: costs of procurement and installation of major equipment
P_2: costs of procurement and installation of other devices (25% of P_1)
P_3: costs of construction of charging house = KSh. 130,000
P_4: commission charges
(10% of above for primary schools)

The costs of major equipment of PV system (P_1) are estimated by required number of units of power package and unit price. The required units of each power package are estimated as mentioned above, and unit prices of major equipments in each power package are estimated as in Table 4.3.4.

Table 4.3.4 Estimated Unit Price of Major Equipment in each Power Package

Major Equipment	Lighting Model			Charging Model
	PP0	PP1	PP2	
1. Solar module (120 W)	12,000 (1 unit)	24,000 (2 units)	48,000 (4 units)	24,000 (2 units)
2. Roof mounting structure	1,800	3,500	7,000	3,500
3. Isolator	5,000	5,000	5,000	5,000
4. Charging controller	9,000	9,000	11,000	11,000
5. Battery	19,000 (1 unit)	38,000 (2 units)	54,000 (2 units)	19,000 (1 unit)
6. Inverter	25,000	25,000	35,000	25,000
7. DC fuse/breaker	9,200	9,200	9,200	9,200
8. Consumer units	8,500	8,500	8,500	8,500
Total	89,400	122,100	177,600	105,100

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The cost of other devices (P_2), such as cables, LED, switches, boxes, sockets, security light, maintenance tool box, etc. are estimated to be 25% of the amount of major equipment.

The cost of charging house (P_3) is estimated to be KSh. 130,000/unit.

The commission charges are estimated to be 10% of the total of, P_1, P_2, and P_3.

c) O&M Costs [Primary School and County MoEST]

The O&M costs of PV system consist of daily operation costs and replacement costs of major equipment.

Daily Operation Expenses [Primary School]

The daily operation expenses include distilled water, consumables, transportation, etc and salary of operator if it is paid from the proceeds of the charging service[4]. It is learnt from the pilot projects that the most important expenditure is purchase of distilled water and repair of hair clippers.

[4] As the portion of salary is relatively high, it is proposed to the facilities to pay operator's salary from their budget by assigning one of their subordinates to work for O&M. However, as the assigned subordinate cannot provide his/her full working time for O&M and charging business, a trade-off between reduction of salary and reduction of income is observed.

They are estimated by the following formula based on the monitoring results of the pilot projects.

$$P_{OM} = 1{,}000 + 100 \times N_{BT}$$

Where, P_{OM}: daily operation expenses (KSh./month)
N_{BT}: number of battery (nos.)

Replacement of Major Equipment [County MoEST]

The major equipment to be replaced during the system life are (i) battery, (ii) charge controller and (iii) inverter. The replacement costs are estimated as follows;

$$P_{RP} = P_1 + P_2$$

Where, P_{RP}: Replacement costs of major equipment
P_1: Cost of procurement and installation of major equipment
P_2: Commission charges (40% of P_1)

Expected lifetime and unit price of major equipment are estimated as shown in Table 4.3.5.

The expected lifetime of equipment is assumed to be five years for battery and seven years for inverter and charge controller on average under proper maintenance and operational conditions. Actual replacement needs depend on the quality of daily maintenance work by operators. The lifetime of equipment may be longer than expected if operators take adequate care; however, poor maintenance work may damage the equipment and lead to earlier replacement.

Table 4.3.5 Estimated Life and Unit Price of Major Equipment

Major Equipment	Capacity	Unit Price (KSh./unit)	Equipment Life
Battery			5 years
For lighting model of PP0, 12 V	100 Ah	19,000	
For lighting model of PP1, 12 V x 2 = 24 V	100 Ah	38,000	
For lighting model of PP2, 12 V x 4 = 48 V	200 Ah	54,000	
For charging model, 12 V	100 Ah	19,000	
Charge Controller			7 years
For lighting model of PP0, 12 V	10 A	9,000	
For lighting model of PP1, 12 V x 2 = 24 V	10 A	9,000	
For lighting model of PP2, 12 V x 4 = 48 V	20 A	11,000	
For charging model, 12 V	20 A	11,000	
Inverter			7 years
For lighting model of PP0, 12 V	300 W	25,000	
For lighting model of PP1, 12 V x 2 = 24 V	300 W	25,000	
For lighting model of PP2, 12 V x 4 = 48 V	400 W	35,000	
For charging model, 12 V	300 W	25,000	

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The replacement cost is estimated by unit price and number of major equipment as well as the commission charge of 40% based on the experience of the pilot projects.

(4) Estimation of Charging Service Revenue [Primary School]

Demand and revenue for charging service depends on the surrounding conditions of the target facility such as population and type of neighbourhood community. Based on the monitoring results of the pilot projects, the charging service revenue is estimated for four cases (See Table 4.3.6).

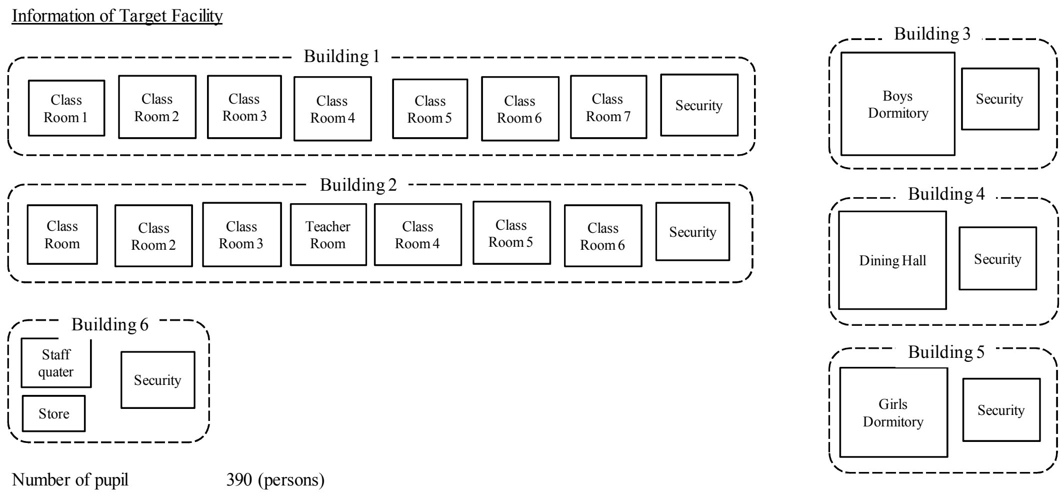
Table 4.3.6 Estimated Charging Service Revenue

	Household within 5 km	Village Type	Monthly Revenue (KSh./month)
Case 1	More than 50 HHs	Concentrated or having core area	2,000
Case 2	More than 50 HHs	Dispersed	1,000
Case 3	50 HHs and less than 50 HHs	Concentrated or having core area	1,000
Case 4	50 HHs and less than 50 HHs	Dispersed	1,000

Prepared by JET

(5) Sample Case of Primary School

This sample case describes financial model of a typical solar PV system for primary school. It is assumed that this school has six buildings in layout shown in Figure 4.3.2.



Prepared by JET

Figure 4.3.2 Sample Target Facility (Primary School)

a) Size of Buildings and Power Demand:

Building 1: Class Room (160 Wh/day) x 7 + Security (440 Wh/day) = 1,560Wh/day

Building 2: Class Room (160 Wh/day) x 6 + Teachers Room (450 Wh/day) + Security (440 Wh/day) = 1,850 Wh/day

Building 3: Boys Dormitory (320 Wh/day) + Security (440 Wh/day) = 760 Wh

Building 4: Dining Hall (800 Wh/day) + Security (440 Wh/day) = 1,240 Wh/day

Building 5: Girls Dormitory (320 Wh/day) + Security (440 Wh/day) = 760 Wh/day

Building 6: Staff quarter (600 Wh/day) + Store (50 Wh/day) + Security (440 Wh/day) = 1,090 Wh/day

b) Power Packages & Initial Cost

PP0: KSh. 89,400 x 1 = KSh. 89,400

PP1: KSh. 122,100 x 2 = KSh. 244,200

PP2: KSh. 177,600 x 5 = KSh. 888,000

Charging Model: = KSh. 105,100

P1: Initial Cost (Total) = KSh. 1,326,700

P2: Cables, switches, etc. = 25% of Initial Cost = KSh. 331,675

P3: Cost of charging house = KSh. 130,000

P4: Commission charge = (P1+P2+P3) x 10% = KSh. 178,838

P_{IC} = P1+P2+P3+P4 = KSh. 1,967,213 = KSh. 1,970,000

c) O&M Costs

Regular Operation (Daily operation)

$$P_{OM} = 1{,}000 + 100 \times N_{BT}$$

Where, P_{OM}: daily operation expenses (KSh./month)

N_{BT}: number of battery (nos.)

Estimation of O&M Cost

Number of Battery

	PP2	PP1	PP0	Charge	Total
Number of Power Package	5	2	1	1	
Unit number per power package	4	2	1	1	
	20	4	1	1	26

POM 3,600 (KSh./month) = 1,000 + 100 x 26
43,200 (KSh./year)

Replacement Costs

Estimation of Replacement Costs

	PP2	PP1	PP0	Charging	Total
1 Number of Equipment					
Battery	5	2	1	1	9
Charging Controller	5	2	1	1	9
Inverter	5	2	1	1	9
2 Unit Price of Equipment					
Battery	54,000	38,000	19,000	19,000	
Charging Controller	11,000	9,000	9,000	11,000	
Inverter	35,000	25,000	25,000	25,000	
3 Amount of Equipment					
Battery	270,000	76,000	19,000	19,000	384,000
Charging Controller	55,000	18,000	9,000	11,000	93,000
Inverter	175,000	50,000	25,000	25,000	275,000
					752,000

$$P_{RP} = P_1 + P_2$$

Where, PRP: Replacement costs of major equipment

P1: Costs of procurement and installation of major equipment

P2: Commission charges (10% of above)

Replacement Cost of Battery

P_{RP1} =	384,000+	384,000x	40% =	537,600 (Ksh.)	538,000 (Ksh.)

Replacement Cost of Charging Controller and Inverter

P_{RP2} =	93,000+	93,000x	40% =	130,200 (Ksh.)	131,000 (Ksh.)
P_{RP3} =	275,000+	275,000x	40% =	385,000 (Ksh.)	385,000 (Ksh.)

d) Existing Budget for Regular Operation

Free Primary Education Fund (FPEF) of 1,020 KSh./pupil/year is currently provided for general school operation. It includes electricity fee of 64 KSh./pupil/year which is assumed to be spent for regular operation of the solar PV system.

Estimation of Public Budget

64 x 390 = 24,960 (KSh./year)

e) Revenue from Charging Service

Demand for charging service is subject to the location and type of neighbourhood community. It is assumed that the surrounding households are less than 50 and the village is dispersed. In the said case the monthly revenue is estimated to be only KSh. 1,000 per month.

f) Cash Flow Projection

Table 4.3.7 shows the cash flow projection based on the assumptions of the sample case of primary school. The projection is expressed in 2014 constant price. The annual deficit from regular operation (difference of charging service revenue and regular operation expenses) amounts at KSh.6,240 which will be borne by the primary school. During the system lifetime of 20 years, MoEST must allocate KSh. 2,646,000 in total for the budget for major replacements

Table 4.3.7 Cash Flow by Financial Model (Primary School)

Year	Initial Cost	O&M Cost (KSh)					Revenue (KSh)			Balance (KSh)		**Required Budget Allocation (KSh)**		
		Regular Operation (Local Cost)	Major Replacement: Battery (Foreign Cost)	Major Replacement: Inverter (Foreign Cost)	Major Replacement: CC (Foreign Cost)	Sub-total (1)	Existing Budget (Local)	Charging Service (Local)	Sub-total (2)	Per Year	Accumlation	Initial Cost **REA**	Reguar Operation **Primary**	Major Maintennace **MoEST**
		(a)	(b)	(c)	(d)	(e) =	(f)	(g)	(h) = (f)+(g)	(i) = (h)-(e)	(j) = Σ (i)	(k)	(l) = (a) - (h)	(m) =
0	1,970,000											1,970,000		
1		43,200				43,200	24,960	12,000	36,960	-6,240	-6,240	0	6,240	0
2		43,200				43,200	24,960	12,000	36,960	-6,240	-12,480	0	6,240	0
3		43,200				43,200	24,960	12,000	36,960	-6,240	-18,720	0	6,240	0
4		43,200				43,200	24,960	12,000	36,960	-6,240	-24,960	0	6,240	0
5		43,200	538,000			581,200	24,960	12,000	36,960	-544,240	-569,200	0	6,240	538,000
6		43,200				43,200	24,960	12,000	36,960	-6,240	-575,440	0	6,240	0
7		43,200		385,000	131,000	559,200	24,960	12,000	36,960	-522,240	-1,097,680	0	6,240	516,000
8		43,200				43,200	24,960	12,000	36,960	-6,240	-1,103,920	0	6,240	0
9		43,200				43,200	24,960	12,000	36,960	-6,240	-1,110,160	0	6,240	0
10		43,200	538,000			581,200	24,960	12,000	36,960	-544,240	-1,654,400	0	6,240	538,000
11		43,200				43,200	24,960	12,000	36,960	-6,240	-1,660,640	0	6,240	0
12		43,200				43,200	24,960	12,000	36,960	-6,240	-1,666,880	0	6,240	0
13		43,200				43,200	24,960	12,000	36,960	-6,240	-1,673,120	0	6,240	0
14		43,200		385,000	131,000	559,200	24,960	12,000	36,960	-522,240	-2,195,360	0	6,240	516,000
15		43,200	538,000			581,200	24,960	12,000	36,960	-544,240	-2,739,600	0	6,240	538,000
16		43,200				43,200	24,960	12,000	36,960	-6,240	-2,745,840	0	6,240	0
17		43,200				43,200	24,960	12,000	36,960	-6,240	-2,752,080	0	6,240	0
18		43,200				43,200	24,960	12,000	36,960	-6,240	-2,758,320	0	6,240	0
19		43,200				43,200	24,960	12,000	36,960	-6,240	-2,764,560	0	6,240	0
20		43,200				43,200	24,960	12,000	36,960	-6,240	-2,770,800	0	6,240	0
Total	1,970,000	864,000	1,614,000	770,000	262,000	3,510,000	499,200	240,000	739,200	2,770,800	-	1,970,000	124,800	2,646,000
Annual Avg.	-	43,200	80,700	38,500	13,100	175,500	24,960	12,000	36,960	138,540	-	-	6,240	132,300

Prepared by JET

4.4 Salient Points in Financial Management

4.4.1 Nationwide Program and Mid- and Long-term Expenditure Plan

As seen in 4.3, it is obvious that solar PV projects will not generate sufficient income to even cover the daily operation expenses. Also, timely reinvestment in major replacements is inevitable to ensure sustainable operation in the long run. Therefore, when REA prepares the forthcoming nationwide program of solar PV development, it is strongly recommended that comprehensive mid- and long-term expenditure plan should be included to advise all the concerned agencies and stakeholders on their fiscal requirement derived from implementation of the program. For this purpose, the cash flow projection presented in the financial model may be utilized as a rule of thumb; however, it is recommended to estimate the O&M costs of every solar project based on actual data for more precise projection.

4.4.2 Price Data for O&M Cost

The unit prices used in this financial section are all estimated from the monitoring results of the pilot projects. Prices change over time for many reasons e.g. inflation, technology advancement, demand-supply balance, etc. especially for solar PV system. Charging service unit rate, therefore, must be adjusted to a competitive level among similar service providers in project area.

Therefore, for the annual budget proposal and allocation of O&M and replacement costs, the responsible agencies/ stakeholders should refer to the latest available data such as:

- ✓ The actual costs in the previous year;
- ✓ Price quotations from suppliers/ contractors; and
- ✓ Actual O&M costs of other operating systems

For this purpose, REA should closely monitor the operational status of the systems installed and gather price information in consultation with the system users as well as other stakeholders such as suppliers.

MoEST and County MoEST should use the updated data prepared by REA to formulate annual budget for replacements and subsidy for daily O&M throughout the operation period.

4.4.3 Cash Flow Projection

The cash flow projection (Table 4.3.7) is also based on the price data of the pilot projects and expressed in year 2014 constant price because there is great uncertainty in price escalation and exchange rates in such a long-term perspective as 20 years. As stated above, the stakeholders should use the latest price information by REA when updating their mid-term projections. The cash flow projection with price escalation is presented as per Annex 3-1 for further reference.

4.4.4 Planning and Budgeting

(1) Annual Plan

MoEST is responsible for planning and budgeting of electrification of facilities under their supervision. They should have both mid-term and annual plans for anticipated revenue and expenditure of its PV systems which should be revised every year. Revenue is generated from charging service operation while expenditure is for operation, maintenance, and major replacements of the PV systems. The financial model should be utilized to identify and understand the O&M cost items and charging service revenue (See 4.3). For actual cost estimation, however, it is proposed that REA will keep updating the latest price information from on-going projects, which the ministry may refer to (See 4.3 (5)).

(2) Regular Operation Costs (See 4.3 (5))

Regular operation cost includes recurrent cost items for PV system operation such as distilled water, bulbs, small repairs, transportation, allowance for operator, bank charges, etc.

(3) Major Replacement Costs (See 4.3 (5))

Batteries, inverters and controllers are required to be replaced every five to seven years (after an average use of seven years).

(4) Charging Service Revenue (See 4.3 (5))

Charging service revenue is part of the funds to be used for daily O&M and, if possible, future replacement. As seen in 4.3 (5), the charging service revenue depends on the community type and population. Since charging service in rural communities is a private business activity in general, relevant stakeholders and REA shall check the prevailing market price in the project area to determine PV system's actual charging fee applicable to customers.

In most cases, the charging service income cannot even cover the regular operation cost, therefore deficit is generated every year. Since the charging fee level is determined to match the market price and hard to increase, relevant ministries and REA shall encourage management committees to increase number of customers.

(5) Budgeting

Deficit from regular operation and all the major replacement cost must be covered by government budget subsidy to ensure sustainable operation over system lifetime of 20 years. To receive the budget from the treasury, MoEST should make budget plan to apply to the treasury based on the budget proposal and expenditure projection.

Primary schools have only one income source: the fund called FPEF allocated from the National Government for necessary expenditure to implement the school education in general. However, the amount of the funds is too small to cover all necessary requirements.

4.5 Financial Management for Public Facilities

This section explains the financial management for primary schools on their O&M of solar PV systems, including charging service operation. Primary school staff and respective management committees are primarily responsible for the daily operation and charging service.

This section includes organizational setup, budget planning, and the proposed accounting system. REA and relevant stakeholders shall enhance capacity of facility staff and members of management committees so that they can effectively and correctly manage the solar PV system.

4.5.1 Background

REA has the mandate to promote rural electrification by both electricity grid expansion and alternative measures including solar PV systems. Recently REA has a nationwide plan to install PV systems in trading centres, secondary schools and health centres in un-electrified rural communities. However, dispensaries and primary boarding schools have also priority of electrification. Once installed, the operation and maintenance of the PV systems for system lifetime (approximately 20 years) will be handed over to these public facilities.

To cover part of recurrent O&M expenses, the PV systems may provide charging service as an income generating activity to cover part of daily operational expenses for distilled water, simple repairs, etc; however, most of the O&M costs including major replacement need to be covered by additional budget allocated by National Government.

The financial management for solar PV systems should be based on responsibility sharing among the users of the facility, the National Government and other stakeholders. This will ensure the sustainability of the PV systems and user benefit from the installed PV systems. The financial section aims to promote awareness of stakeholders on the need for necessary funding for the O&M and replacement costs. Without appropriate planning, it will be difficult to have sustainable PV system operation. Appropriate trainings covering those basic aspects of "Financial Management" are therefore necessary for the management committees and the selected operators from every facility with PV system.

4.5.2 Objectives of Financial Management

The following are the expected objectives of the financial management of each stakeholder.

a) Provide the users with the basic knowledge on financial management

b) Explain the importance of planning, budgeting and how to manage expenditure

c) Provide better understanding of good financial control

d) Provide a simple accounting system for sustainable use of a PV system (addressed to the school management committee).

e) Explain how to record daily transactions, balance simple account, and prepare monthly report (addressed to the school management committee)

4.5.3 Proposed Accounting System for the Management Committee

Each facility with solar PV system should keep appropriate accounting records of its charging service transactions. It is the most essential part of the financial management at the facility level. REA and relevant stakeholders shall give financial training on these issues to the facility staff and management committee members. The accounting procedure in solar PV charging service is designed and proposed as follows and relevant formats are attached in Annex 3-2.

a) Daily Sales Record

Every transaction with customers must be recorded by the operator in detail on a daily basis. Incomplete records may cause incidents such as lost cash, etc.

(b) Sales Receipt

Receipt or voucher must be given to customers whenever payment for charging service is made. It will be easy to check the total sales on daily business record with the receipt copies and make sure they match.

(c) Cash Book

Cash book is prepared for operators to keep cash income and spending records on a daily basis. Simplified form is prepared for easy comprehension by operators.

(d) Bank Account

Bank account must be prepared before starting the charging service with installed PV systems. This bank account should be a separate account from the existing one for usual education activities. For the purpose of security, cash should be deposited in the bank account at least once a week. The deposit slip should be retained by the treasurer or kept in file with the secretary.

(e) Monthly Financial Report (Revenue & Expenditure Statement)

The management committee will prepare monthly income and expenditure statement, i.e. Monthly Financial Report of PV system, showing the amount collected from the charging service, the total amount spent for O&M, the bank account balance, etc. Cash balance should be carried forward to the following month.

(4) Capacity Building Plan of Financial Management

It is envisaged that REA will enhance capacity of public facilities so that they can implement O&M and management of solar PV systems properly. This capacity building should include the financial management trainings in order to ensure appropriate O&M activities in facility including charging service operation. This section for financial management would be utilized by trainers as a basis of training contents and the users' manual would be utilized by the facility staff and management committee members who operate and manage the system at the facility.

In these financial management trainings, REA shall employ competent financial experts as trainers. Trainees shall be users of the PV systems consisting of management committee members, staff of public facilities (school teachers, etc.).

It is proposed that the financial management training course will consist of two parts: "before installation" and "after installation".

The training done before the installation is to focus especially on the operator who is to be responsible from the day of commissioning the charging systems for services: to operate charging services, collect cash, provide receipts and to record necessary items. Most operators are not trained professionals of solar PV system operation or accounting and some of them cannot even write and count. According to their social conditions, they cannot easily comprehend the O&M and accounting. Therefore the training should be repeated after the installation within three months. The second training will be conducted to review and assure the procedures for necessary regular actions.

The following table is the summary for the training items to each person in charge.

Table 4.5.1 Role Sharing

Books & Forms	Purpose & Contents	Person in Charge	Check & Keep
Daily Sales Record	Income record	Operator	Secretary
Sales Receipt	Evidence	Operator	Customers
Cash Book	Monthly income & expenditure	Treasurer	Treasurer/chairman
Bank Account	Official Record	Chairman/treasurer	Chairman
Monthly Report	Monthly income, expenditure and monthly balance	Chairman/treasurer	County and sub-county offices

Prepared by JET

Training contents will include, but not limited to, contents of this section of the guideline. In general, the first training will take a maximum of two days with two sessions of two hours in each day while the second training will take a maximum of one day with two sessions of two hours each. However, the trainer, appointed among the employees of REA, may adjust the contents and the training period depending on the location and trainee level.

The trainer from REA should provide all the training materials that JET prepared including the manual for the trainees which could be utilized as reference manual at each facility. REA may issue internal certificates of training attendance for the trainees.

CHAPTER 5 ENVIRONMENTAL AND SOCIAL CONSIDERATIONS

5.1 Environmental Management System in Kenya

5.1.1 National Environmental Management Authority (NEMA)

The National Environment Management Authority (NEMA) is a practical official body responsible for managing environment, reviewing “EIA Project Reports” and “EIA Study Reports” and issuing Environment Licenses for development projects in Kenya.

Under the Board and the Director General at the top of NEMA, the Authority has established six departments and one sub-department. Among those departments, the following ones have functions on EIA related activities. (Source, National Environment Management Authority Strategic Plan 2008-2012, June 2009, NEMA)

- The Director General appoints members of Environmental Impact Assessment Technical Advisory Committee (EIA-TAC) and prescribes the terms of reference and rules of procedure of the review of EIA related reports received by NEMA.
- The Compliance and Enforcement Department, identifies projects and programmes or types of projects and programmes, plans and policies for which environmental audit (EA) or environmental monitoring must be conducted under the Act and ensure EIAs and EAs are conducted.

5.1.2 Environmental Management System at County Level

(1) Decentralization and Administrative Structure Reform (Transitional Period)

Since the New Kenyan Constitution came into force in 2010, decentralization, administrative structure reforms and regulatory revisions for “Country System” in place of former “Province and District System” have started.

- ✓ As a matter of fact, NEMA issued a public notice with regard to the decentralization of its county functions on EIA as of 1st of July 2012 (See Figure 5.1.1).

As far as reforms of environmental management and EIA review procedure are concerned, the reform processes are in the transitional period as of January 2014.

- ✓ Due to the fact that the environmental management and EIA procedural reforms have not adequately come into effect in order to conform to the new constitutional dispensation especially on administrative units, the provisions of the current EMCA 1999 and EIA/EA Regulations (Amendment) 2009 are still in force until such a time that they will be reviewed. However NEMA through an administrative procedure has done away with District and Provincial offices and effectively replaced them with County offices.
- ✓ The transition period therefore means that the former systems (especially where the relevant laws are concerned) are still in operation alongside the current administrative re-alignment. Therefore, the former local systems of “Provincial Environmental Committee” as well as “District Environmental Committee” are envisaged to be reviewed.

(2) Provincial Environmental Committee (PEC) & District Environmental Committee (DEC)

According to the current EMCA 1999 and EIA/EA Regulations (Amendment) 2009, NEMA operates at provincial and district levels. Namely the Provincial Environment Committees (PECs) and District Environment Committees (DECs) are a primary mechanism for NEMA to undertake its functions, which will be reviewed to County Environment Committee in order to conform to the new administrative structure of County system.

nema

NATIONAL ENVIRONMENT MANAGEMENT AUTHORITY

PUBLIC NOTICE

DECENTRALIZATION OF NEMA FUNCTIONS AND SERVICES

The National Environment Management Authority (NEMA), effective **1st July 2012** implemented a decentralization programme to counties. This is in adherence to the Constitution of Kenya 2010 provisions for government agencies to devolve their operations and functions to counties to ensure efficient provision of their services. The decentralization will in particular address processing of Environmental Impact Assessment, Environmental Audit, Noise and Excessive Vibration Control and transportation of waste (garbage and sewage) licences.

SPECIFIC CRITERIA FOR DECENTRALIZATION

A. Low impact Environmental Impact Assessment (EIA) projects

The EIA for the following low impact projects shall be submitted and processed at respective offices of the County Director of Environment:

1. Residential houses (bungalows, maisonettes, flats) in zoned area (of not more than 30 units)
2. Commercial buildings (of not more than 10 storey's) in zoned areas
3. Go-downs for storage of goods only in zoned areas
4. Community based and/or constituency development Fund (CDF) projects such as;
   i. Water projects, boreholes and water pans
   ii. Roads (small feeder roads) and bridges
   iii. Markets
   iv. Cattle dips
5. Cottage industry/jua kali sector/garages
6. Car and bus parks
7. Restaurants (excluding tourism facilities in or surrounding National parks and game reserves).
8. Expansion of existing facilities for same use especially socially uplifting projects (SUPs) such as schools and dispensaries
9. Afforestation/re-afforestation programmes
10. Sand harvesting, quarrying and brick making
11. Slaughter houses (handling not more than 15 animals a day)
12. Construction of churches and mosques
13. Timber harvesting

B. Medium and low risk Environmental Audit (EA)reports

Medium and low impact project audits will be processed at respective offices of County Directors of Environment. These include:

1. Animal feed milling
2. Apartments
3. Colleges
4. Campsites
5. Metal welding
6. Restaurants
7. Schools
8. Tea farms
9. Transport Companies
10. Timber Products
11. Warehouses
12. Stadiums

C. High impact/risk projects will be processed at NEMA headquarters

All high impact/risk projects will be processed at NEMA headquarters. These include:

1. Asbestos manufacturing /based industries
2. Battery recycling
3. Airports
4. Airports hangars
5. Base transceiver stations(BTS)
6. Cement factories
7. Chemical factories
8. Distilling and blending spirits
9. Geothermal plants
10. Hydroelectric power generation plants
11. Incinerators
12. Landfills
13. Large scale irrigated agriculture farming (exceeding 50ha)
14. Molasses plants
15. Petroleum refining
16. Paper mills
17. Vegetable oil refineries
18. Steel mills
19. Sewerage works
20. Thermal power generation
21. Tanneries
22. Tourist facilities in protected areas
23. Wood preservation

N.B. All other facilities/projects not included in the high risk category list shall be submitted and processed at the respective offices of the County Director of Environment.

D. Noise and excessive vibration control licensing

Noise and excessive vibration control licences and permits shall be issued at the county level for one off activities, where noise emitted is expected to go beyond maximum permissible noise levels. Such one off activities include: weddings and birthday parties, road shows, ceremonies, parties, religious festivals, mobile cinemas among others. The licence is valid for a maximum of seven days and costs Kshs 2,200.

Permits will be issued for the following one off activities: demolition activities, construction sites, fireworks, mines and quarries, firing ranges, specific heavy duty industry. The permit shall be valid for a period of up to three months and costs KShs 5,500.

Commercial activities, discos/ live bands/ pubs, entertainment joints, places of worship among others, shall not be licenced as they are required to sound proof their premises to keep their noise to within permissible noise levels.

E. Waste transportation licensing

Licenses to transport garbage and sewage waste shall be issued at the county level. All the other categories of waste management license applications will continue to be received at county level. These will be forwarded to NEMA Headquarters for processing.

Office contacts of respective County Directors of Environment (CDE) can be found on the NEMA website at www.nema.go.ke.

For further information, please contact:

PROF. GEOFFREY WAHUNGU
DIRECTOR GENERAL
NEMA
Popo road, off Mombasa Road
P.O. Box 67839- 00200, Nairobi, Kenya
Tel: (254 020) 6005522, 020 2101370, 0724 253398, 0735 010237
Fax (254 020) 6008997

Email: dgnema@nema.go.ke Website: www.nema.go.ke
Face book: National Environment Management Authority
Report any environmental related corruption to: anticorruption@nema.go.ke

Source: a Clip DAILY NATION, Monday July 9, 2012

Figure 5.1.1 Public Notice on Decentralization of NEMA Functions and Services

5.2 EIA Procedures and Licensing System in Kenya

5.2.1 Projects Sectors Subject to EIA

Project Sectors subject to EIA procedures in Kenya are specified in the Environmental Management and Coordination Act of 1999 (EMCA) as “Second Schedule” as shown in Table 5.2.1.

Table 5.2.1 "Second Schedule" specified in EMCA (Project Sectors Subject to EIA)

Sector	Including	
General	· An activity out of character with its surrounding, any structure of a scale not in keeping with its surroundings	· Major changes in land use
Urban development	· Designation of new townships · Establishment of industrial estates · Establishment or expansion of recreational areas	· Establishment or expansion of recreational townships in mountain areas, national parks and game reserves · Shopping centers and complexes
Transportation	· All major roads · All roads in scenic, wooded or mountainous areas and wetlands, Railway lines	· Airports and airfields · Oil and gas pipelines · Water transport
Dams, rivers and water resources	· Storage dams, barrages and piers · River diversions and water transfer between catchments	· Flood control schemes · Drilling for the purpose of utilizing ground water resources including geothermal energy
Aerial spraying	-	-
Mining	· Quarrying and open cast extraction of · Precious metal, Gemstones, Metalliferous ores, Coal, Phosphates, Limestone and dolomite	· Stone and slate · Aggregates, sand and gravel, Clay, Exploration for the production of petroleum in any form, Extracting alluvial gold with use of mercury
Forestry related activities	· Timber harvesting · Clearance of forest areas	· Reforestation and afforestation
Agriculture	· Large scale agriculture · Use of pesticide · Introduction of new crops and animals	· Use of fertilizers · Irrigation
Processing and manufacturing industries	· Mineral processing, reduction of ores and minerals · Smelting and refining of ores and minerals · Foundries · Brick and earth wear manufacture · Cement works and lime processing · Glass works · Fertilizer manufacture or processing · Explosive plants · Oil refineries and petrochemical works · Tanning and dressing of hides and skins · Abattoirs and meat processing plants · Chemical works and processing plants · Brewing and malting	· Bulk grain processing plants · Fish processing plants · Pulp and paper mills · Food processing plants · Plants for manufacture or assembly of motor vehicles · Plant for the construction or repair of aircraft or railway equipment · Plants for the manufacture or assembly of motor vehicles · Plants for the manufacture of tanks, reservoirs and sheet metal containers · Plants for manufacture of coal briquettes · Plants for manufacturing batteries
Electrical infrastructure	· Electrical generation stations · Electrical transmission lines	· Electrical sub-stations · Pumped storage schemes
Management of hydrocarbons	· Storage of natural gas and combustible or explosive fuels	
Waste disposal	· Sites for solid waste disposal · Sites for hazardous waste disposal · Sewage disposal works	· Works involving major atmospheric emissions · Works emitting offensive odours
Natural conservation areas	· Creation of national parks, game reserves and buffer zones · Establishment of wilderness areas · Formulation or modification of forest management policies · Formulation of modification of water catchment management policies	· Policies for the management of ecosystems especially by use of fire · Commercial exploitation of natural fauna and flora · Introduction of alien species of fauna and flora · Introduction of alien species of fauna and flora into ecosystems
Nuclear reactors	-	-
Major development in biotechnology	· Introduction and testing of genetically modified organisms	

Source: Environmental Management and Coordination Act of 1999 (EMCA)

However, “Second Schedule” does not specify the scale and size of each project. Namely without reference to scale or size of a project fall under the Second Schedule, such a project shall go through the EIA procedures.

(1) Renewable Energy Projects and necessity of EIA

Renewable Energy Projects (PV, Mini hydro, Bio-gas and Wind power systems) which falls under “No. 10 Electrical Infrastructure” in the “Second Schedule” of EMCA. Therefore, all Renewable Energy Projects are naturally subject to the EIA procedures.

(2) Draft NEMA EIA Guidelines and Administration Procedures

In addition, NEMA developed a Draft EIA Guidelines and Administration Procedures in November 2002 in response to the National Policy on Environment and EMCA 1999. The NEMA Draft EIA Guidelines provides procedural guidelines for,

- Implementation of EIA
- Monitoring and Environmental Audit (EA)
- Strategic Environmental Assessment (SEA)
- Issues of Trans-boundary, Regional and International Conventions, Treaties and Agreements
- Steps in EIA studies and Environmental Audits
- The contents and format of the study reports to be submitted to NEMA
- The EIA study review process and decision-making, and others.

CHAPTER 7 of the NEMA Draft EIA Guidelines mentions that Lead agencies are mandated by section 58 of the EMCA 1999, in consultation with the Authority to develop EIA Guidelines to ensure that environmental concerns are integrated in sector development policies, plans, projects or programmes. The sector guidelines shall focus on specific mandates in line with the statutory relationships with the administration of the EIA process.

- However, such sector guidelines have not been developed by relevant lead agencies excluding the sector of petroleum (Source, A meeting with NEMA HQ).
- In addition, the Draft Guidelines is rendered a rather conceptual guidance. Practically, the processes of EIA and the licensing shall refer to EIA/EA Regulations (Amendment) 2009.

5.2.2 EIA Review Process and Licensing

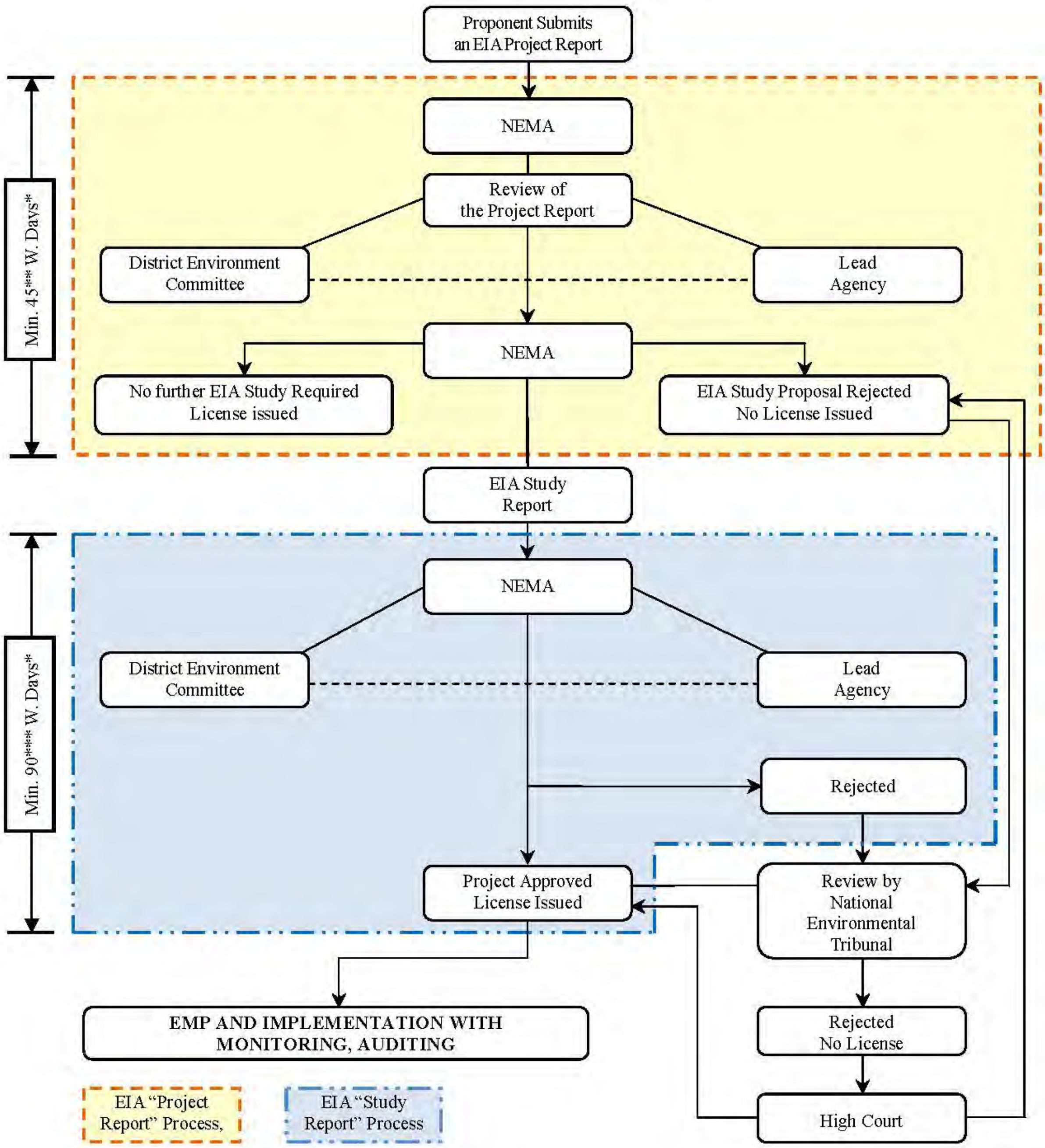
The Environmental Management and Coordination Act of 1999 (EMCA) and EIA/EA Regulations (Amendment) 2009 specify the EIA Review process which consists of the following two steps.

- EIA “Project Report” Process
- EIA “Study Report” Process

(1) Overview of the EIA Process

Based on EMCA 1999, EIA/EA Regulations (Amendment) 2009 and discussions with NEMA officials as well as considering the decentralization of NEMA’s functions at the County level, Kenyan EIA entire procedures can be depicted as shown in Figure 5.2.1.

Detail flows of “EIA Project Report” and “EIA Study Report will appear afterward (See Figure 5.2.2 and Figure 5.2.3).



*Note; *According to NEMA, "days" in the procedures stands for "Working days"*
****According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period*
*****According to NEMA, not "within 90 days" but "Minimum 90 Working days" for the EIA Project Report Review and Licensing period*

Source: NEMA, (modified by the JET based on discussions with NEMA Headquarters officials)

Figure 5.2.1 Overview of the EIA Process

(2) EIA "Project Report"

According to EMCA 1999, EIA/EA Regulation (Amendment) 2009 and discussions with NEMA officials as well as considering the decentralization of NEMA's functions at the County level, the EIA "Project Report" Process can be summarized as follows and depicted in Figure 5.2.2.

- The process starts by a project proponent, selecting a consultant which must be licensed and registered with NEMA as a Lead Expert on EIA/EA

- An EIA "Project Report" shall be prepared by the consultant (Registered Lead Expert on EIA/EA). The following shows contents to be stated in the "Project Report".

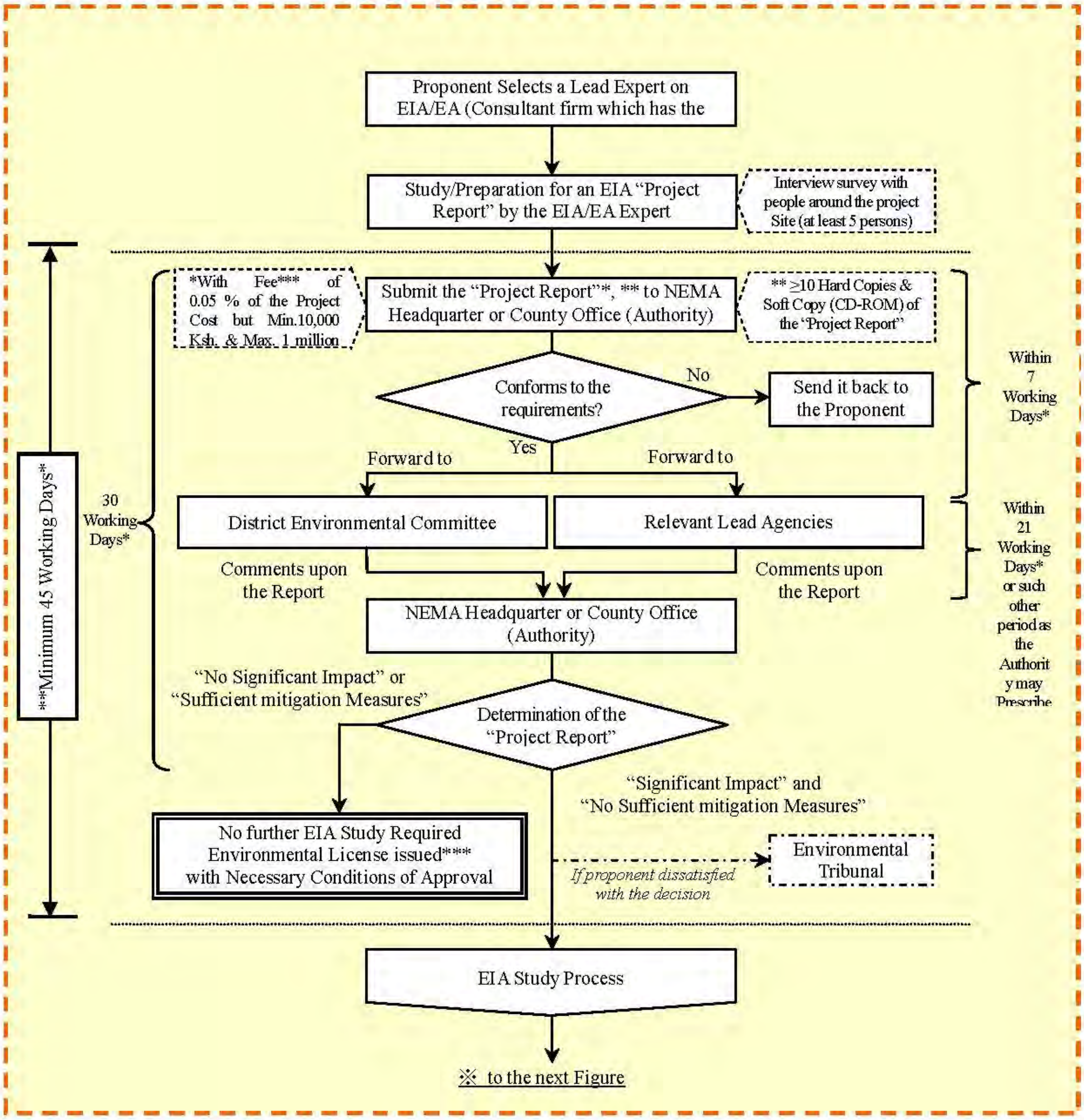
Table 5.2.2 Contents of the Project Report

· Nature of the project, · Location of the project including the physical area that may be affected by the project's activities, · Activities that shall be undertaken during the project construction, operation and decommissioning phases, · Design of the project, · Materials to be used, products and by-products, including waste to be generated by the project and the methods of their disposal, · Potential environmental impacts of the project and the mitigation measures to be taken during and after implementation of the project,	· Action plan for the prevention and management of possible accidents during the project cycle, · Plan to ensure the health and safety of the workers and neighbouring communities, · Economic and socio-cultural impacts to the local community and the nation in general · Project budget, and · Any other information the Authority may require.

Prepared by JET

- The proponent shall submit at least ten copies and one soft copy (CD-ROM) of the EIA "Project Report" to the Authority (NEMA HQ or its County Office(s)) accompanied by the prescribed fees of 0.05% of the project cost. (50% of the 0.05 of the project cost paid at the time of submission of the EIA "Project Report" and the remainder of 50% paid at the time of collection of license)
- The Authority shall **within seven (7) days** upon receipt of the project report, where the "Project Report" conforms to the requirements of regulation, distribute a copy of the "Project Report" to Relevant Lead Agencies and Relevant District Environment Committee(s) (DEC(s)) for their review and written comments.
- Those comments of Lead Agencies and DECs shall be submitted to the Authority **within twenty one (21) days** from the date of receipt of the "Project Report" from the Authority, or such other period as the Authority may prescribe.
- On receipt of the comments or where no comments have been received **by the end of the period of thirty (30) days** from the date of receipt of the "Project Report", the Authority shall proceed to determine the project report.
- On determination of the "Project Report", the decision of the Authority, together with the reasons thereof, shall be communicated to the proponent **within forty-five (45) days**[5] of the submission of the "Project Report".
- Where the Authority is satisfied that the project will have no significant impact on the environment, or that the project report discloses sufficient mitigation measures, the Authority may issue a license
- If the Authority finds that the project will have a significant impact on the environment, and the project report discloses no sufficient mitigation measures, the Authority shall require that the proponent undertake an EIA study.
- A proponent, who is dissatisfied with the Authority's decision that an environmental impact assessment study is required, may **within fourteen (14) days** of the Authority's decision appeal against the decision to the Tribunal.

5 According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period



Note: *According to NEMA, "days" in the procedures stands for "Working days"
**According to NEMA, not "within forty-five days" but "Minimum forty-five days" for the EIA Project Report Review and Licensing period
*** 50% of the 0.05 of the project cost paid at the time of submission of the EIA Project Report and the remainder of 50% paid at the time of collection of license

Source: Prepared by the JET referring to the EIA/EA Regulations (Amendment) 2009 and based on discussions with NEMA headquarters

Figure 5.2.2 EIA Project Report Review Process and Duration

(3) EIA "Study Report"

According to EMCA 1999, EIA/EA Regulation (Amendment) 2009 and discussions with NEMA officials as well as considering the decentralization of NEMA's functions at the County level, the EIA "Study Report" Process can be summarized as follows and depicted in Figure 5.2.3.

- An EIA study shall be conducted in accordance with a TOR (Terms of Reference) to be developed during the "Scoping" exercise, Then the TOR shall be submitted to be approved **within seven (7) days** by the Authority, Every EIA study shall be carried out by an EIA/EA Lead Expert

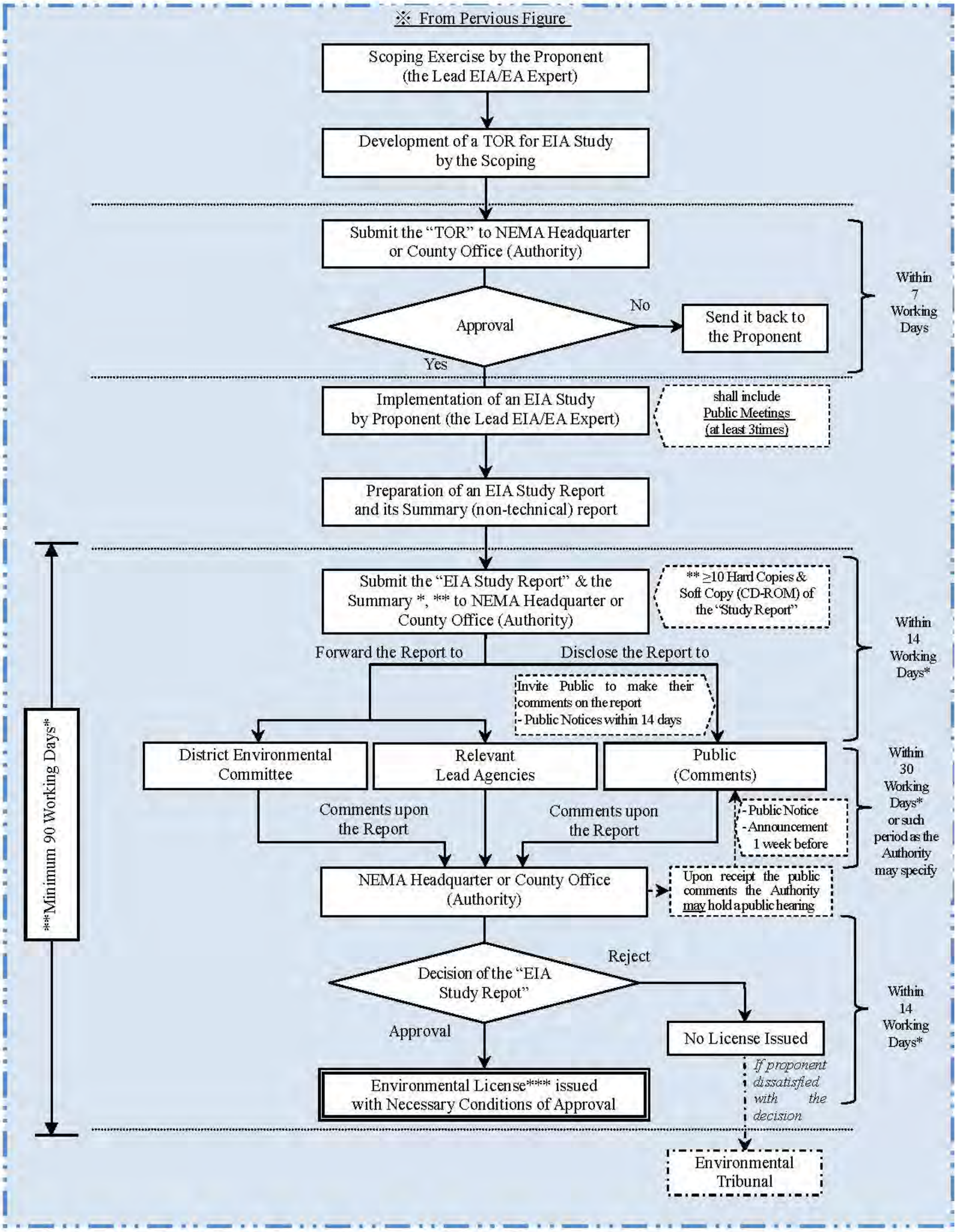
- During the process of conducting an EIA study, the proponent shall in consultation with the Authority, seek the views of persons who may be affected by the project.
- Namely, holding at least three public meetings with the affected parties and communities to explain the project and its effects, and to receive their oral or written comment
- A proponent shall submit to the Authority, an environmental contents of EIA "Study Report" incorporating but not limited to the following information:

Table 5.2.3 Contents of the Study Report

· Proposed location of the project, · Concise description of the national environmental legislative and regulatory framework, baseline information, · Any other relevant information related to the project, the objectives of the project, · Technology, procedures and processes to be used, in the implementation of the project, · Materials to be used in the construction and implementation of the project, · Products, by-products and waste generated project, · Description of the potentially affected environment, · Environmental effects of the project including the social and cultural effects and the direct, indirect, cumulative, irreversible, short term and long-term effects anticipated, · Alternative technologies and processes available and reasons for preferring the chosen technology and processes, · Analysis of alternatives including project site, design and technologies and reasons for preferring the proposed site, design and technologies,	· Environmental management plan proposing the measures for eliminating, minimizing or mitigating adverse impacts on the environment, including the cost, time frame and responsibility to implement the measures, · Provision of an action plan for the prevention and management of foreseeable accidents and hazardous activities in the cause of carrying out activities or major industrial and other development projects, · Measures to prevent health hazards and to ensure security in the working environment for the employees and for the management of emergencies, · Identification of gaps in knowledge and uncertainties which were encountered in compiling the information, · Economic and social analysis of the project, · Indication of whether the environment of any other state is likely to be affected and the available alternatives and mitigating measures, and · Such other matters as the Authority may require.

Prepared by JET

- EIA "Study Report" shall be accompanied by a non-technical summary outlining the key findings, conclusions and recommendations of the study, Proponent shall submit ten copies and a soft copy (CD-ROM) of an EIA "Study Report" to the Authority
- The Authority shall **within fourteen (14) days** of the receipt of the EIA "Study Report" submit a copy of the report to any Relevant Lead agencies as well as District Environmental Committee(s) (DEC(s)) for their comments.
- Upon receiving the EIA "Study Report", the lead agencies and DEC(s) shall review the report and shall thereafter send their comments on the "Study Report" to the Authority **within thirty (30) days** or such extended period as the Authority may specify.
- The Authority shall **within fourteen (14) days** of receiving the EIA "Study Report", invite the public to make oral or written comments on the report, at the expense of the proponent.
- Upon receipt of these comments, the Authority may hold a public hearing
- The Authority shall give its decision on EIA "Study Report" **within three (3) months** of receiving an EIA "Study Report"
- Where the Authority approves an EIA "Study Report" , it shall issue an EIA license on terms and conditions as it may deem necessary
- A person who is aggrieved by the decision may appeal to the Tribunal against the decision.



*Note: *According to NEMA, "days" in the procedures stands for "Working days"*
***According to NEMA, not "within 90 days" but "Minimum 90 Working days" for the EIA Project Report Review and Licensing period*
*** 50% of the 0.05 of the project cost paid at the time of submission of the EIA Project Report and the remainder of 50% paid at the time of collection of license

Source: Prepared by the JET referring to the EIA/EA Regulations (Amendment) 2009 and based on discussions with NEMA

Figure 5.2.3 EIA Study Report Review Process and Duration

(4) Public Comments and Public Hearing in the EIA Study Report Process

Table 5.2.4 shows differences between "Public Comments" and "Public Hearing" in the course of the EIA Study Report Process. Both public comments and public hearing are means of public consultation.

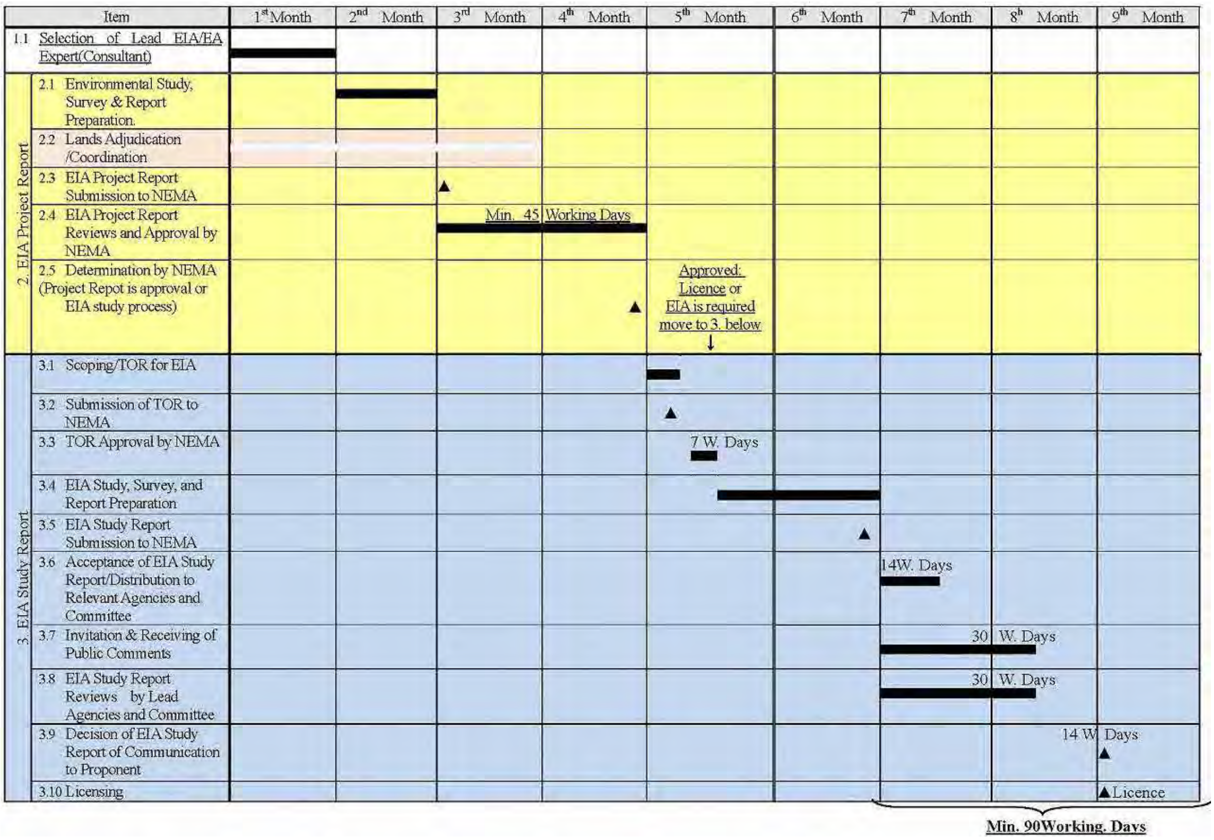
Table 5.2.4 Public Comments and Public Hearing in EIA Study Report Process

Public Comments	Public Hearing
- Invitation is done both at the time of conducting EIA and after submission of Study report.	- Conducted only after submission of the EIA study report at NEMA offices
- Invitation of public comments must be done as follows. - At least three public meetings for comments must be done by the EIA consultant in the course of the study. - One public comments window after submission of EIA study report at NEMA office.	- Public hearing done only once after submission of EIA study report.
- Comments are received both by EIA consultant and NEMA.	- Sessions for public hearing only organized by NEMA and the report of the public hearing only prepared by the presiding NEMA official.
- Invitation for public comments is mandatory as per the regulations.	- Conducting public hearing sessions is at the discretion of NEMA based on the nature of the proposed study and adequacy of the study report.

Prepared by JET

(5) Possible Schedule of EIA Review Process and Licensing for Renewable Energy Projects

In accordance with EIA processes noted above, a possible schedule of EIA reviews and licensing for renewable energy projects can be depicted as a bar-chart shown in Figure 5.2.4.



Prepared by JET

Figure 5.2.4 Possible Schedule for EIA/Environmental Licenses

(6) Revision of EMCA and EIA/EA Regulation in 2014

In light of the new constitution enacted in 2010, the relevant laws and regulations, especially EMCA 1999 and the EIA/EA regulations 2009 are being reviewed (as of January 2014) to conform to the expectations of the new constitution. Therefore, revised EMCA and EIA/EA regulations may apply to relevant projects after 2014. For more details on any revisions, contact NEMA.

5.3 Specific Subject (Solid Waste Management)

Solid waste management issues shall be addressed in compliance with the following laws and regulations in Kenya.

- Environmental Management and Coordination Act of 1999 (EMCA)
- Environmental Management and Coordination (Waste Management) Regulations 2006
- Guidelines for E-Waste Management in Kenya 2010
- Others (if any)

5.3.1 Construction Stage

All trash and packaging materials which might result from the construction process will be collected by the contractor(s) for adequate disposal, which shall be one of the prerequisites for the contract(s) for the contractor(s) to be employed. In this regard, the solid waste management during construction stage can be secured as follow.

- REA is required to instruct contractor(s) to ensure such solid waste management.

5.3.2 Operation Stage

Replacement of used batteries, fluorescent tubes and other electrical appliances shall be managed by each project facility. REA is required to have discussions with each facility, and/or initiate stakeholder meetings in each site to discuss and find solutions for management of such solid waste as follows.

(1) E-waste

The issues of “e-waste management” are prominent. Especially e-waste components like used batteries, used fluorescent lamps and other used electrical appliances including solar PV panels, inverters, etc. are the core issues as summarized in Table 5.3.1.

Table 5.3.1 E-waste Components in Renewable Energy Projects

E-waste	Hazardous Element
Used Lead-acid batteries	Lead and Sulfuric Acid
Used Fluorescent tubes	Mercury
Used PV panels, Inverters and other appliances	Other heavy metals

Prepared by JET

(2) Hazardous and Non-Hazardous Elements

Hazardous elements and Non-Hazardous Elements in Table 5.3.1 are regulated by EMCA, especially by the Guidelines for E-Waste Management in Kenya (See Table 5.3.2 and Table 5.3.3).

Table 5.3.2 Hazardous Elements in Electrical and Electronic Equipment

Element	For example found in electrical and electronic equipment such as:
Americium	Smoke alarms (radioactive source).
Mercury	Fluorescent tubes (numerous applications); tilt switches (pinball games, mechanical doorbells, thermostats)
Sulfur	Lead-acid batteries
PCBs	Prior to ban, almost all 1930s-1970s equipment, including capacitors, transformers, wiring insulation, paints, inks and flexible sealants used PCBs.
Cadmium	Light-sensitive resistors, corrosion-resistant alloys for marine and aviation environments and nickel-cadmium batteries.
Lead	Old solder, CRT monitor glass, lead-acid batteries and formulations of PVC.
Beryllium oxide	Filler in some thermal interface materials such as thermal grease used on heat sinks of CPUs and power transistors, magnetrons, X-ray-transparent ceramic windows, heat transfer fins in vacuum tubes, and gas lasers.
Polyvinyl chloride	PVC contains additional chemicals to change the chemical consistency of the product. Some of these additives can leach out of vinyl products e.g. plasticizers that are added to make PVC flexible.

Source: Guidelines for E-Waste Management in Kenya, December 2010, National Environmental Management Authority

Table 5.3.3 Non Hazardous Elements in Electrical and Electronic Equipment

Element	For example found in electrical and electronic equipment such as:
Tin	Solder, coatings on component leads.
Copper	Copper wire, printed circuit board tracks, component leads.
Aluminum	Nearly all electronic goods using more than a few watts of power, including electrolytic capacitors.
Iron	Steel chassis, cases, and fixings.
Germanium	1950s-1960s transistorized electronics (bipolar junction transistors).
Silicon	Glass, transistor, ICs, printed circuit boards.
Nickel	Nickel-cadmium batteries.
Lithium	Lithium-ion batteries.
Zinc	Plating for steel parts.
Gold	Connector plating, primarily in computer equipment.

Source: Guidelines for E-Waste Management in Kenya, December 2010, National Environmental Management Authority

Possibility of “hazard to health and environment” caused by the hazardous elements shown in Table 5.3.2, which is one of the reasons for the necessity of e-waste management.

(3) Handling Procedure of E-waste

Not like domestic waste which is generated daily, e-waste is generated after life span of each component of the project facilities has finished.

Namely, the life span of batteries and fluorescent lamps are up to about two years and that of electrical appliances including solar PV panels, inverters, etc. are up to 10-25 years. Their disposals shall be handled as summarized in Table 5.3.4.

Table 5.3.4 Handling Procedure of E-waste

Component	Possible Life Span* (years)	Handling	Remarks
Battery	3 to 8	- In order to prevent diffusion of toxic substances in batteries, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly disposed. - Used batteries can be sold to licensed e-waste handlers and/or battery producing companies in Kenya.	- Licensed e-waste handlers (See Table 6.3.5) or contact each NEMA county office to get updated information on such handlers. - Battery Producing Companies (See Figure 6.3.1 or contact each NEMA county office). - Purchase Prices are subject to the market trends.
Fluorescent Lamp	2 to 4	- In order to prevent diffusion of mercury in fluorescent lamps, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly disposed. - Used Fluorescent Lamps shall be transported to licensed e-waste handlers in Kenya to be disposed.	- Licensed e-waste handlers (See Table 6.3.5) or contact each NEMA county office to get updated information on such handlers.
LED Lamp	5	- Used LED Lamps shall be transported to registered e-waste handlers in Kenya to be disposed.	
Solar PV Panel	20 to 25	- Used solar PV panels shall be transported to registered e-waste handlers in Kenya to be disposed.	
Inverter	5 to 10	- Used Inverters shall be transported to licensed e-waste handlers in Kenya to be disposed.	

* Note: Vary depending on the intended use as well as status of use

Prepared by JET

Taken by JET

A battery manufacturer already has a program to buy used batteries at KSh. 40 per kilogram.

Figure 5.3.1 Used Battery Purchasing by a Battery Manufacturer

Table 5.3.5 Licensed E-waste Handlers in Kenya (As of August 2013)

Handler	Contact	District	Waste Type
East Africa Computer Recyclers Ltd.	P.O. Box 49266-00100, Nairobi Email: eastafricancomputer@yahoo.com 07215036515, 0729308221	Mombasa	Electronic Recycling
Waste Electrical and Electronic Equipment Center	P.O. Box 48584-00100, Nairobi Email: infor@weecenter.com 0733-986-558, 202060921	Nairobi	Electronic Recycling

Source: NEMA (tabulated by JET)

(4) E-waste Management Structure

Used batteries, fluorescent tubes and other used electrical apparatuses/devices can be handled by organizing an e-waste management sub-committee under the Pilot Project management structure to be set up by each community and/or facility as follows:

i) The structure (sub-committee) to be organized for the e-waste management shall be discussed among stakeholders on the initiative of REA

ii) Each community is to be enlightened that even the electrical apparatuses/devices such as PV panels and inverters which have a longer lifespan eventually need replacement

iii) Each community is to be enlightened that those hazardous elements shown in Table 5.3.2 are hazardous to health and environment, and some hazardous substances like "lead" in batteries and some non-hazardous elements shown in Table 5.3.3 can be recycled and reused.

(5) E-waste Disposal System

Practically, the aforementioned e-wastes shall be transported to the licensed E-waste Handlers and/or battery manufacturers, in the following approach:

i) Request suppliers to take away used ones from each facility when carrying out replacements (this shall be set as a condition for carrying out replacements).

ii) Public property of the project, earnings from the sale of used e-waste including batteries shall be remitted using the "m-pesa" system by suppliers receiving earnings from the licensed E-waste Handlers and/or battery manufacturers.

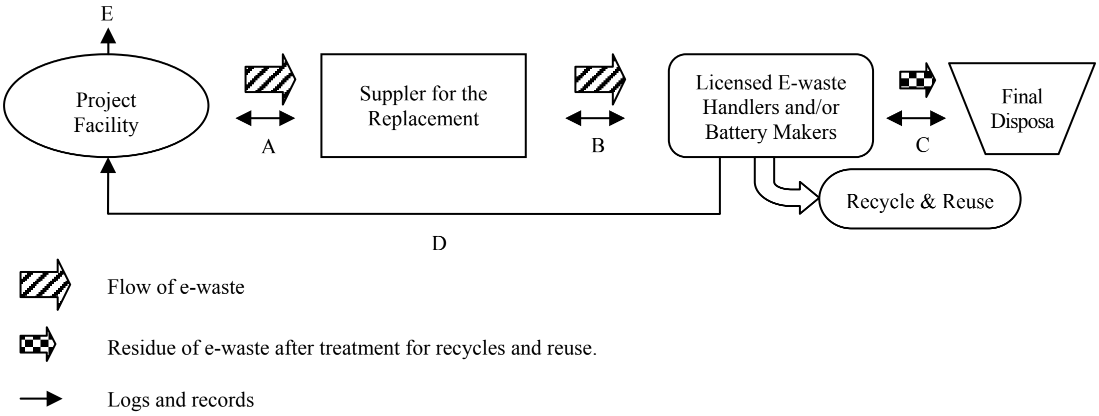
iii) The earnings shall be kept in each facility as revenue.

iv) In order to ensure proper transportation and treatment, an e-waste manifest system shall be introduced in the e-waste disposal system as shown in Figure 5.3.2 and Table 5.3.6.

* Manifest system: A system to keep all logs from e-waste discharge stage to transportation as well as final treatment in order to prevent illegal dispose of e-waste during the transportation as well as to make sure appropriate final treatment of such waste.

** The following web site of USEPA on Hazardous Waste Manifest System can be referred as reference.

http://www.epa.gov/waste/hazard/transportation/manifest/index.htm



A	Keep two logs on e-waste between Generator (facility) and Suppler which will transport e-waste to the (2 logs: one is for the generator and one is for the suppler)
B	Keep two logs on the e-waste between the Suppler and Licensed e-waste handler and/or Battery Maker for the treatment of the e-waste (2 logs: one is for the suppler and one is for the Licensed E-waste Handlers and/or Battery Makers)
C	Keep two logs on the reside of the e-waste between the Licensed e-waste handler and/or Battery Maker and a final disposal site (2 logs: one is for the Licensed e-waste handler and/or Battery Maker and one is for the final disposal facility like a landfill)
D	Send two copies of the logs of B and C to Generator (project facility) by which each project facility can identify the proper transportation, treatment and final disposal of the e-wastes by mail.
E	After receiving the copies in D, each facility shall report showing one of the copies to REA, as well as regulatory agency such as Ministry of Education (for Primary Schools) or Ministry of Health (for Dispensaries).

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Figure 5.3.2 Conceptual Diagram of E-waste Manifest system

Table 5.3.6 Draft E-waste Manifest Log From

	Date:		No. of Manifest	
1	Facility (Generator)	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	E-waste	name 1:	Quantity	mode of packing
		name 2:	Quantity	mode of packing
		name 3:	Quantity	mode of packing
		name 4:	Quantity	mode of packing
		name 5:	Quantity	mode of packing
2	Suppler (Transportation)	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	Received the above listed e-waste from the Facility on date and Sign			
3	Licensed E-waste Handler and/or Battery Maker	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	Received the above listed e-waste from the Suppler on date and Sign			
	Treated appropriately the e-waste on date and Sign in compliance with the relevant laws and regulations in Kenya, especially the followings ✓ Environmental Management and Coordination Act of 1999 (EMCA) ✓ Environmental Management and Coordination (Waste Management) Regulations 2006 ✓ Guidelines for E-Waste Management in Kenya 2010			
4	Final Disposal	Name	Address/TEL/FAX	
		Person –in Charge:	Contact address/TEL	
	Received the residues of above listed e-waste from the Licensed E-waste Handler and/or Battery Maker on date and Sign			
	Disposed the residues on date and Sign n compliance with the relevant laws and regulations in Kenya, especially the followings ✓ Environmental Management and Coordination Act of 1999 (EMCA) ✓ Environmental Management and Coordination (Waste Management) Regulations 2006 ✓ Guidelines for E-Waste Management in Kenya 2010			

Note: At least eight copies are necessary.

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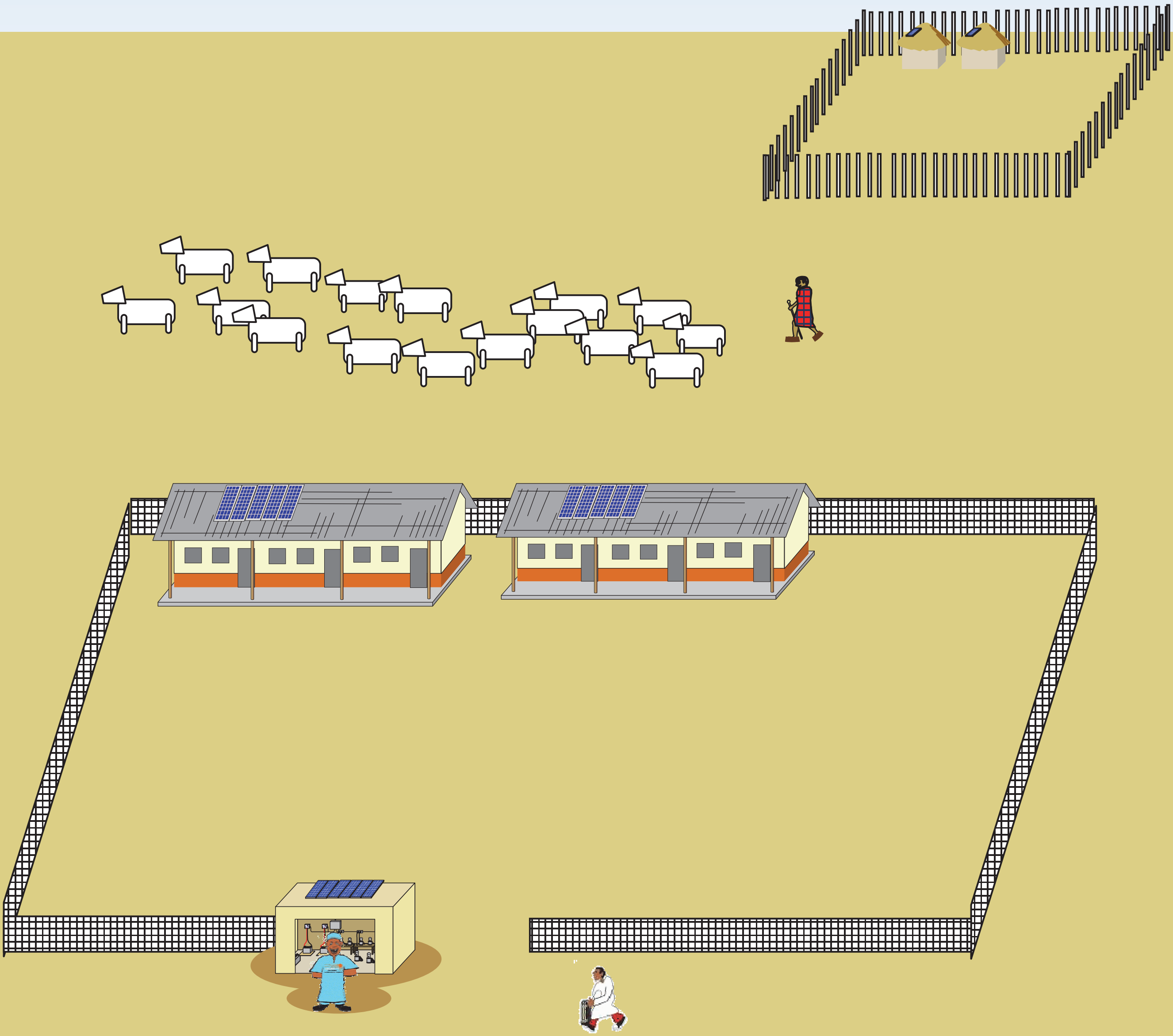
List of Annexes

Annex 1 Solar PV Operation Manual

Attachment F-2

Solar PV Operation Manual



JICA

Rural Electrification Authority

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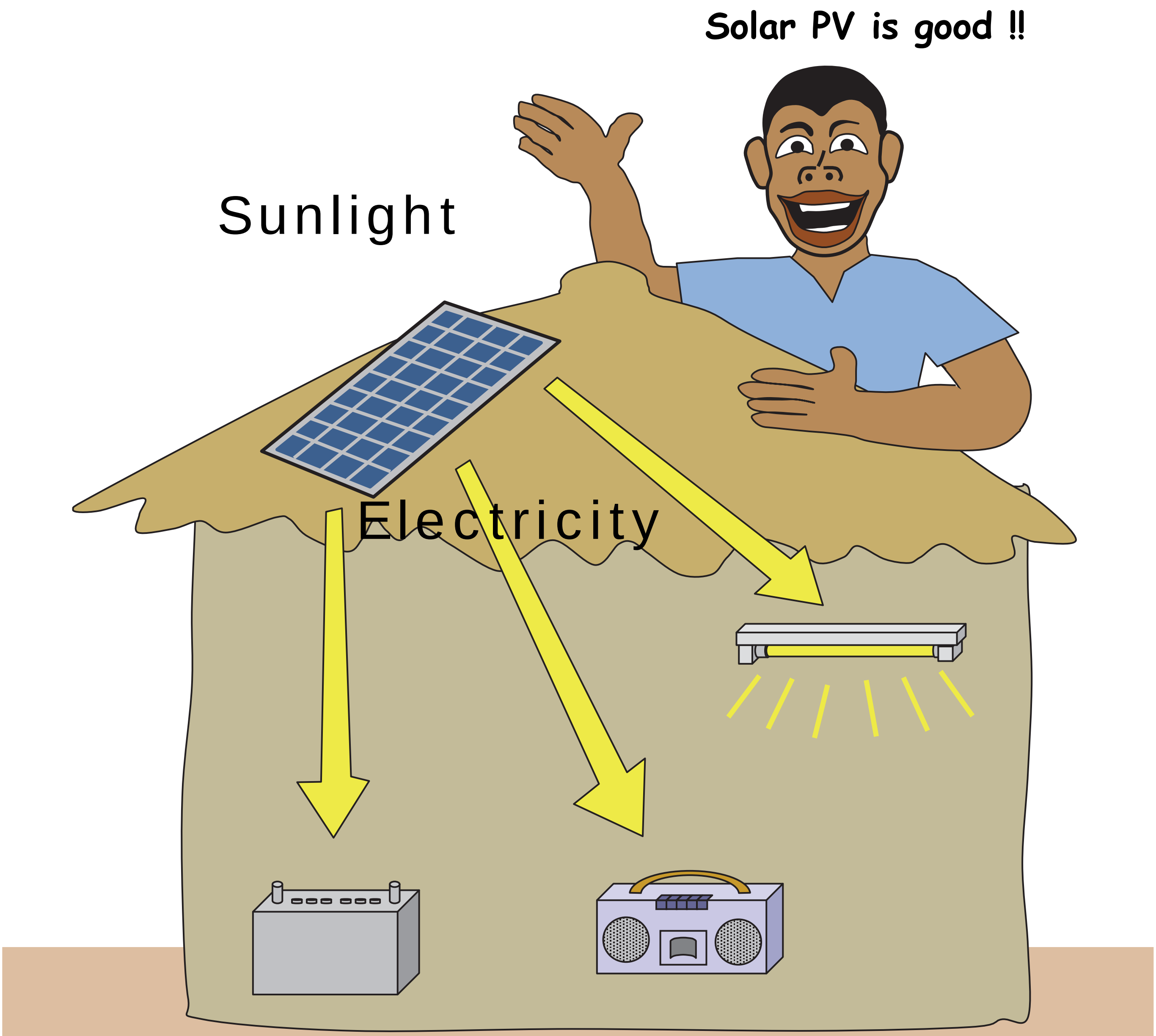
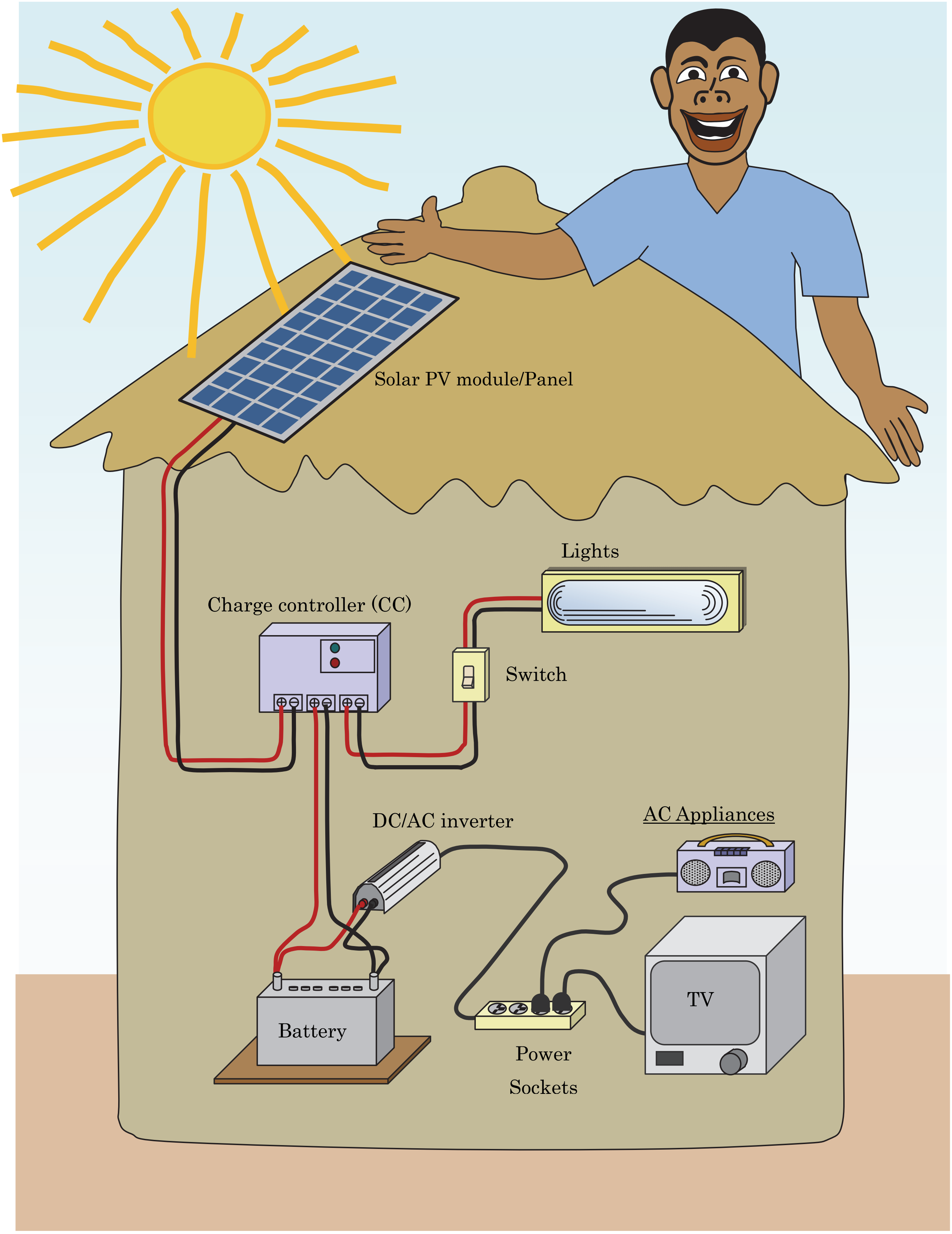
Solar PV Operation Manual

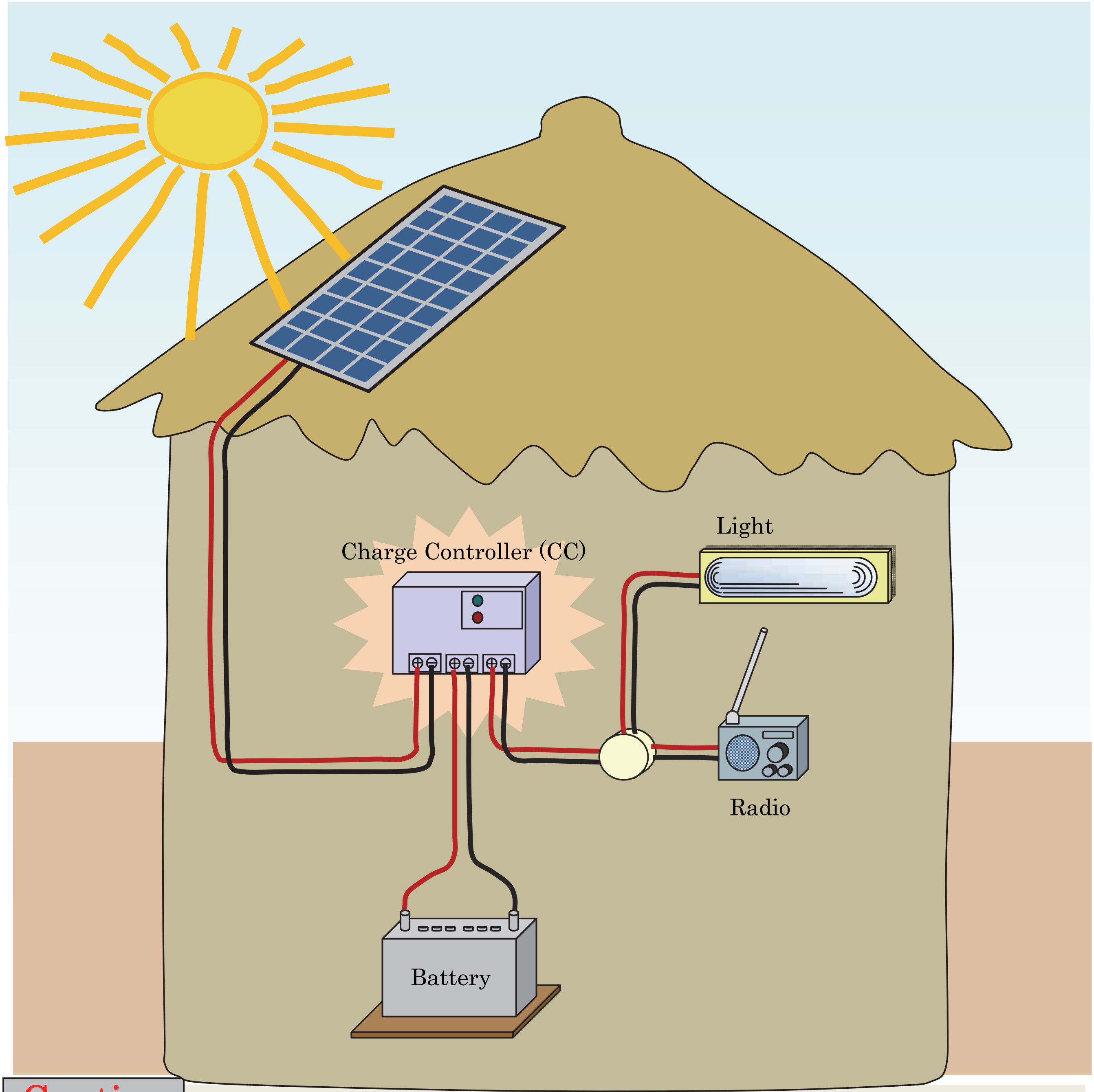


The solar PV is a device which changes light energy to electric energy. Solar PV does not store energy. The light energy (sunlight) acts as a "fuel" for conversion process to produce output (energy).

Basic configuration



DC system

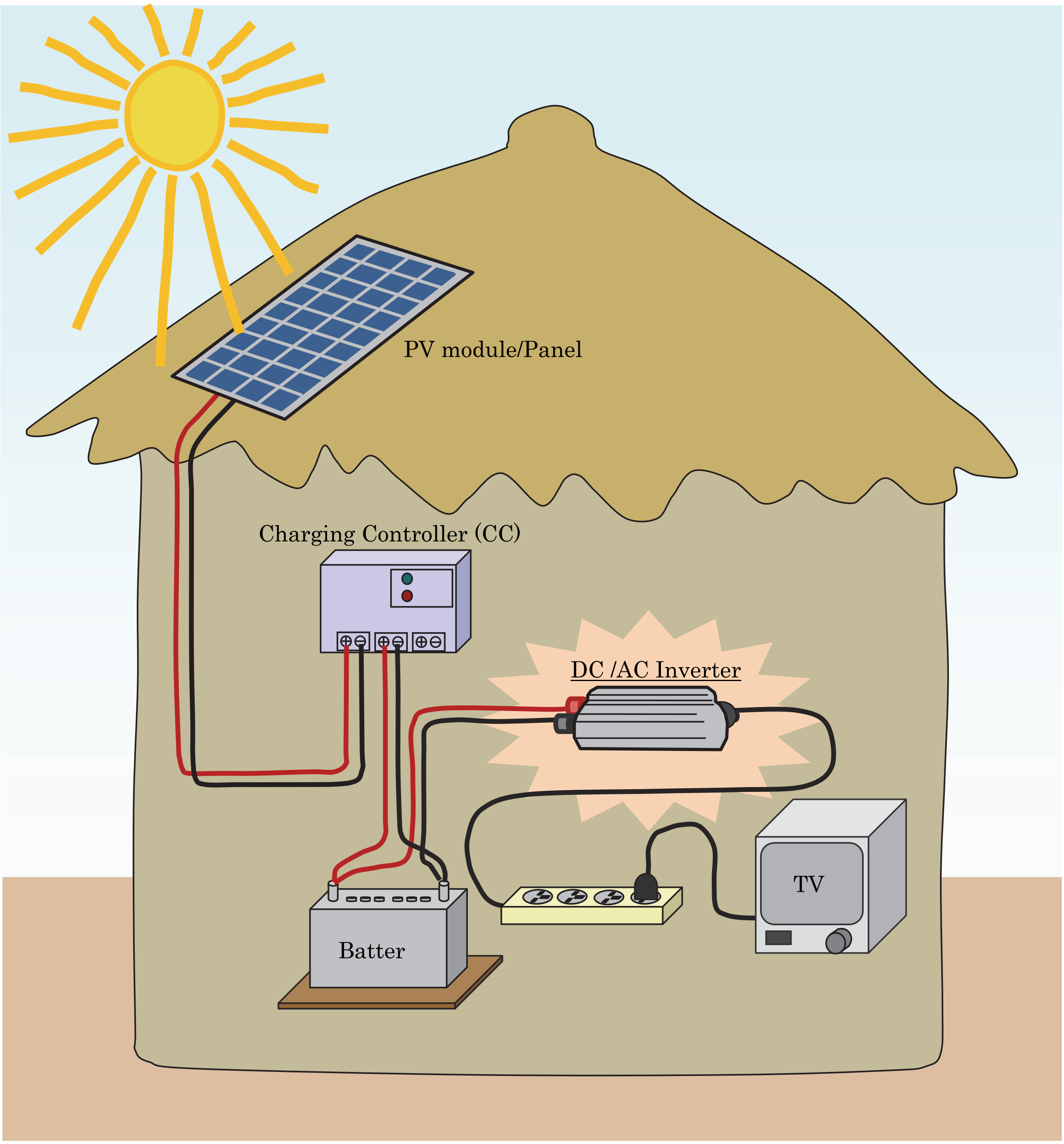


Caution

Direct Current (DC) systems have polarity ("Positive" and "Negative"). The Positive (+ tive) wire is red, while the negative (- tive) wire is black.

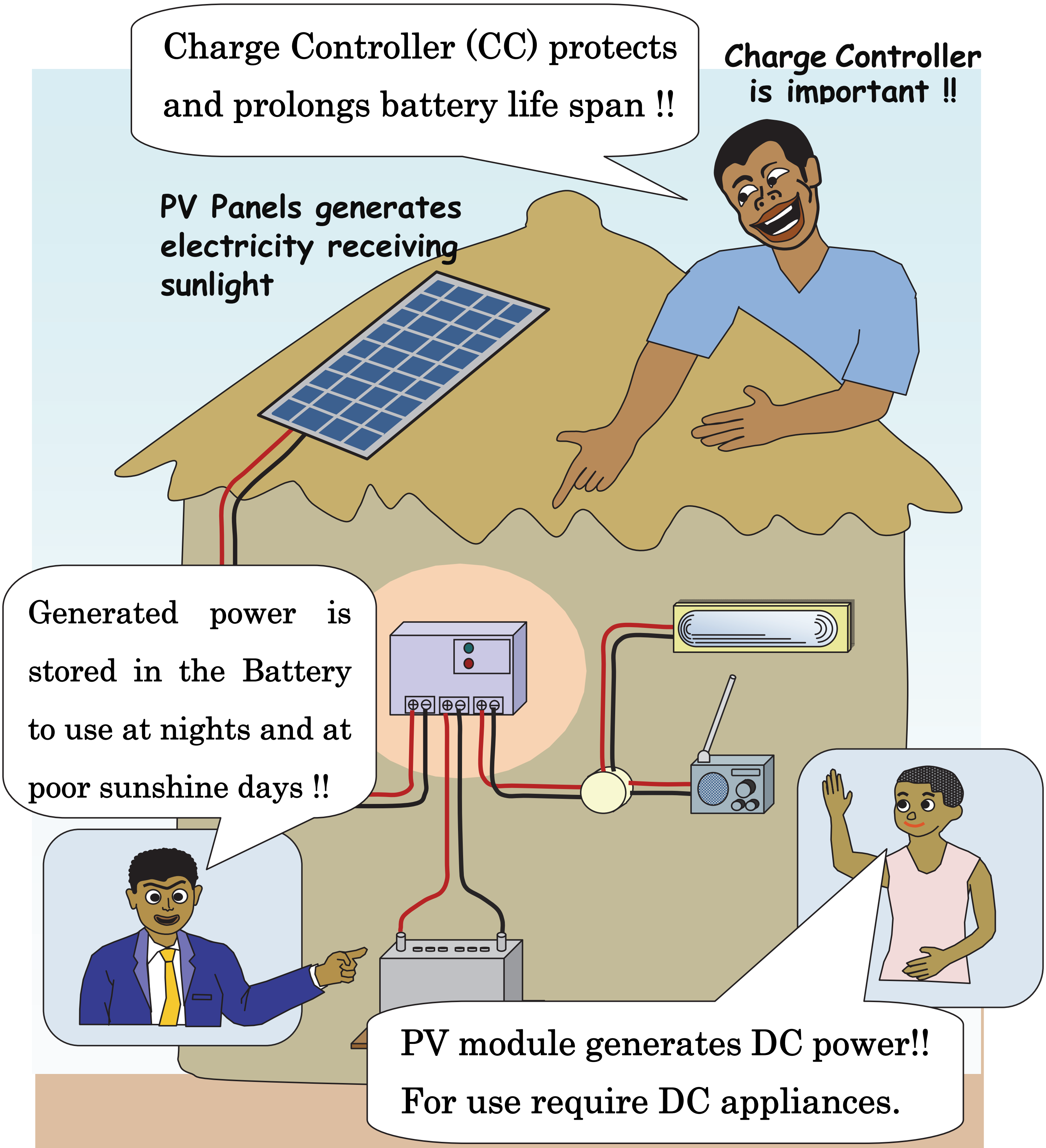
DC systems are similar to the car battery power supply

AC system



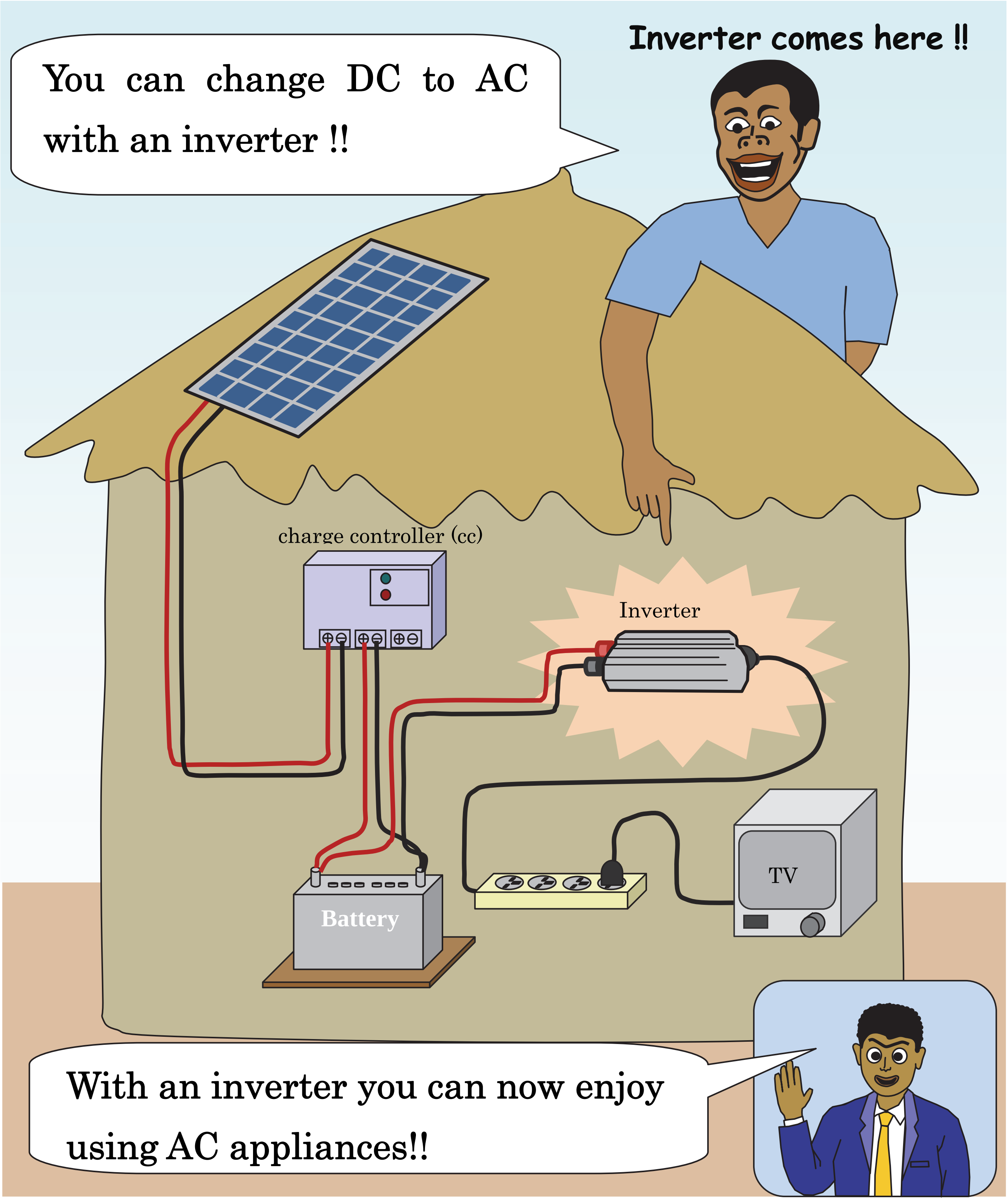
An inverter converts DC power to AC power. This means after the inverter (output), we recive AC power. Therefore, appliances which run on AC are possible to use.

Function of PV components

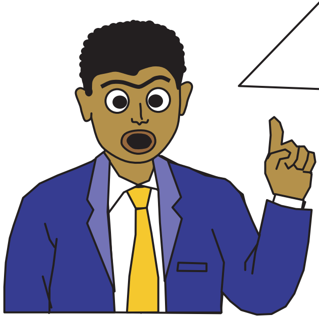


The equipment which runs on DC power does not need Inverter.
DC appliances need to match the DC system voltage to connect with installed PV system.

DC appliances are not so common in practice. But you can use AC appliances if you have an inverter



In a PV system,



The amount of electricity generation in a day depends on

1. Brightness and duration of Sun visibility.
2. Installation capacity of the PV module/panel

If

Brightness and sun visibility are limited!!

Panel capacity is limited!!

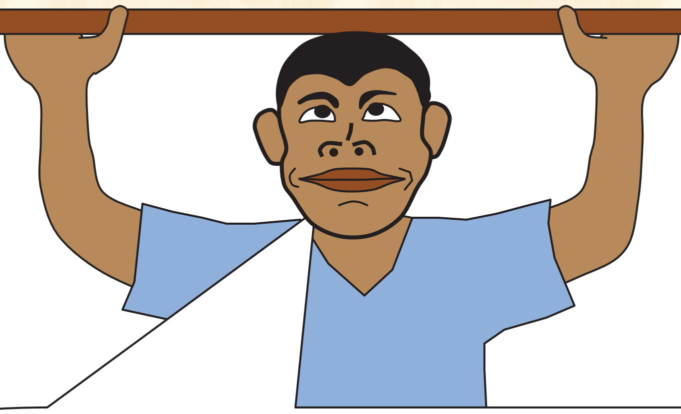
Battery capacity is limited!!

Then,

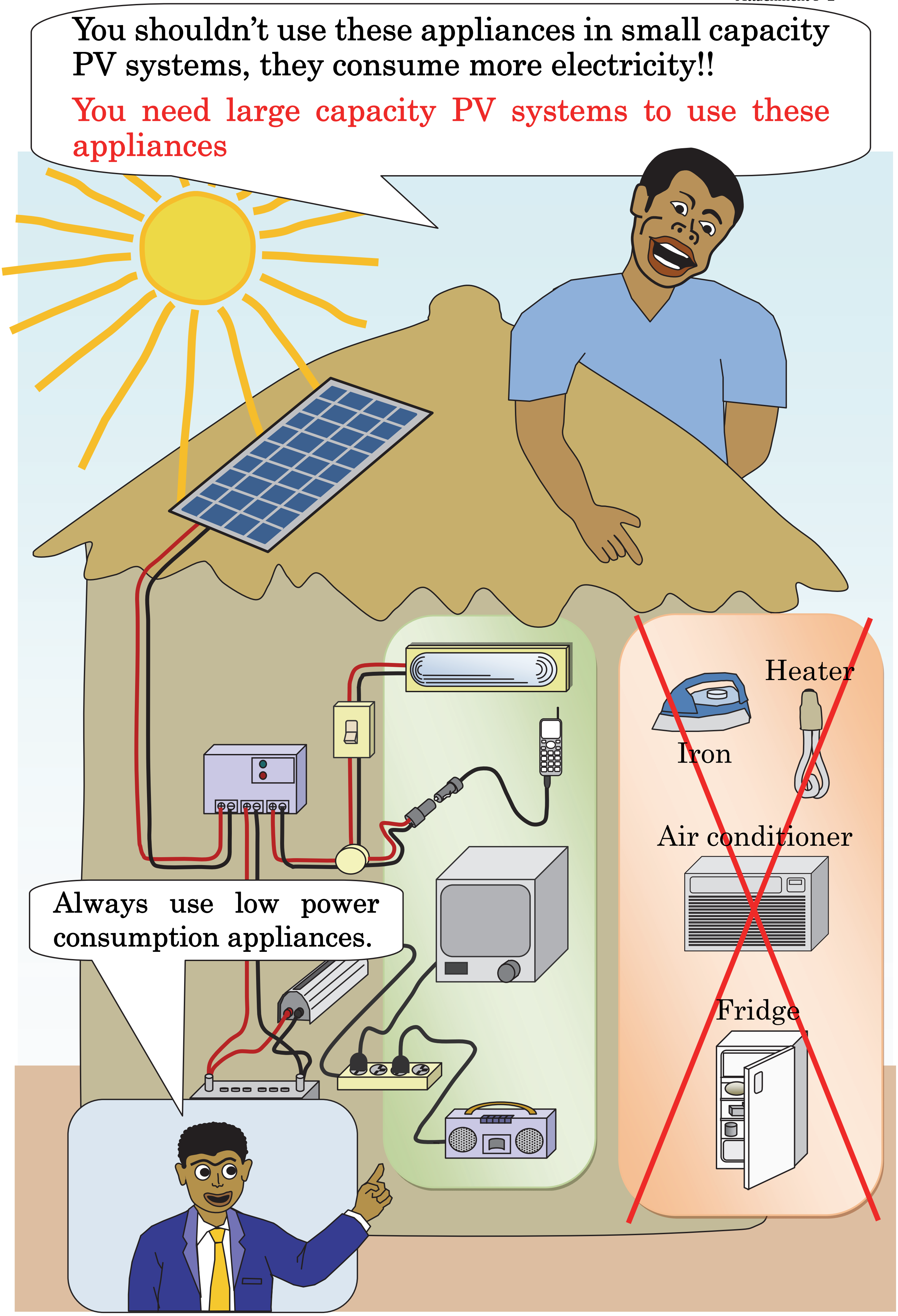
Electricity you can use is limited.

And,

Appliances you can use are limited.



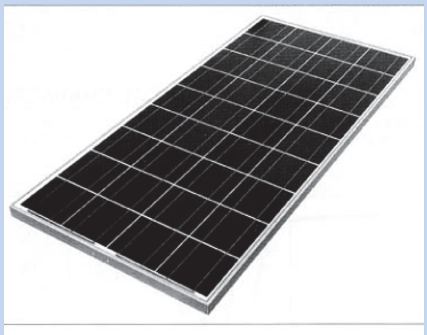
You have to be careful when you choose appliances to use in a PV system!!


You shouldn't use these appliances in small capacity PV systems, they consume more electricity!!
You need large capacity PV systems to use these appliances
Heater
Iron
Air conditioner
Fridge
Always use low power consumption appliances.

Components of PV systems

Panels





Panels generate electricity receiving sunlight.

Output: DC

Capacity: 70W–120W are popular

Lifespan: 20 – 25 years

Batteries

Batteries are use to store electricity for night and on poor sunshine days.

Sealed batteries (no refilling)

Flooded batteries (periodic refilling is necessary)

Capacity: 50 – 200Ah are popular

Lifespan: 3-8 years (depends on use conditions)

Charge Controllers (CC)

Controller protects batteries. They indicate battery condition (“battery full, battery empty, charging).

Capacity: 10-50 A are popular

Lifespan: Around 5-10 years

AC/DC Inverters

Inverters convert DC input to grid electricity (AC). You can use AC appliances with inverters.

Capacity: 300-700 W are popular

Lifespan: Around 5-10 years

Batteries

Battery is important in PV system.

It needs **replacement** in every 3-8 years and it is very expensive. (Life of battery depends on type, intended use and use status).

Savings is necessary for replacement.

In addition, **some batteries** need special care.

There are two types of batteries !!

Flooded type

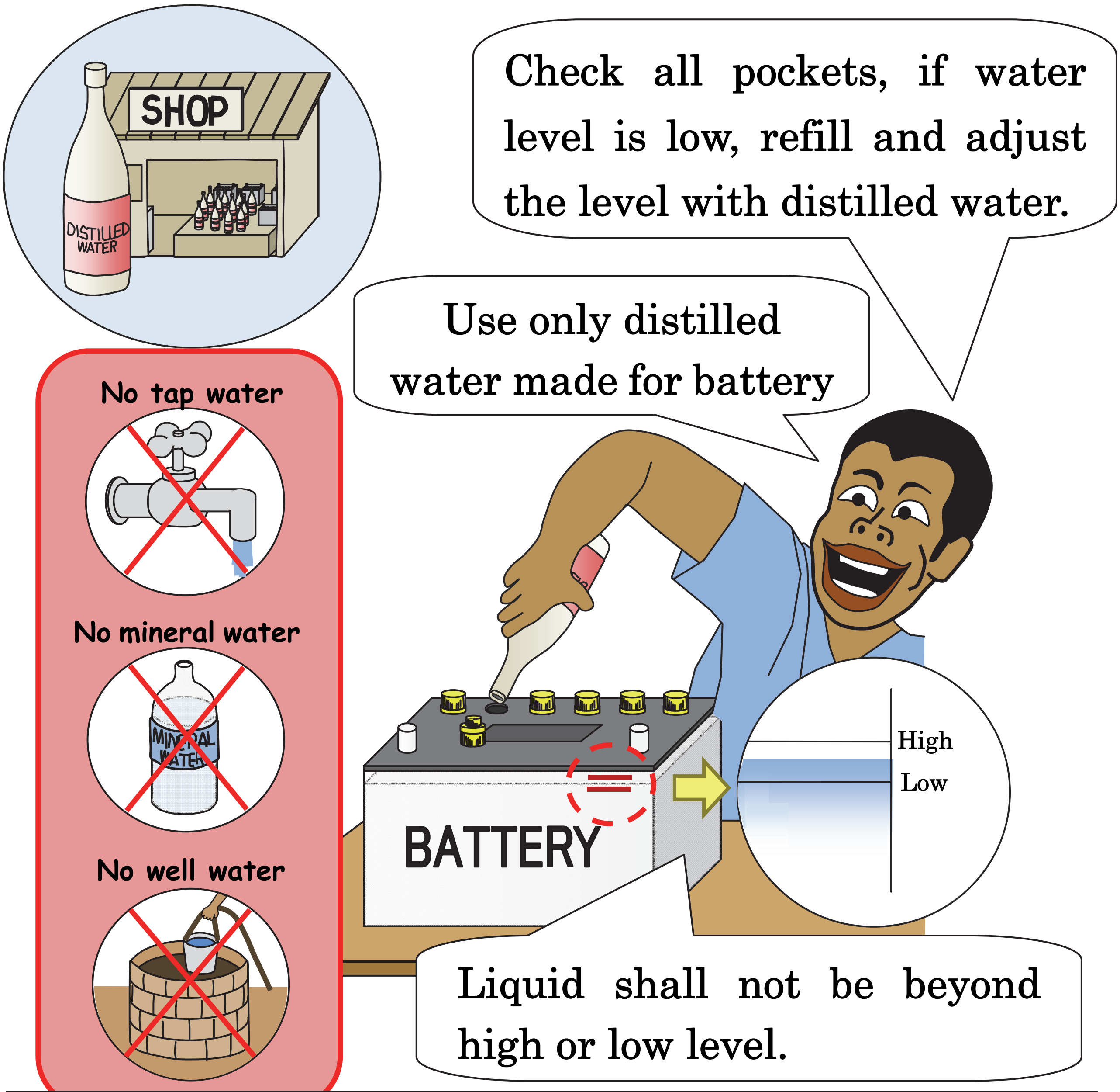
This type needs maintenance, but cheaper comparing to sealed type

Sealed type

This type does not need maintenance but expensive comparing to flooded type

Battery maintenance
(Flooded type battery)

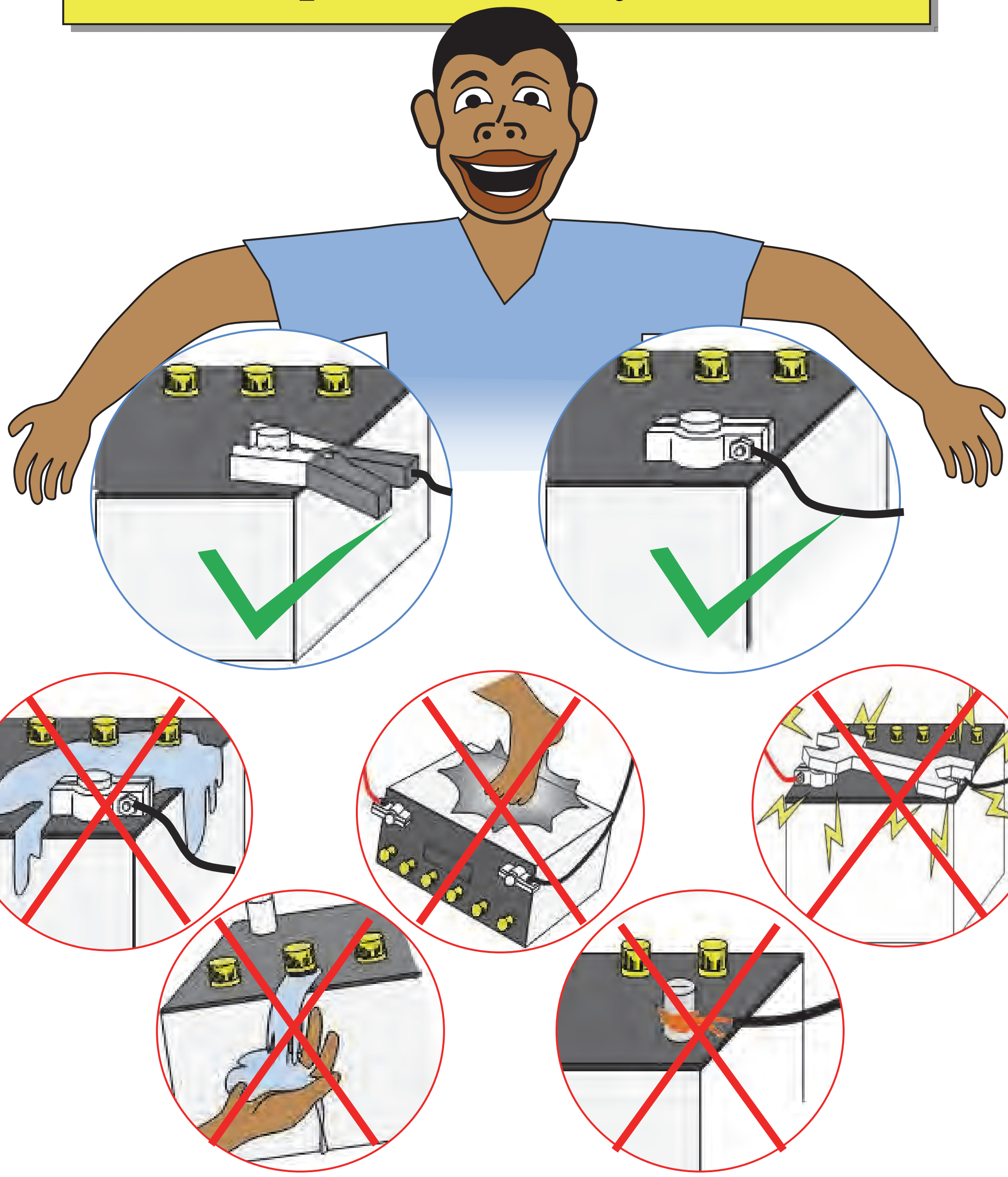
You have to check the water level at least once a month.



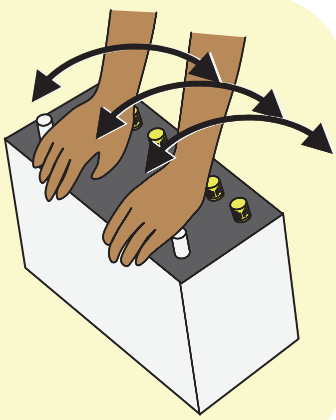
CAUTION

1. Every time you touch battery or battery liquid wash your hands with soap and clean water.
2. Do not touch battery terminals by hand or metallic objects.
3. Do not touch any installed equipment by wet hands, wet clothes or by metallic objects.

Tips on battery use

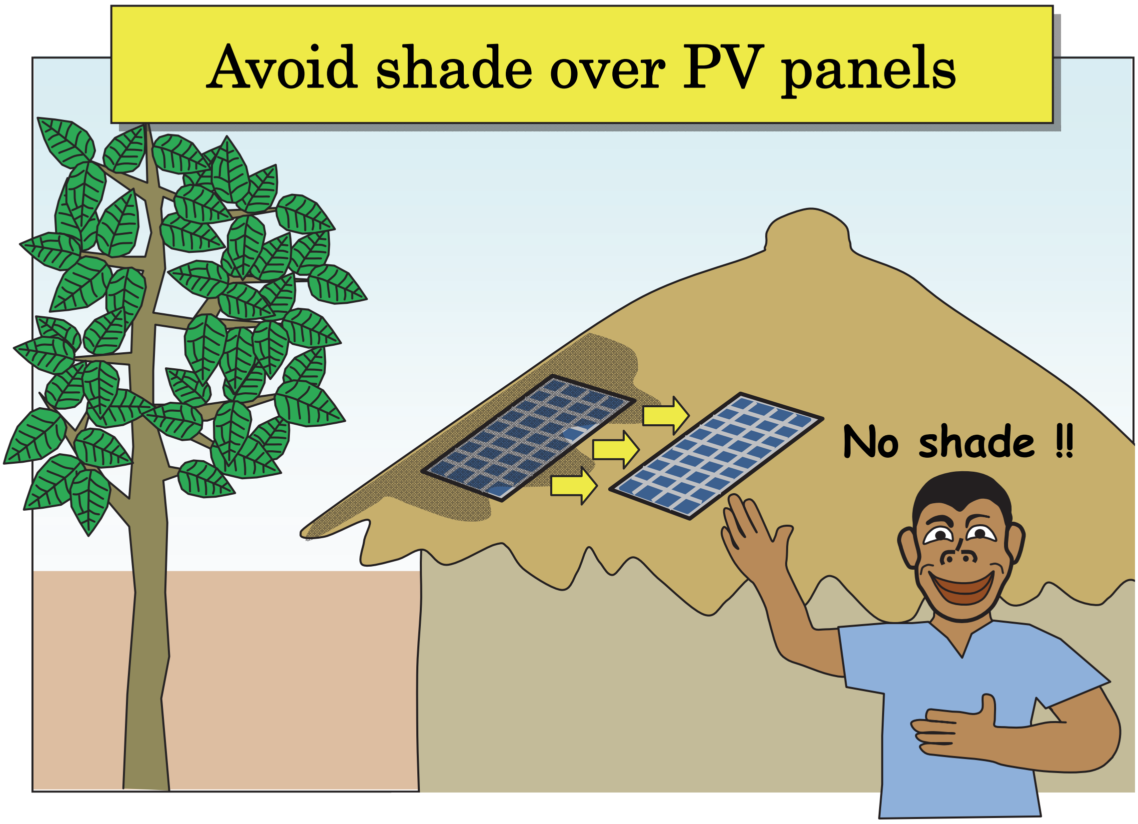


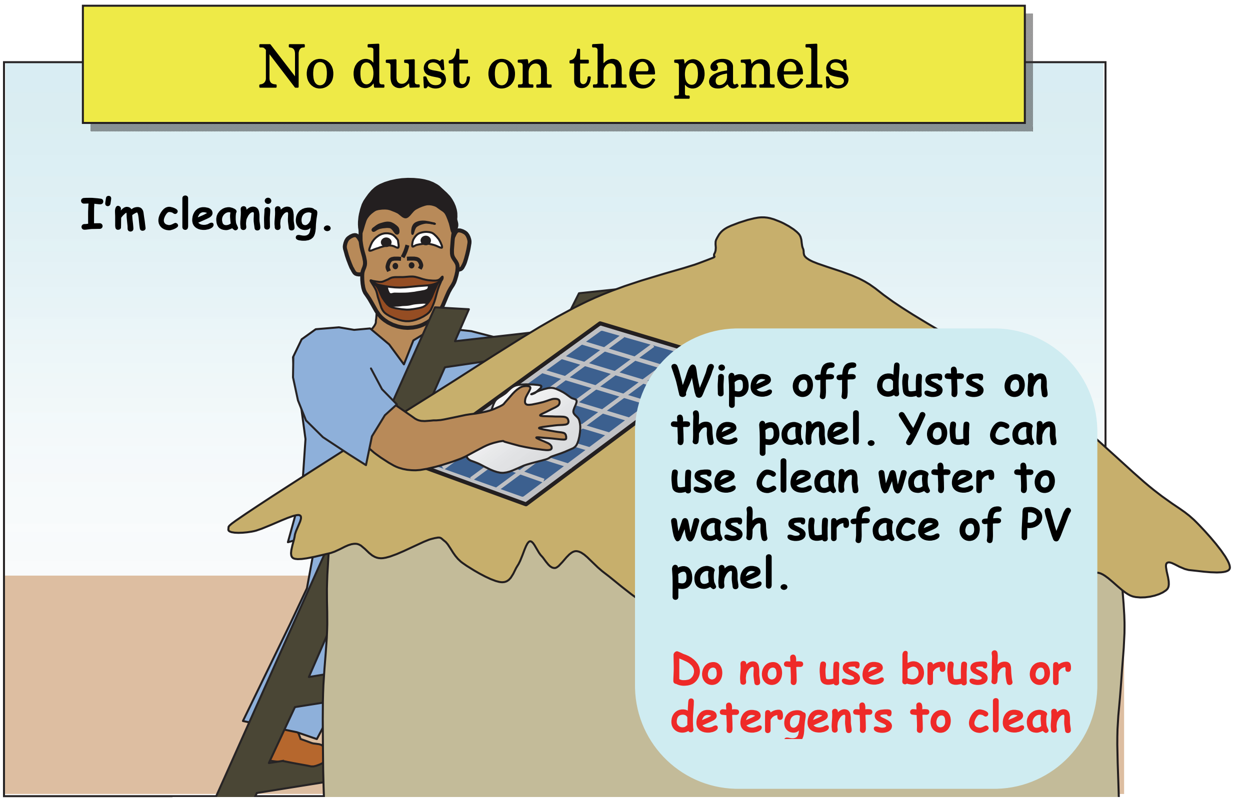
If possible, ...



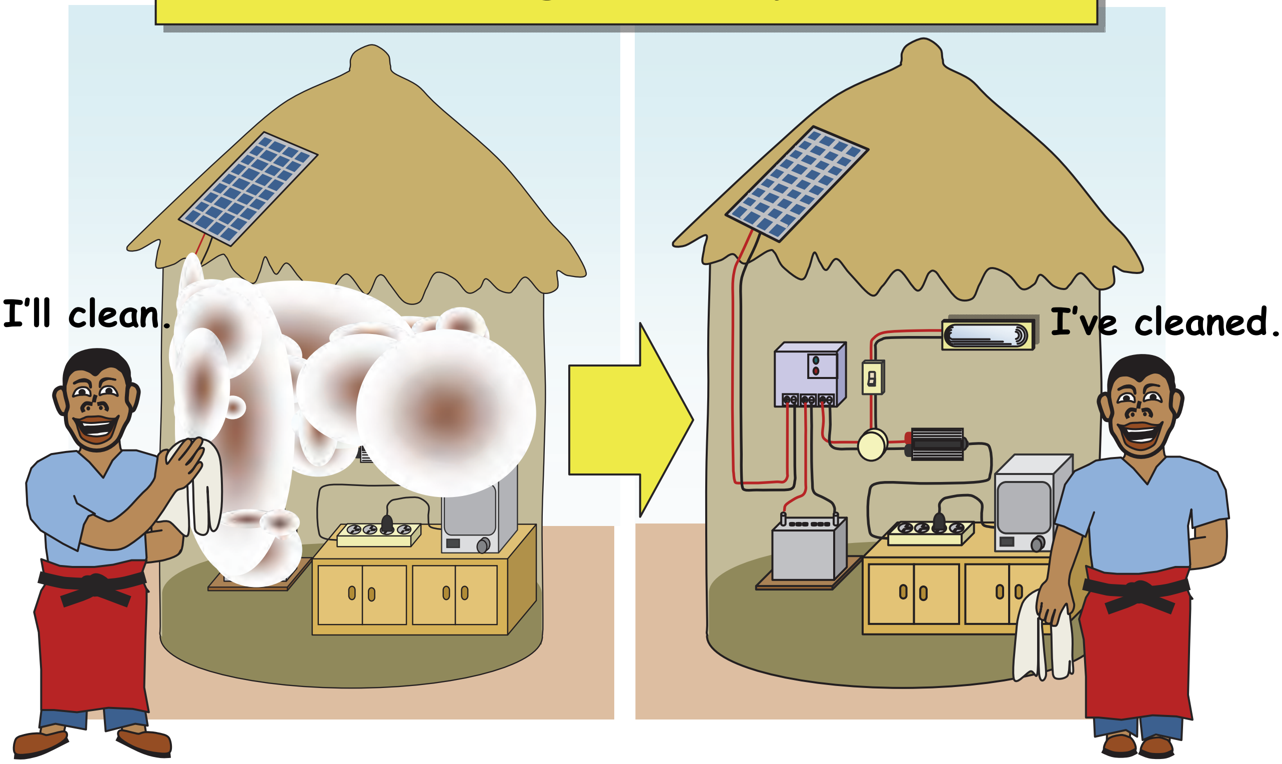
Shaking prolongs battery life span. Around once a month more than 10 times shaking. **But don't force and should not be unreasonable.**

Other maintenance for PV system

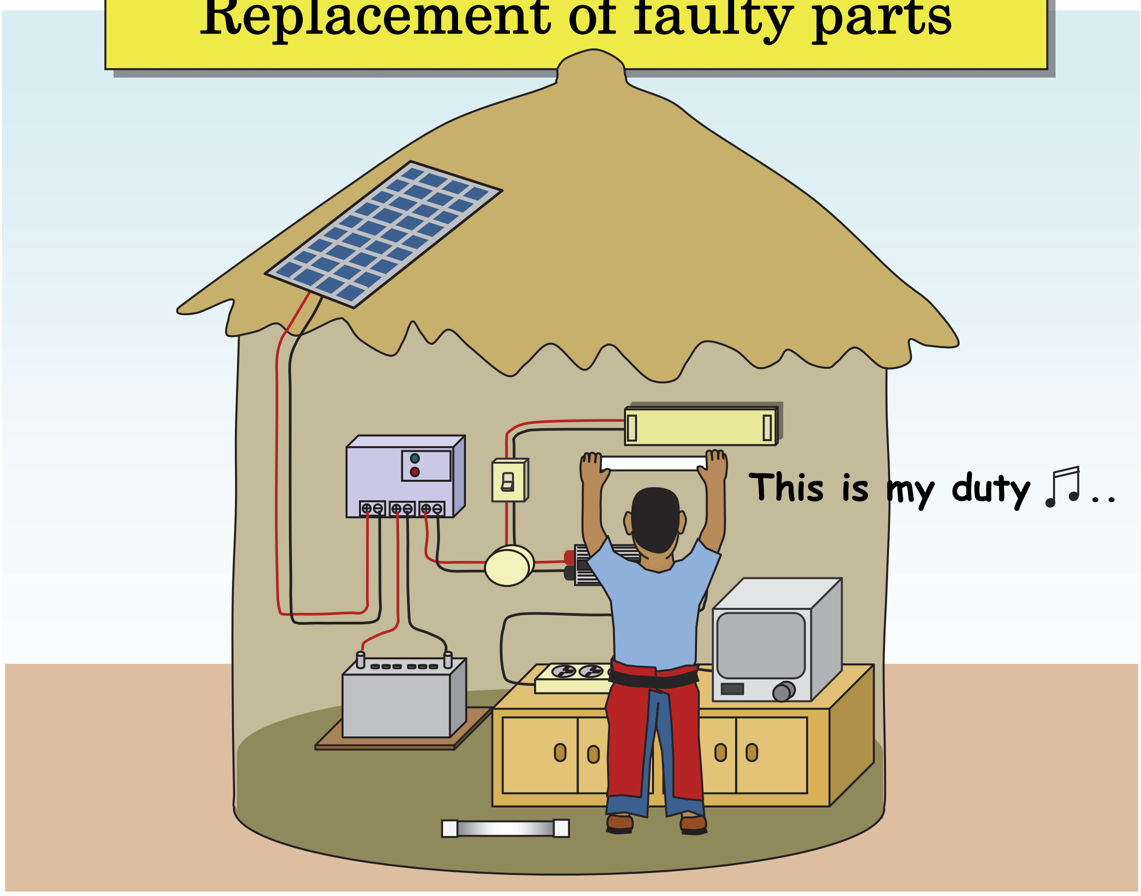




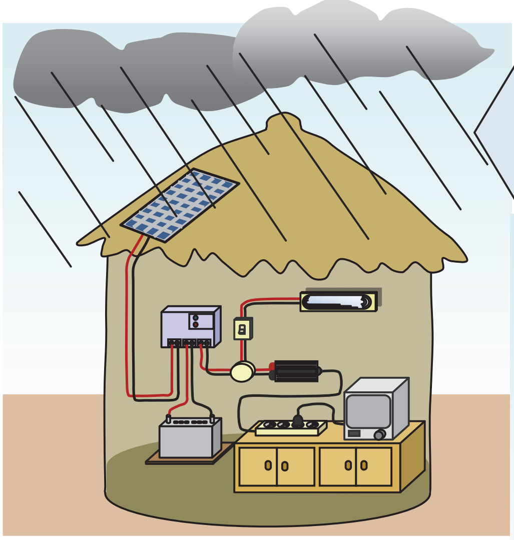
Cleaning of PV system



Replacement of faulty parts

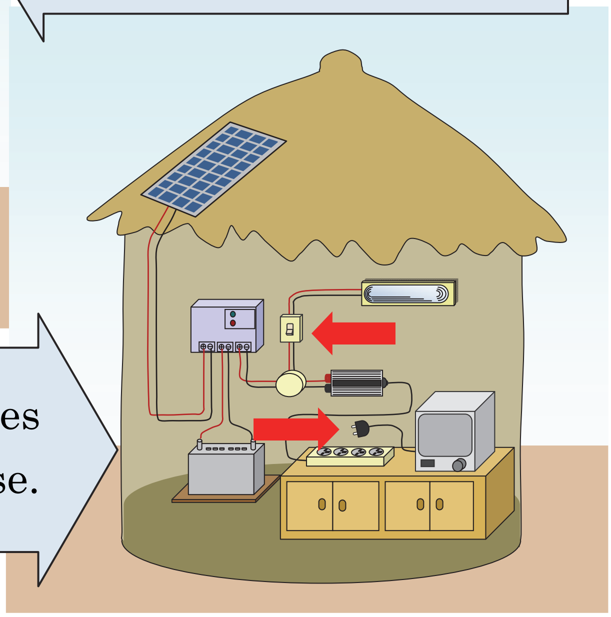


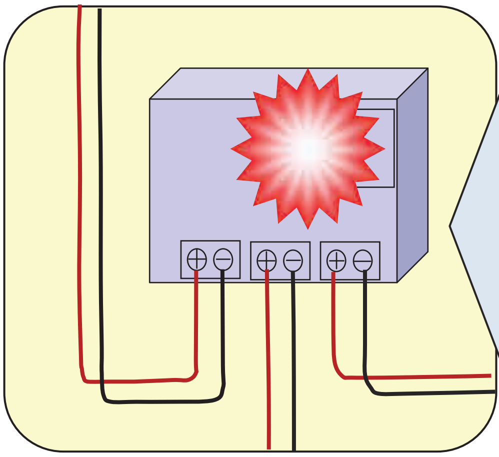
General operation tips



Save energy use on rainy days and cloudy days.

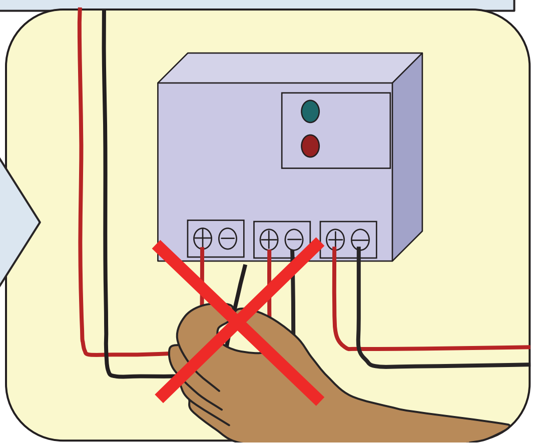
Switch off appliances when they are not in use.





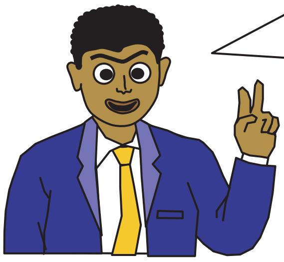
Check the indicator on the controller. If "battery is low", then switch off appliances and manage the supply until Battery indicates charged.

Don't change wiring.



PV systems at public institutions

Electrification of public institution is important. Solar PV is often used for electrifying remote rural public institutions. The government is responsible for the electrification, but maintenance is left to each institution's hand.



Two issues for PV maintenance.

- Saving money. **Financial issue**
- Having proper knowledge. **Technical issue**

With charging business,

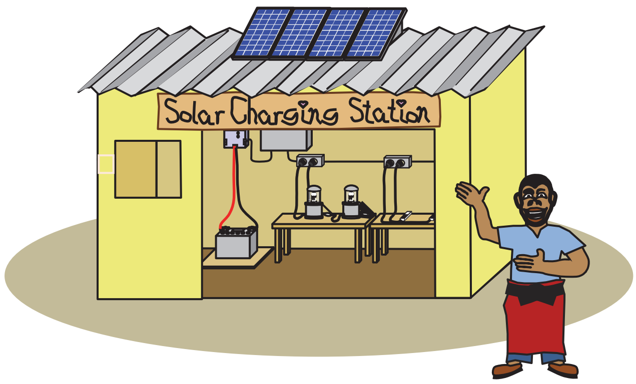
Financial issue

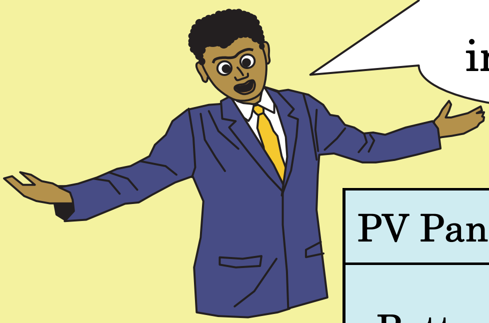
The business can generate money. You can use it for maintenance.

Technical issue

The operator must have proper knowledge on operation and maintenance.

The community people can enjoy rechargeable appliances, in addition.



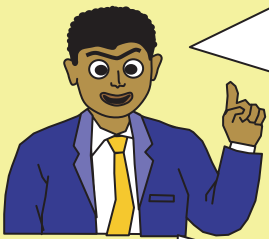


Life of equipment depends on the type and use status. Replacement is an important part of sustainability.

How long they will work?

PV Panel/module		20 - 25 years
Battery	Solar battery	3 - 8 years
	*Car battery	2 - 3 years
Inverter and Controller		5 - 10 years
Lamps	Tube	2 - 4 years
	LED	5 - 10 years

*Generally Car batteries are not recommended for Solar PV systems



Battery should be periodically replaced.
And battery is very expensive.

A lot of money is needed periodically !!

Financial issue

The operator of the charging station should be **trained properly** so that replacement will be possible to carry out properly.

Technical issue

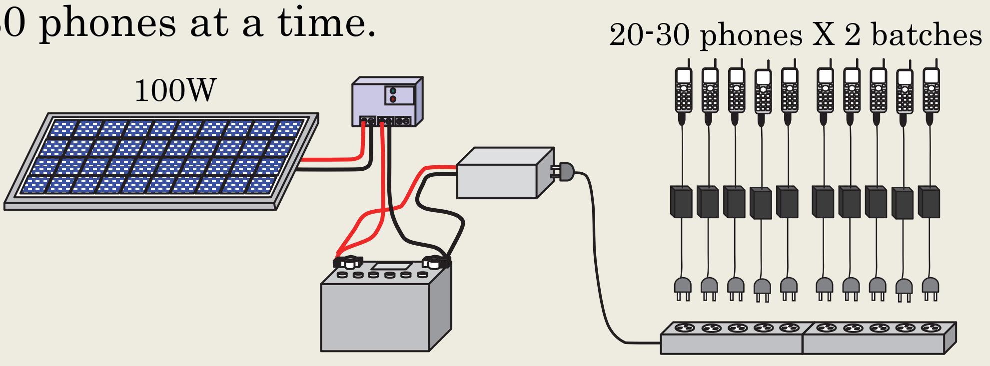
I am trained!!

I can repair the system!!

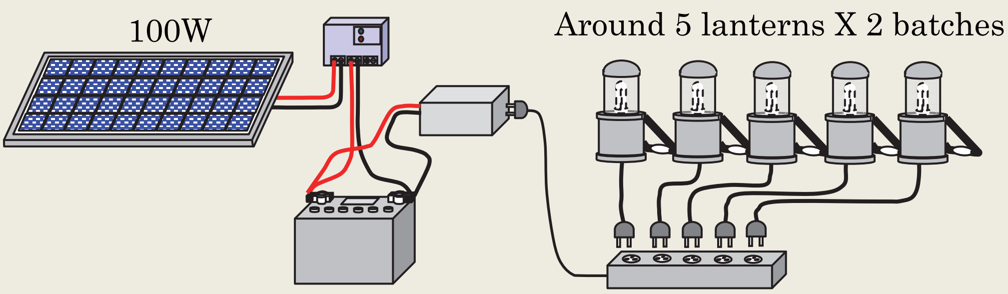
Save energy use and prolong battery life. Then you can save battery replacement cost.

Possible number of charges (Example)

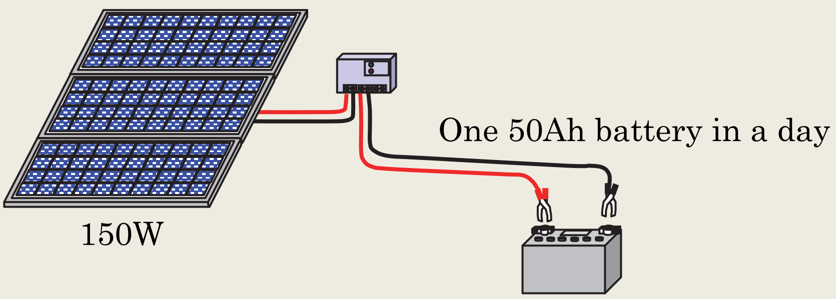
Around 50 Mobile phones can be charged in a day by a 100W panel.
20-30 phones at a time.



10 lanterns can be charged in a day by a 100W panel.
5 lanterns at a time.



One 50Ah battery needs 150W panel to charge in a day.
Battery needs much energy to charge.



Business tips

- **Lanterns shall be recharged at least once a month even it is not used.**

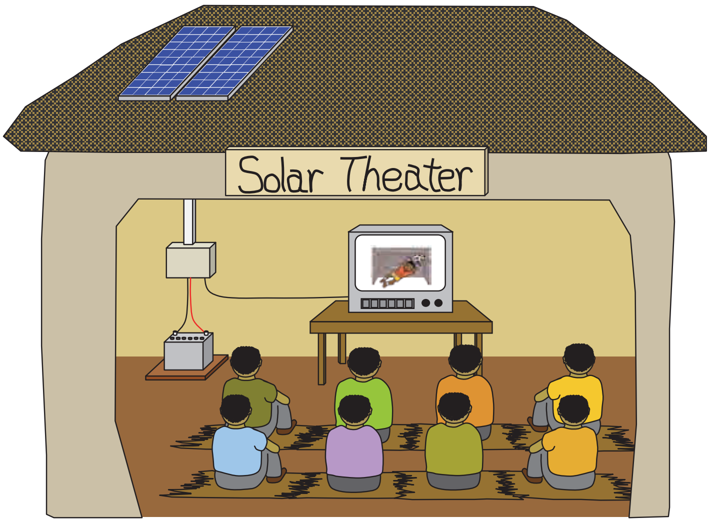
Most batteries in lanterns are sealed type lead acid. If lanterns are left uncharged for several months, these batteries will be damaged. Even if the lanterns are not used, they have to be charged at least once a month. This should be known to users so that they would not store lanterns for a long time without charging. Less discharge and frequent charge will extend the life of the battery.

- **Maintenance tools**

Good tools are needed for good maintenance. The charging station has to be equipped with such tools.

Possible PV business

- TV viewing



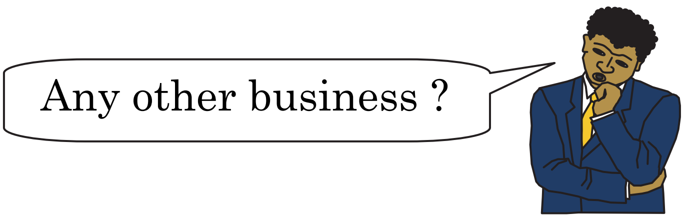
100 – 200W PV system is needed.

DVD player and TV are necessary.

- Hair salon

Minimum 50W PV system is needed.

The barber can use electric hair clippers.



Troubleshooting

Many Problems are caused by loose connection, rust and dusts.

**Before going into troubleshooting,
you should check wirings and retighten connections!**

After this,

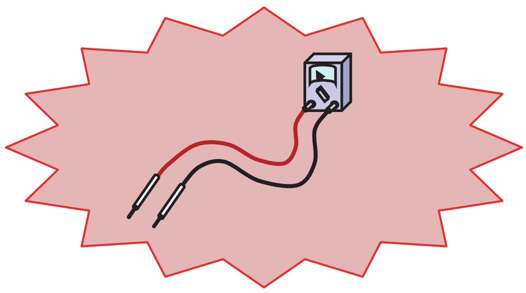
If only one appliance is in trouble, problem is the appliance itself or the wiring to it. Replace the appliance or the wiring.

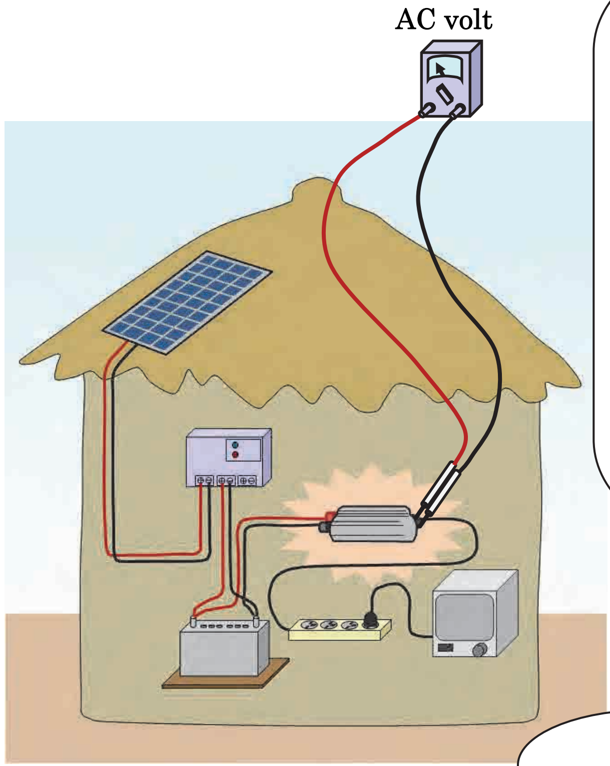
If many appliances are in trouble, then the power supply system is doubtful.

Then, you have to start checking the system.

- - - - - next page

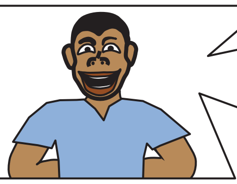
You need a multi-meter!!

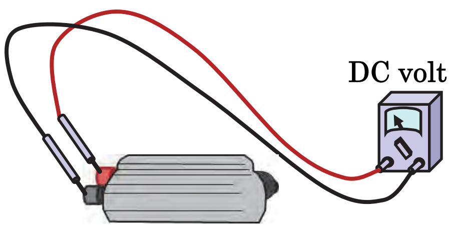




1. Inverter check

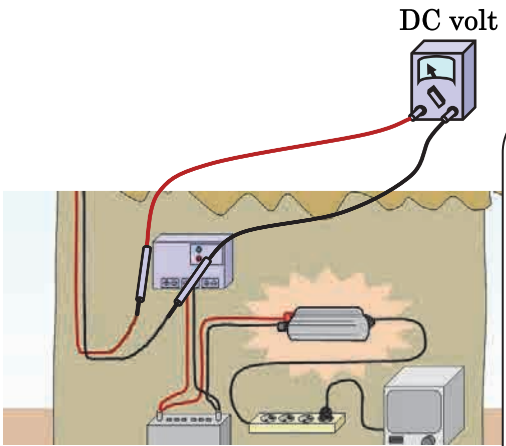
Measure the inverter output. If it is around AC220V to 240V, then Inverter is OK, check the AC wiring and connections.
If it is less than AC220V, then check the inverter input. If it is around DC12V for 12V system, DC24V for 24V system and DC48V for the 48V system (laptop system) then the inverter is faulty.





2. Battery check

If Voltage is less than DC12V for a 12V PV system or less than 24V for a 24V PV system, and DC48V for the 48V system (laptop system) in sunny day then the battery is faulty.



Disconnect panel line.
Then, measure voltage.

3a. Panel check

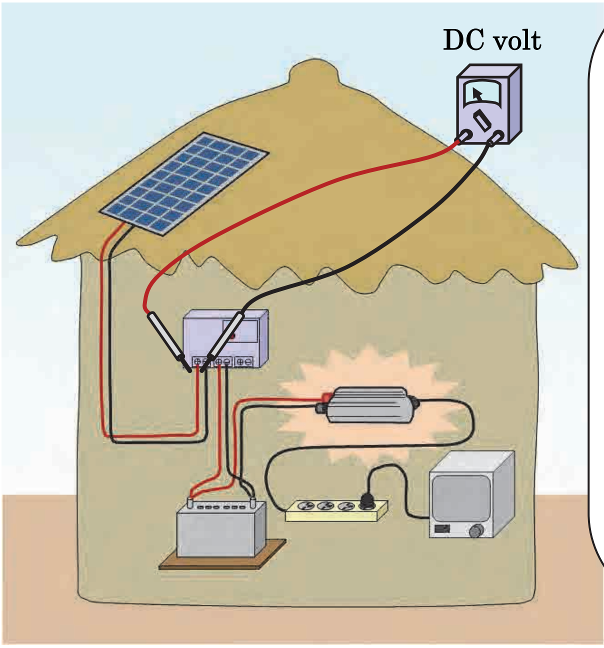
Disconnect panel lines from the controller (turn Isolator to OFF) and measure panel voltage at the isolator. If PV panel voltage is less than DC16V for 12V system or 32V for 24V system on a sunny day then the panel is faulty.
If panel output is more than DC16V or DC32V then panel is OK.

3b. Panel check for laptop system

Disconnect panel lines from the controller (turn off all the breakers at Junction Box) and measure panel voltage at the sub breakers inputs. If PV panel output voltage is more than DC64V then the panel string is OK. If PV panel Voltage is less than DC64V on a sunny day then that panel string is faulty.

Measure all strings one by one and keep record. There will be some difference. It should not be more than ±10%

If PV panel output voltage is more than DC64V for all the strings then turn on the sub breaker one at a time and check the voltage at the input of the main breaker. If the voltage is nearly the same as the one on the input of the sub breaker then the diode is OK, If there is a very big difference between the voltage at the input of the main breaker and the input of the sub breaker (when the other 3 sub breakers are off) then the diode might be faulty.

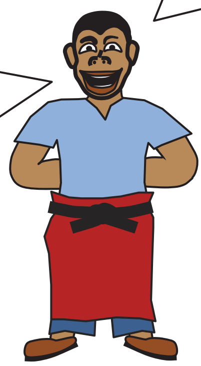


4. Charge Controller check

Measure DC voltage at battery terminal of the controller. If it is around DC 12V for 12V system or 24V for 24V system, then the battery is OK.

Reconnect the PV panel lines to the controller (turn Isolator to ON) and check the PV panel terminal of the controller. If it is more than DC 16V for 12V system or 32V for 24V system, then the controller is faulty.

If you are using DC output (load terminals) of the controller, check the load terminal of the controller.
If the output is not nearly the same as the battery voltage, then the controller is faulty.

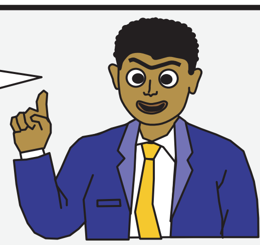


To decide whether the controller is faulty or not, first disconnect the PV panel by turning isolator to OFF position. Then check the fuse installed in between the Charge Controller (CC) and the battery, if the fuse is blown then change the fuse.
To reconnect, follow exactly opposite of disconnection.

CAUTION

Never take out the fuse installed in between the CHARGE CONTROLLER and BATTERY before turning OFF the ISOLATOR, installed between PV panel and Charge Controller (CC)

You have to report the results to the installer or a local PV technician and discuss how to repair it.



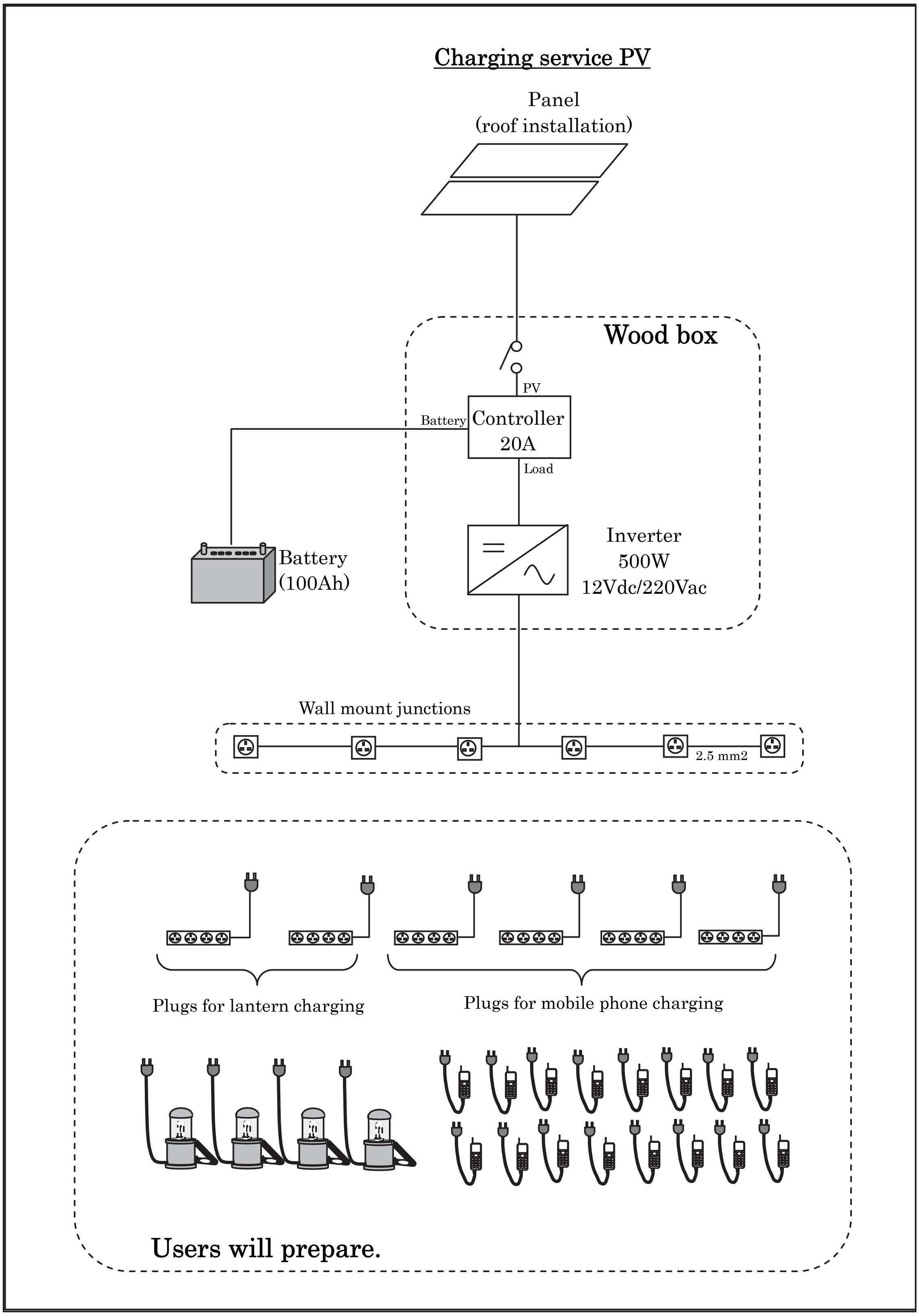
Charging station

Charging station is not so large.

Operating by Technician.

Power outlets on the wall and a shelf are convenient for the operation.

line drawing of PV charging system



Important Tips

Isolator is a switch which can isolate PV panel from connecting to the Charge Controller (CC)

SW off when thunder comes and during O&M when required.

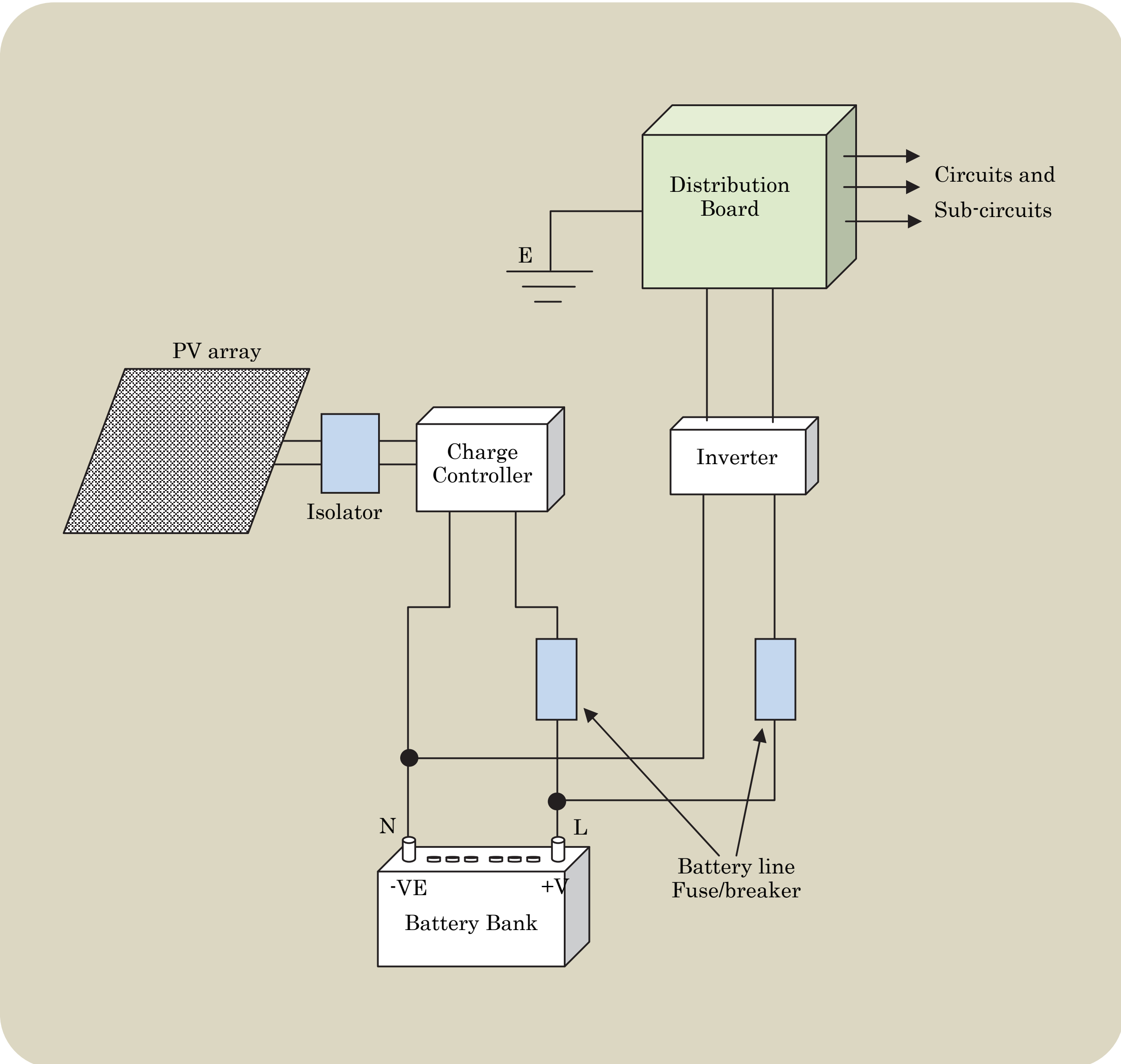
Fuse/Breaker is necessary in between;

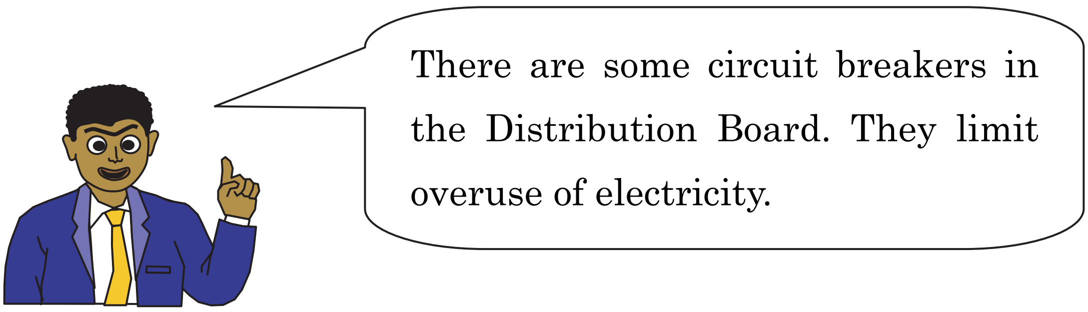
1. Charge controller and Battery
2. Battery and Inverter

The Fuse/breaker protects the circuit from short circuit trouble

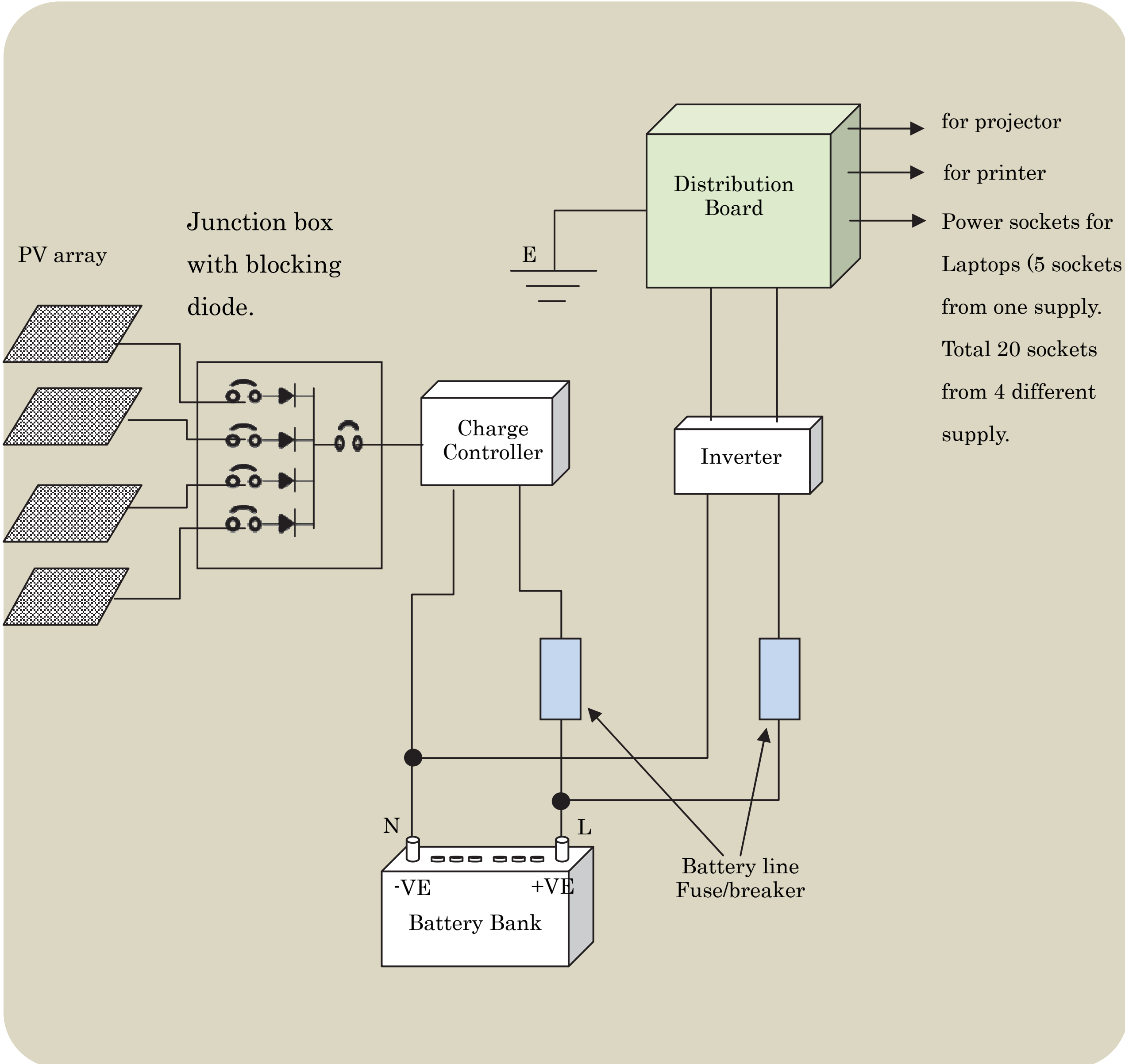
General configuration

of PV power supply system



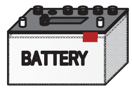
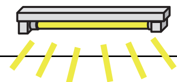
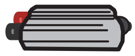
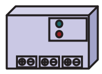
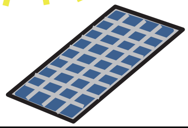


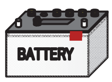
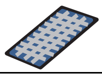
General configuration
of laptop PV power supply system



Manual for E-waste Disposal

E-Waste is generated after long life span of equipment.

E-waste	Hazardous Element
Used Lead-acid batteries	Lead and Sulfuric Acid 
Used Fluorescent tubes	Mercury 
Used PV panels, Inverters and Other appliances	Other Heavy Metals   

Component	Possible Life Span* (years)	Handling	Remarks
Battery 	3 to 8	・ To prevent diffusion of toxic substances in batteries, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly dispose them. ・ Used batteries can be sold to licensed e-waste handlers and/or battery producing companies in Kenya	・ Get latest information from licensed e-waste handlers or NEMA county offices. ・ Purchase prices of used batteries are subject to the market trends
Fluorescent Lamp 	2 to 4	・ To prevent diffusion of mercury in fluorescent lamps, used ones shall safely be kept without damage (Do not Crash! Do not Take Apart!) until properly dispose them. ・ Used Fluorescent Lamps shall be transported to licensed e-waste handlers in Kenya to be disposed.	Get latest information from licensed e-waste handlers or NEMA county offices. 
LED Lamp 	5	・ Used LED Lamps shall be transported to registered e-waste handlers in Kenya to be disposed.	
PV Solar Panel 	20 to25	・ Used PV Solar Panels shall be transported to registered e-waste handlers in Kenya to be disposed.	
Inventor 	5 to 10	・ Used Inventor shall be transported to licensed e-waste handlers in Kenya to be disposed.	

* Note: Vary depending on the intended use as well as status of use

E-wastes such as used-batteries shall be transported to the licensed E-waste handlers and/or battery makers. You can ask for disposal when replace used batteries!!

2. Solar PV Organizational Management Manual

Public facilities, i.e. dispensaries and primary schools and people of their neighbourhood communities benefit from solar PV systems for health care and improvement of education. Solar PV systems will not function well if they not operated and maintained properly.

Public facilities and management committees have responsibility to take care of the PV systems by establishing management system and finance for sustainable system use.

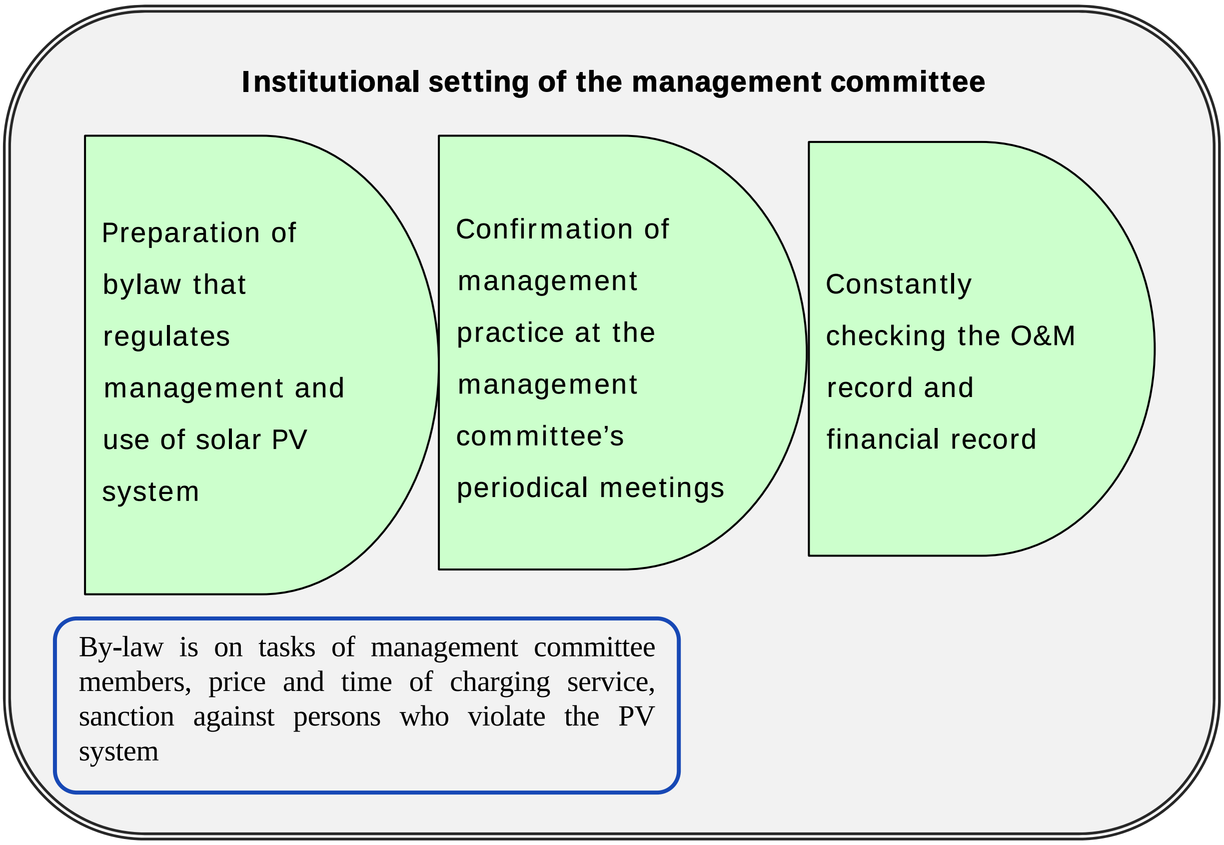
This manual explains to dispensary/school staffs and management committee members how they should manage the solar PV system to get long time use up to the life time of solar panels.

(1) Tasks of management committee members and operator

Organization	Responsibility
Operator	• operation and checking condition of solar PV system daily, • periodical water topping, • collecting and recording proceeds from charging service, hair shaving, and other businesses • informing daily sales to treasurer (or secretary)
Treasurer and/or secretary	• examining the daily record and collecting proceeds • keeping account book • reporting the financial state to the chairman and other members • deposit of proceed at the bank account • purchase of distilled water and other necessary equipment and tools
Chairperson	• Confirmation of the financial report and O&M report • Submission of the financial report and O&M report to the county ministry office (monthly) • Overall supervision about the solar PV system management
Dispensary, school and management committee	• advertizing and implementation of charging service, • securing the safe condition of solar panels
Users (community people, pupils):	• use of the charging service, • keeping solar panels safe
County offices of MOH (and MOEST)	• budget preparation for future replacement of batteries, inverters and controllers, • receiving financial status report (included in the regular report) and

Organization	Responsibility
	O&M report, • identifying problems of solar PV system mentioned in the reports, • by-yearly inspection of system condition = MOH

(2) Institutional setting

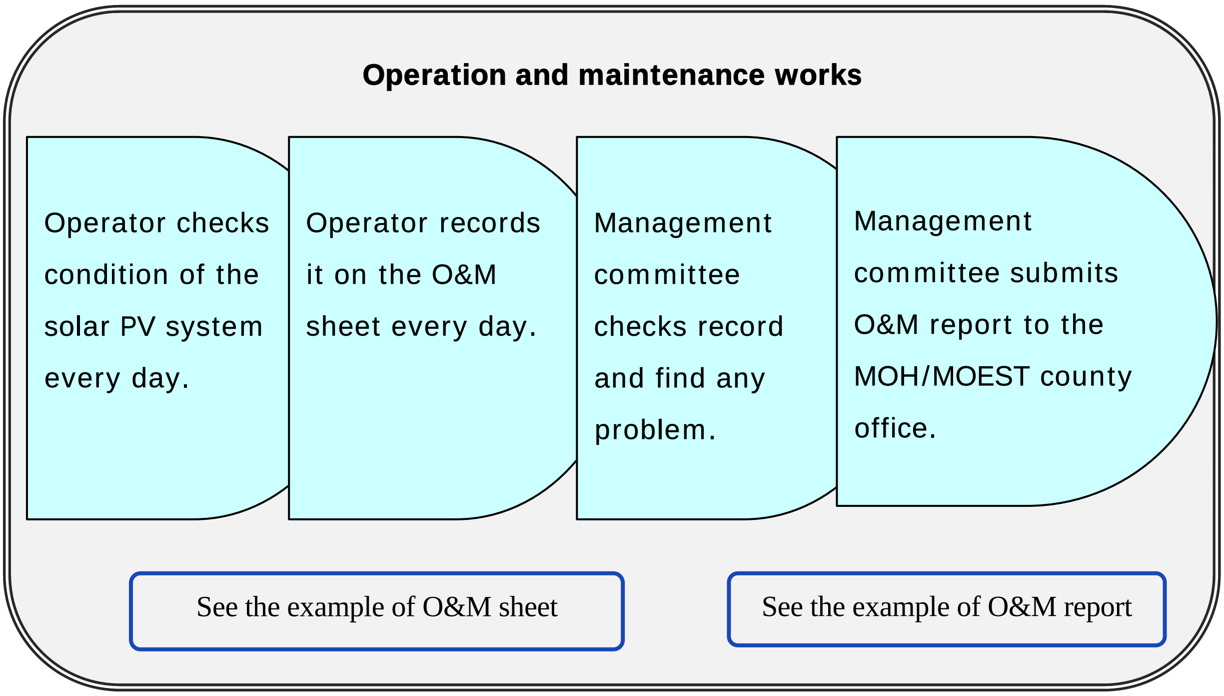


What is important for management committee? Management committee and facility staff members are responsible persons for PV system management. They need to establish institutional framework within the committee to ensure sustainable system use.

What is important for management committee? Management committee and facility staff members are responsible persons for PV system management. They need to establish institutional framework within the committee to ensure sustainable system use.

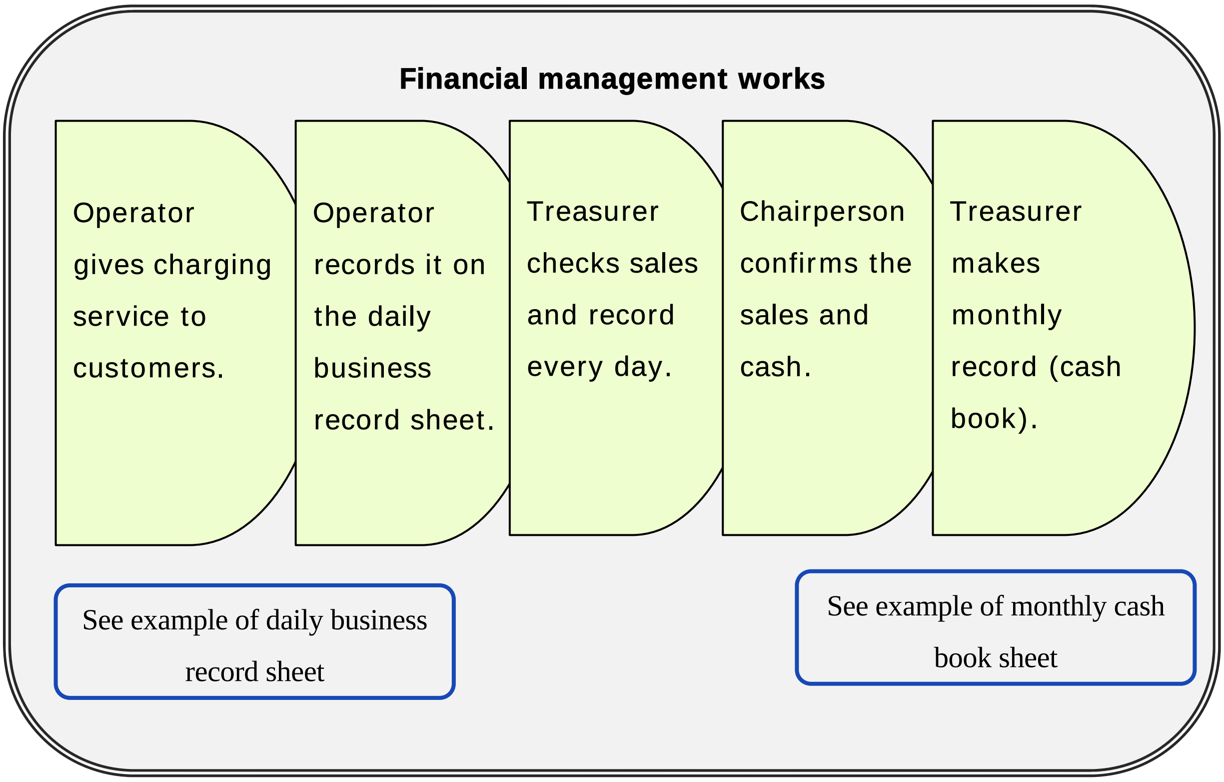
By-law contains works of management committee members and operator, time and price of charging service, sanction against persons who violate the solar PV system and other necessary items.

(3) Operation and Maintenance



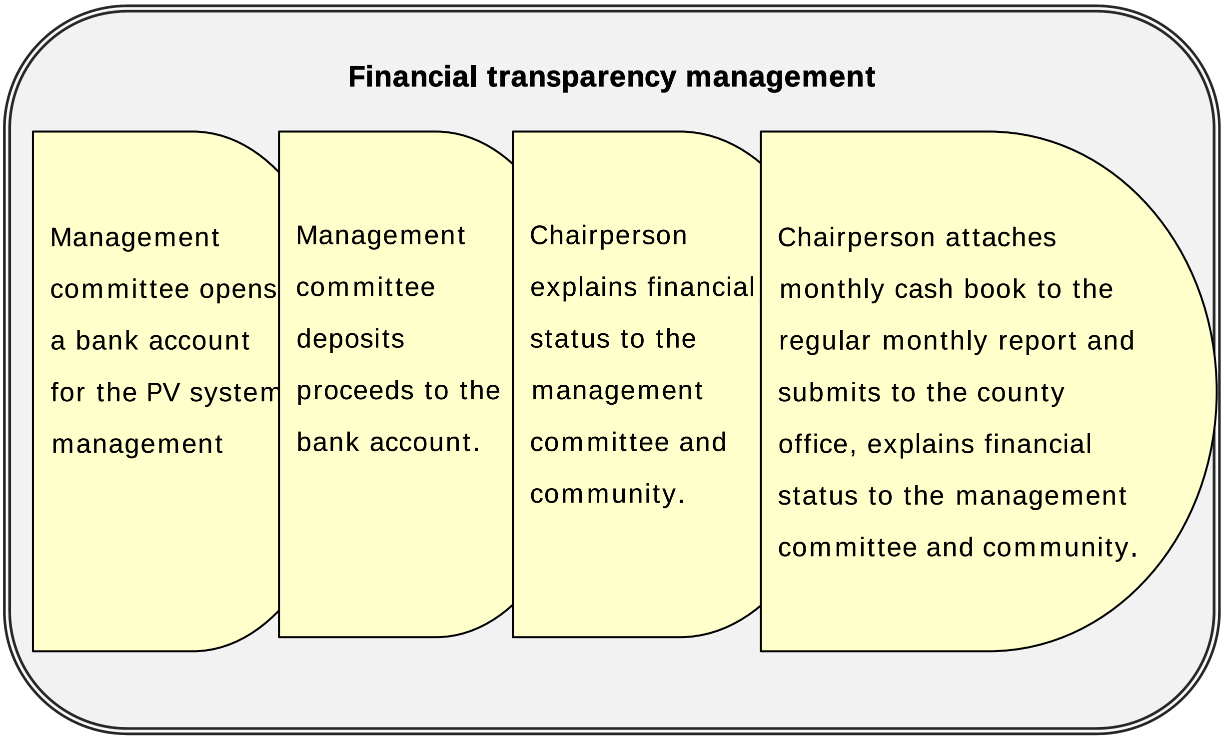
Daily operation is simple but a very important task of the operator as the basis of sustainable system use. If he/she finds water level lows, he/she top up distilled water immediately.

4. Financial management at dispensary/school



Income from charging service sales is a valuable source for the cost of daily solar PV system O&M and management such as purchase of distilled water, replacement of bulbs, transportation and so on.

5. Transparency



Keeping transparency of charging service is indispensable in order that both concerned ministries and community people rely on the performance of management committee.

Reporting of the financial state shall be attached to the facility monthly report and submitted to the county office of the relevant ministries.

6. E-waste management

(i) Request suppliers to take away used ones from each facility when carrying out replacements (this shall be set as a condition for carrying out replacements).

↓

(ii) Earning from the selling of used batteries and other used substances of e-waste shall be remitted using the “m-pesa” system by the suppliers when getting selling money from the licensed E-waste Handlers and/or battery makers.

↓

(iii) The earning money shall be kept in each facility as revenue.

↓

(iv) To make sure the proper transportation and treatment, the **e-waste manifest system** shall be introduced in the e-waste disposal system

Manual for

Financial Management and Accounting for Public Facilities

Public Facilities and surrounding community people benefit by solar PV systems for health care and education. The new responsibility with the stakeholders of the public facilities to take care of the PV systems should be considered as unavoidable for sustainable use. The manual is prepared for "Management Committee" to pursue their new responsibility focusing on the financial aspect for sustainable use and its benefit.

Person in Charge

Chairman
Secretary
Treasurer

Operator

Necessary Books and etc.

Daily Business Record
Cash Book
Monthly Report

Receipt
Bank Account

Members of Management Committee, Chairman/ Secretary/ Treasurer and Operator share the responsibilities for sustainable use of solar PV systems as follows:

Role Sharing

Tools	Purpose & Contents	In Charge	Check & Keep
Daily Business Record	Income record	Operator	Secretary
Cash Book	Income & Expense	Operator	Treasurer
Monthly Report	Cash Balance & Profit	Chairman	Chairman
Receipt	Evidence	Operator	Customers
Bank Account	Official Record	Chairman	Chairman

The cash balance from the result of charging service is transferred to the bank account by Chairman monthly or regularly. Cash and bank books are managed by Management Committee.

EXAMPLE FOR FILLING

Annexes

Delete not applicable

1. Daily Business Record

DAILY BUSINESS RECORD FOR

Iltumtum ~~DISPENSARY~~ / PRIMARY

Sheet No. :______1____

Date: _1 st September 2014_ Weather:__Sunny___

Name of school or dispensary

Full name

No.	Name of Customer	Type of appliance *	Amount (KSh.)	Comment/ Remarks/ Complaints e.g. customer misplaced receipt
1.	Mr.Aaaaa Bbbbb	Mobile	20	Normal
2.	Ms.Ccccc Ddddd	Haircut	35	Normal
3.	Mr. Eeee Ffffff	Mobile	20	Did not pay cash, Next day paid
4.	Ms. Oooo Ppppp	Mobile	20	Normal
5.	Ms. Qqqq Rrrrr	Mobile	20	Normal
6.	Mr. Sssss Ttttt	Mobile	20	Pay 50%, Next day paid
7.	Ms. Ttttt Uuuuu	Mobile	20	Normal
8.	Mr. Uuuu Vvvv	Mobile	20	Normal
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
Daily Total		Phone: 140 Lantern: Battery: Clippers: Other (Hair cut etc.) : 35	175	

To be checked and signed by Treasurer or Secretary.
Finally submit to Chairman together with cash and whole books

Break down of the day income

Total of the day to be checked with the break down

Daily Totals checked by: Mr. Ggggg Hhhhh

signature: *Ggggg Hhhhh*

* Type of appliance: mobile phone, LED lantern, rechargeable battery, hair clippers, other (specify)

The treasurer gives a number to the sheet and issues this sheet to the secretary who issues it to the operator. At the end of the day, the operator returns the sheet to the treasurer who verifies the cash collected against this sheet.

When the number of customers exceeds 25 persons, continue recording on the Sheet 2 and input the daily total at the bottom of Sheet 2.

EXAMPLE FOR FILLING

Fill in name of school or dispensary

2. Copy of Sales Receipt

CASH SALERECEIPT			No. 1
Name of Customer **Mr. James Kamweru** **Mobile: 070-111-222**	**Iltumtum**		~~Dispensary/~~ **Primary School**
	P.O. BOX XXX		
Mobile phone:	**DATE: 1 / 9 / 2014**		
No.	**DESCRIPTIONOFMOBILE/LANTERN etc.**		**AMOUNT(Ksh.)**
1	**NOKIA Mobile**		**20**
		Total	20
Received by: Mr. Kkkkk Lllll	**Signature:** ***Kkkkk Lllll***		

Delete not applicable one

Full name, contact number

Signed by operator
Together with cash and other books, Copy of Sales Receipt are transferred to treasure or secretary

EXAMPLE FOR FILLING

3. Cash Book

CASH BOOK FOR
ILTUMTUM DISPENSARY / PRIMARY SCHOOL

Month/Year: September 2014 **Sheet No. :** 1

Date	Revenues		Expenses		Balance (KSh.)
	Item	Amount (KSh.)	Item	Amount (KSh.)	
1.	Charging Income	175			
2.	Charging Income	140			
3.	Charging Income	170	Stationary	100	385
4.					
5.					
6.					
7.					
8.					
9.	Charging Income	180	Transportation for bank	100	465
10.	Charging Income	120	Bank charge	100	485
11.	Charging Income	160	Bank deposit	385	100
12.	Charging Income	175			
13.					
14.					
15.	Charging Income	175			
16.	Charging Income	140			
17.	Charging Income	170			
18.	Charging Income	170			
19.	Charging Income	140			1,230
20.					
21.					
22.	Charging Income	175	Distilled water	500	905
23.	Charging Income	140			
24.	Charging Income	170			
25.	Charging Income	120			
26.	Charging Income				1,495
27.					
28.					
29.	Charging Income	160	Transportation for bank	100	
30.	Charging Income	175	Bank charge	100	
31.			Bank deposit	1,000	630
Monthly Total		3,015	Monthly Total	2,385	630

Monthly Totals
Checked by: Mr.Ggggg Hhhhh
signature: *Ggggg Hhhhh*

A
Stationary

B
Transportation
Bank

C
Bank Charge

D
Bank Account

E
Distilled Water

F
Transportation
Bank

G
Bank Charge

H
Bank Account

I
Monthly Total

The Cash book kept by the treasurer who makes entries.

Signed by Treasurer or Secretary
Together with other books and Copy of
Sales Receipt are transferred to Chairman

EXAMPLE FOR FILLING

4. Monthly Record

MONTHLY REPORT OF ILKILNYETI DISPENSARY

Month/Year: September 2014		Sheet No. : 1	
Income in the month	**(KSh.)**	**Expenditure in the month**	**(KSh.)**
Cash Balance last Month (a)		1. Operation cost	
1. Revenue from charging service (b)	3,015	(1) Distilled water	500
2. Other revenues:		(2)	
		(3)	
		(4)	
		(5) Miscellaneous	
Sub-total (c)	3,015	(e)	500
3. Withdrawals from Bank		cost	
Date			
Date			
Date			
Sub-total (d)	0	Sub-total (f)	0
		3. Administration cost	
		transportation	200
		committee expenses	
		meeting expenses	
		bank charge	200
		others (stationary)	100
		Sub-total (g)	500
		5. Deposit to bank (h)	1,385
Cash Income Total (a)+(b)+(c)+(d)	3,015	**Cash Expenditure Total** (e)+(f)+(g)+(h)	2,385
Balance (Cash income carried forward)			Ksh 630

BANK CONTROL		Unit: Ksh	
Balance in last month		Withdrawals in this month (d)	0
Deposit in this month (h)	1,385		
Deposit Total	1,385	**Withdrawals Total**	0
Balance (Cash income carried forward)			KSh. 1,385

Cash Book E

Cash Book I

Cash Book B+F

Cash Book C+G

Cash Book A

Cash Book D+H

Available Balance Cash & Bank Deposit

Form

1. Daily Business Record

Daily Business Record of ________________________Dispensary / Primary School

Sheet No. :__________				
Date: ________________			Weather:__________________________	
No	**Name of Customer**	**Type of appliance ***	**Amount (KSh.)**	**Comment/ Remarks/ Complaints** e.g. customer misplaced receipt
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
Daily Total		Phone: Lantern: Battery: Clippers: Other (Hair cut etc.):		
Daily Totals checked by: ______________________ **signature:** ______________________				
* Type of appliance: mobile phone, LED lantern, rechargeable battery, hair clippers, other (specify)				

The treasurer gives a number to the sheet and issues this sheet to the secretary who issues it to the operator. At the end of the day, the operator returns the sheet to the treasurer who verifies the cash collected against this sheet.

When the number of customers exceeds 25 persons, continue recording on the Sheet 2 and input the daily total at the bottom of Sheet 2.

Form

2. Copy of Sales Receipt

CASH SALERECEIPT				No.
<u>Name of Customer</u>				Dispensary/ School
		P.O. BOX		
Mobile phone:		DATE: / /		
No.	DESCRIPTIONOFMOBILE/LANTERN etc.			AMOUNT(KSh)
			Total	
Received by:		Signature:		

Form

3. Cash Book

CASH BOOK FOR ILKILNYETI DISPENSARY

Month/Year: ______________________			Sheet No. : _1_		
Date	Revenues		Expenses		Balance (KSh.)
	Item	Amount (KSh.)	Item	Amount (KSh.)	
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
Monthly Total					

Monthly Totals
Checked by: ___________________________________
signature: _____________________________________

The Cash book is kept by the treasurer who makes entries.

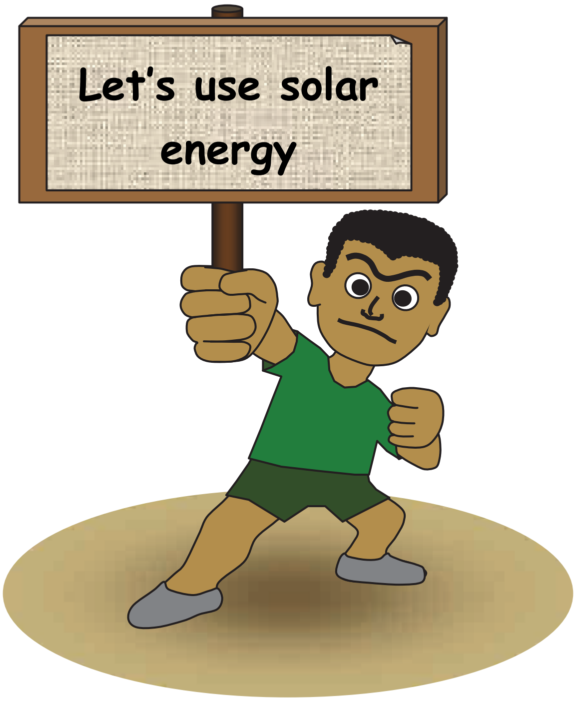
Form

4. Monthly Record

MONTHLY REPORT OF ILKILNYETI DISPENSARY

Month/Year: ________________		**Sheet No. :** 1	
Income in the month	**(KSh.)**	**Expenditure in the month**	**(KSh.)**
Cash Balance last Month (a)		1. Operation cost	
1. Revenue from charging service (b)		(1)	
2. Other revenues:		(2)	
		(3)	
		(4)	
		(5) Miscellaneous	
Sub-total (c)		Sub-total (e)	
3. Withdrawals from Bank		2. Maintenance cost	
Date			
Date			
Date			
Sub-total (d)		Sub-total (f)	
		3. Administration cost	
		- transportation	
		- committee expenses	
		meeting expenses	
		bank charge	
		others	
		Sub-total (g)	
		5. Deposit to bank (h)	
Cash Income Total (a)+(b)+(c)+(d)		**Cash Expenditure Total** (e)+(f)+(g)+(h)	
Balance (Cash income carried forward)		Ksh	

BANK CONTROL		Unit: Ksh	
Balance in last month		Withdrawals in this month (d)	
Deposit in this month (h)			
Deposit Total		**Withdrawals Total**	
Balance (Cash income carried forward)		KSh.	



Contact :

Annex 2 Forms for O&M and Management

Annex 2-1 Questionnaire for the Baseline Survey

2-1-1 Baseline Survey to the Public Facilities

1. Interview data

(1) Date of interview ____________ Interviewer

(2) Name of the facility

(3) Sub-county ______________ Division
Location _______________ Sub-Location

(4) Interviewee's name, sex, age

(5) Position/title in the facility

2. Facility structure and function

(6) Number of communities in the service catchment area

(7) How many persons in the facility?

<School>

School: Teachers _____ non-teacher workers _____ Total Number of pupils ___ (number of boarders ______)

<Dispensary>

Dispensary: Medical staff __non-medical staff __ Total
Average number of patients/day ____ (average number of night patient/day ____)

(8) 1) Does the facility have any expansion plan? /______/
2) If yes, please explain (area expansion, number of rooms, etc.)
3) Has the facility got the budget already? /______/
4) When the construction starts? /______/

3. Actual energy use

(9) Source of actual energy use. Please add the device names used in your facility.

Purpose of energy use	Type (& fuel type)	Number	Amount consumed in a month (unit)	Amount of money Ksh/month
Lighting 1				
Lighting 2				
Radio and/or TV				
PC				
Vaccine refrigerator				
Security light				

Note: Energy source: Grid, generator, dry cell, kerosene, etc.

4. Experience of power generation

(10) Does the facility have or had power generation system?/

Item	Generator	PV system
Number		
Does it function now or stopped?		
Number of system actually functions		
Year of installation		
Who paid and took initiative for installation?		
Capacity of power generation		

(11) 1) If the facility has/had power generation systems, who operates it?
2) Is/was there any fee for the operator?
3) If yes, how much and who pays?
3) Has that person got training of operation/maintenance technique?
4) Is/was there any trouble or problem concerning generator/PV system operation?
5) If yes, please explain.

5. Management and use of electricity to be installed by the pilot project

(12) If you start phone charging service, how much Ksh do you think is appropriate for the fee of one phone charging?
__________ Ksh/phone

(13) Do you have any idea using PV power to get income other than phone charging?

Asante Sana !

END

....

2-1-2 Baseline Survey to Chief or Assistant Chief

1. Interview data

1) Date of interview /______________ / Interviewer /_____________ / Name of facility /_____________/
2) Interviewee's name and position / ____/

2. Village profile

(4) Latest Population of
Sub-location ____(Year _) Location _____(Year ___)
(5) Number of households of ____ is __HHs in the year of
(6) Ethnic groups living in the community in order of population
1.________ 2.________ 3.________ 4.________ 5.
(7) Public facilities in the sub-location. Please enter the number if it exists.
1. Primary school /__/ 2. Secondary school /__/ 3. Dispensary /__/
4. Office of governmental organization (specify) /________/

3. **Economic and social condition**

(8) Main income sources of the location (specify products, in order of importance)
1.____________ 2.____________ 3.____________ 4.____________ 5.
(9) Is there any project (on- going and planning) for community development in this village?

4. Actual energy use and electricity (general tendency in the community)

(10) Sources of energy in the community

Purpose of energy use	Energy source*	Place of fuel collection/ purchase/charging	Unit price of fuel and unit
Lighting 1			
Lighting 2			
Radio and/or TV (if any)			
Mobile phone charging			

Note: Energy source: Grid, diesel, dry cell, kerosene, etc.

(11) 1) Where is the nearest town where inhabitants go to charge phones?

2) How much is the transportation cost (round trip) to go there? /_______/Ksh

3) Where is the nearest town where the facility can buy distilled water?

4) Does anyone in the community do charging service using the power from their generator/PV system?

Power generation type		Diesel generator	PV system
Number in the service providers			
1. Mobile charging	Number of service in the village		
	Fee Ksh/1 time		
	Total sales Ksh/month		
2 Other	Specify the type of service		
	Number of service in the village		
	Fee Ksh/ (unit)		

(12) How many percent of the village inhabitants have mobile phone? /_________/
(13) Do inhabitants use LED rechargeable lantern? /________/
(14) 1) Does the community have an electrification plan? /________/
2) If yes, what plan? Please explain.

(15) How much Ksh/time is appropriate for inhabitants to pay to charging mobile phone? Ksh________per phone

Asante Sana !

END

2-1-3 Baseline Survey to Household

1. Interview data

(1) Date of interview_____________ Interviewer
(2) Name of community
(3) Interviewee's name, sex and age
(4) Interviewee's occupation and position in the community

2. Household profile

(5) 1) Number of household members Male /_____/ Female /_____/ Total /_____/
2) Number of household members who live in the community throughout the year /______/
(6) Ethnic group of the household head
(7) Main income source of your household in order of importance and person who mainly engage in it? (in order of importance)

	Occupation/ work 1	Occupation/ work 2	Occupation/ work 3
Name of work			

(8) Household cash income of **last month** ________Ksh, and **last year**________Ksh
(9) Household expenditure of **last month** ________Ksh, and **last year**________Ksh

3. Household energy use

(10) Do you have diesel generator(s) and/or PV system?

Power generation type	Diesel generator	PV system
Number		
Generation power (kWh)		
Fuel consumption (liter/month)		-
Fuel expenses (Ksh/month)		-
Purpose of use		

(11) Do your household own following appliances? Please answer the number.
Mobile phone /______/ television /______/ Radio /_____/
(12) If you have mobile phone(s),
If no, why?
1) Where do you charge?
2) How many hours does it take to reach the charging place?
3) How many times do you charge it in **a month**?
4) How many Ksh do you pay for one time recharging? ________Ksh/time
5) How much can you pay at maximum for charging in **a month**? ________Ksh/month
(13) If the dispensary or primary school in this community starts charging service, will you use the service? /________/
(14) 1) What kind of lighting appliance do you use?
2) If it is kerosene lantern, where do you buy the fuel?
3) How much do you pay for kerosene in a month? ________Ksh/month

Asante Sana !

END

Annex 2-2 Monitoring Sheet

2-2-1 Interview to the facility staff and chairman of the management committee

1. Basic data of the monitoring

1.1 Date ____________ 1.2 Site name __________________ 1.3 Member of the monitoring team /_________________/

1.4 Name and position of interviewees /____/

2. Organizational management

(1) Bylaw (rule and manner of PV system use and charging service) drawing

1) Existence of a bylaw

Drawn and approved by the committee /_______/ Drawn but not approved yet /______/ Not drawn up /______/

2) If not, future plan to make up the bylaw

(2) Do the members of management committee constantly work as planned?

1) Does the treasurer check the daily sale after closing service every evening together with operator? /______/

2) Does treasurer/secretary make monthly summary report? /______/

3) Does he/she explain the report at the committee's meeting? /______/

4) Does the committee submit the monthly financial report to the county health/education office? /______/

5) Do they explain to the surrounding community about the management of PV system? /______/

3. Financial management

(1) Has the management committee opened a bank account exclusively used for the PV system? /_______/

(2) Fund raising

1) Does the management committee check the amount of money collected and accumulated for operation and administrative expenses? /______/

2) Is it sufficient for general expenditure (distilled water, transportation, etc.) till now? /______/

(3) What measure does the management committee take if the amount is not enough?

(4) If the management committee finds problem in the charging business, what is it?

(5) Does the committee advertise charging service to community people? /______/

4. Operation and Maintenance of PV system

(1) Does the operator work every day for charging service? /______/

(2) Does he/she do water topping up? Please observe the condition.

Room/building of the PV system	Water level at the proper level (G/NG)	Record of water topping (yes/ no)	Remarks

(3) Does he/she understand the contents of the Operation and Maintenance record? /_____/

(4) Does he/she fill the Operation and Maintenance record?

Record writing Yes/no	Contents of the O&M record (good/not good)	Remarks

(5) Performance of operator: evaluation of chairman (or head teacher, nurse) : mark <Good / Not Good>

Daily charging service	Recording of "Daily business record"	Recording of "Cash book" every evening	Informing mal function and other troubles to the chairman, if any

5. Change after electrification

(1) What change occurred after the pilot project had started?

<To school>

1) Has the student's studying time changed at night after the pilot project started?

<To dispensary>

2) Number of night patient in this month: total /_______/ and previous month total /_______/

<All sites>

3) Any other change?

(4) Satisfaction of the electrification by PV system (pilot project) /mark one answer /

Satisfied 5 -- 4 -- 3 -- 2 -- 1 Not satisfied

*If the respondent mentioned question or claim at the previous monitoring, the monitoring team should answer to it.

6. Description

(1) Problems the committee faced and measures taken at this moment

(2) Advice of the monitoring team to the facility and management committee

(3) Observation of the monitoring team, if any

End

ASANTE SANA!

....

2-2-2 Interview to the treasurer and/or secretary

1. Treasurer's work

(1) Do you understand the contents of the daily record sheet? Please explain to the monitoring team.

Result, observation of the monitoring team

(2) Do you check the proceeds of charging service every evening? /________/

(3) Do you record day's total? /________/

If not, what is the problem?

(4) Do you make a monthly summary of income & expenditure as trained? /________/

If not, what is the problem?

(5) What are the administration expense items at this moment? /____/

(6) Do you inform the income & expenditure to the committee members including chairman and secretary every month? /________/

(7) If not, what is the reason

(8) Do you advertize charging service to community people? /________/

2. Report

<To dispensaries>

(1) Does the secretary (or treasurer) add the monthly proceeds from charging service to the monthly report and submit it to the county health director's office? /________/

(2) If not, what is the reason?

<To schools>

(3) Does the secretary (or treasurer) make a monthly report of the proceeds from charging service? /________/

(4) If not, what is the reason?

3. Problems and difficulties that the treasurer/secretary has faced concerning PV system financial management

4. Opinion on PV system financial management

End

ASANTE SANA!

....

2-2-3 Interview to operator

1. Working time, Working day in a week and time
2. Do you work every day?
3. Recording

(1) Do you understand the contents of the daily record sheet? Please explain to the monitoring team.

Result, observation of the monitoring team

(2) Do you record day's sale as the JET trained you? /________/

(3) Do you use the format of daily sale as you were trained? /________/

If not, what is the reason?

(4) Do you remember the contents of the training? /________/

(5) Do you want to get training again? /________/

4. O&M

(1) Do you remember the contents of the technical training? /________/

(2) Do you keep the "Solar PV Manual"? (if the operator does not have one, please give him/her a copy) /________/

(3) What is water topping up? Please explain

Result, observation of the monitoring team

(4) Do you check water level? If yes, how often?

(5) Do you check voltage, inverter and controller? /________/

5. Problems and difficulties that operator has faced

6. Opinion on the operation and maintenance of the PV system

End

ASANTE SANA!

....

2-2-4 Observation by the facility staff and the expert team

1. Observation of the accounting books

2. Condition of the equipment (set of batteries, inverters and controllers) at each room.

Does the apparatus functions well without bad smell and abnormal sound?

No.	Name of Room/building of the PV system*	2.1 battery voltage (write the voltage)	2.2 inverter (indicator lamp is ON/OFF)	2.3 controller (indicator lamp is ON/OFF)
1				
2				
3				
4				
5				
6				
7				
8				

* Name of rooms

<Primary school> Class room (specify the room number), staff room, staff dormitory (specify the room number), boy's dormitory, girl's dormitory, hall, charging service room/hat

<Dispensary> Main consultation/treatment room (specify the room number), sub-consultation/treatment room, vaccine refrigerator, staff dormitory, charging service room/hat

3. Report

<To dispensaries>

(1) Does the secretary (or treasurer) add the monthly proceeds from charging service to the monthly report and submit it to the county health director's office? /________/

(2) If not, what is the reason?

<To schools>

(3) Does the secretary (or treasurer) make a monthly report of the proceeds from charging service? /________/

(4) If not, what is the reason?

3. Problems and difficulties that the treasurer/secretary has faced concerning PV system financial management

4. Opinion on PV system financial management

End

ASANTE SANA!

Annex 3 Financial Management

Annex 3-1 Cash Flow Projection
Annex 3-2 Forms for the Financial Management at Facilities

Annex 3-1 Cash Flow Projection (Primary School) with Price Escalation

Year	Initial Cost	O&M Cost (KSh)					Revenue (KSh)			Balance (KSh)		**Required Budget Allocation (KSh)**		
		Regular Operation (Local Cost)	Major Replacement Battery (Foreign Cost)	Inverter (Foreign Cost)	CC (Foreign Cost)	Sub-total (1)	Existing Budget (Local)	Charging Service (Local)	Sub-total (2)	Per Year	Accumlation	Initial Cost **REA**	Reguar Operation **Primary**	Major Maintennace **MoEST**
		(a)	(b)	(c)	(d)	(e) =	(f)	(g)	(h) = (f)+(g)	(i) = (h)-(e)	(j) = Σ (i)	(k)	(l) = (a) - (h)	(m) =
0	1,970,000											1,970,000		
1		43,200				43,200	24,960	12,000	36,960	-6,240	-6,240	0	6,240	0
2		46,716				46,716	26,992	12,977	39,969	-6,748	-12,988	0	6,748	0
3		50,519				50,519	29,189	14,033	43,222	-7,297	-20,285	0	7,297	0
4		54,631				54,631	31,565	15,175	46,740	-7,891	-28,176	0	7,891	0
5		59,078	576,660			635,739	34,134	16,411	50,545	-585,194	-613,370	0	8,534	576,660
6		63,887				63,887	36,913	17,747	54,659	-9,228	-622,598	0	9,228	0
7		69,088		427,235	145,371	641,694	39,917	19,191	59,109	-582,586	-1,205,184	0	9,979	572,606
8		74,712				74,712	43,167	20,753	63,920	-10,792	-1,215,976	0	10,792	0
9		80,793				80,793	46,681	22,443	69,123	-11,670	-1,227,646	0	11,670	0
10		87,370	628,915			716,285	50,480	24,269	74,750	-641,535	-1,869,181	0	12,620	628,915
11		94,482				94,482	54,589	26,245	80,834	-13,647	-1,882,828	0	13,647	0
12		102,172				102,172	59,033	28,381	87,414	-14,758	-1,897,587	0	14,758	0
13		110,489				110,489	63,838	30,691	94,530	-15,960	-1,913,546	0	15,960	0
14		119,483		482,401	164,142	766,026	69,035	33,190	102,224	-663,801	-2,577,347	0	17,259	646,543
15		129,209	685,905			815,114	74,654	35,891	110,546	-704,569	-3,281,916	0	18,664	685,905
16		139,727				139,727	80,731	38,813	119,544	-20,183	-3,302,099	0	20,183	0
17		151,100				151,100	87,302	41,972	129,275	-21,826	-3,323,925	0	21,826	0
18		163,400				163,400	94,409	45,389	139,798	-23,602	-3,347,527	0	23,602	0
19		176,701				176,701	102,094	49,084	151,177	-25,523	-3,373,050	0	25,523	0
20		191,084				191,084	110,404	53,079	163,483	-27,601	-3,400,651	0	27,601	0
Total	1,970,000	2,007,843	1,891,481	909,636	309,513	5,118,472	1,160,087	557,734	1,717,821	3,400,651	-	1,970,000	290,022	3,110,630
Annual Avg.	-	100,392	94,574	45,482	15,476	255,924	58,004	27,887	85,891	170,033	-	-	14,501	155,531

Note:
1. Price escalation applied — Local Cost 8.14% — Average inflation rates (2010-2014) in IMF World Economic Outlook Database (October 2014)
Foreign Cost 1.75%
2. Revenue projection — It is assumed that the existing budget and charging service revenue will increase at the same rate of price escalation.

Annex 3-2 Forms for the financial management at facilities

1. Daily Sales Record

Daily Business Record of ________________________Dispensary / Primary School

Sheet No. :				
Date: ________	Weather:_____________			
No.	**Name of Customer**	**Type of appliance ***	**Amount (KSh.)**	**Comment/ Remarks/ Complaints** e.g. customer misplaced receipt
1.				
2.				
3.				
4.				
5.				
6.				
7.				
8.				
9.				
10.				
11.				
12.				
13.				
14.				
15.				
16.				
17.				
18.				
19.				
20.				
21.				
22.				
23.				
24.				
25.				
Daily Total		Phone: Lantern: Battery: Clippers: Other (Hair cut etc.):		
Daily Totals checked by: _______________ **signature:** _______________				
of appliance: mobile phone, LED lantern, rechargeable battery, hair clippers, other (specify)				

The treasurer gives a number to the sheet and issues this sheet to the secretary who issues it to the operator. At the end of the day, the operator returns the sheet to the treasurer who verifies the cash collected against this sheet. When the number of customers exceeds 25 persons, continue recording on the Sheet 2 and input the daily total at the bottom of Sheet 2.

2. Sales Receipt

CASH SALE RECEIPT			No.
Name of Customer			**Dispensary/ School**
	P.O. BOX		
Mobile phone:	**DATE: / /**		
No.	**DESCRIPTIONOFMOBILE/LANTERN/ HAIR SHAVING/ etc.**		**AMOUNT(Ks.h)**
		Total	
Received by:	**Signature:**		

3. Cash Book

CASH BOOK FOR ______________ DISPENSARY/ PRIMARY SCHOOL

Month/Year: ___________			Sheet No. : _1_		
Date	**Revenues**		**Expenses**		**Balance (KSh.)**
	Item	**Amount (KSh.)**	**Item**	**Amount (KSh.)**	
1.					
2.					
3.					
4.					
5.					
6.					
7.					
8.					
9.					
10.					
11.					
12.					
13.					
14.					
15.					
16.					
17.					
18.					
19.					
20.					
21.					
22.					
23.					
24.					
25.					
26.					
27.					
28.					
29.					
30.					
31.					
Monthly Total					

Monthly Totals
Checked by: ________________________
signature: _________________________

The Cash book is kept by the treasurer who makes entries.

4. Monthly Record

MONTHLY REPORT OF ______________________ DISPENSARY/ PRIMARY SCHOOL

Month/Year: ___________		Sheet No. : _1__	
Income in the month (KSh.)		**Expenditure in the month (KSh.)**	
Cash Balance last Month (a)		1. Operation cost	
1. Revenue from charging service (b)		(1)	
2. Other revenues:		(2)	
		(3)	
		(4)	
		(5) Miscellaneous	
Sub-total (c)		Sub-total (e)	
3. Withdrawals from Bank		2. Maintenance cost	
Date			
Date			
Date			
Sub-total (d)		Sub-total (f)	
		3. Administration cost	
		- transportation	
		- committee expenses	
		- meeting expenses	
		- bank charge	
		- others	
		Sub-total (g)	
		5. Deposit to bank (h)	
Cash Income Total (a)+(b)+(c)+(d)		**Cash Expenditure Total** (e)+(f)+(g)+(h)	
Balance (Cash income carried forward)		Ksh	

BANK CONTROL	Unit: Ksh		
Balance in last month		Withdrawals in this month (d)	
Deposit in this month (h)			
Deposit Total		**Withdrawals Total**	
Balance (Cash income carried forward)		KSh.	

Annex 4 Solar Irradiation Data in Kenya

Annex 4 Solar Irradiation Data in Kenya

Monthly Averaged Insolation Incident on Horizontal Surface (kWh/m^2/day)

Data : 1983 to 2005 (22-year Average)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation (m)
Lat 4 to 5 Lon 34 to 35	6.07	6.34	5.94	5.44	5.53	5.37	5.33	5.63	6.22	5.66	5.42	5.72	5.71	575
Lat 4 to 5 Lon 35 to 36	6.16	6.51	6.17	5.64	5.71	5.65	5.66	6.02	6.47	5.8	5.55	5.89	5.93	654
Lat 4 to 5 Lon 36 to 37	6.16	6.49	6.29	5.79	5.74	5.65	5.7	6.09	6.35	5.8	5.66	5.93	5.96	604
Lat 4 to 5 Lon 37 to 38	6.27	6.58	6.35	5.72	5.68	5.46	5.45	5.89	6.19	5.58	5.55	5.96	5.88	1104
Lat 4 to 5 Lon 40 to 41	6.52	6.95	6.41	5.37	5.09	4.22	4.16	4.73	5.51	4.95	5.22	5.95	5.41	887
Lat 3 to 4 Lon 34 to 35	6.12	6.44	6.13	5.54	5.53	5.31	5.24	5.65	6.3	5.79	5.49	5.82	5.77	1096
Lat 3 to 4 Lon 35 to 36	6.18	6.58	6.39	5.8	5.79	5.66	5.71	6.17	6.62	6.06	5.68	5.87	6.03	586
Lat 3 to 4 Lon 36 to 37	6.37	6.72	6.6	6.06	5.99	5.84	5.97	6.38	6.76	6.19	5.87	6.11	6.23	526
Lat 3 to 4 Lon 37 to 38	6.49	6.9	6.74	6.01	6.05	5.88	6.09	6.46	6.97	6.24	5.86	6.15	6.31	645
Lat 3 to 4 Lon 38 to 39	6.39	6.85	6.49	5.6	5.47	5.24	5.37	5.78	6.26	5.65	5.41	5.9	5.86	835
Lat 3 to 4 Lon 39 to 40	6.4	6.81	6.34	5.23	4.91	4.32	4.32	4.82	5.48	4.97	5.08	5.79	5.36	902
Lat 3 to 4 Lon 40 to 41	6.52	6.98	6.41	5.19	4.95	4.26	4.23	4.76	5.58	4.84	4.87	5.77	5.35	636
Lat 3 to 4 Lon 41 to 42	6.54	6.98	6.57	5.46	5.25	4.68	4.65	5.15	5.82	5.09	5.05	5.88	5.58	419
Lat 2 to 3 Lon 34 to 35	6.23	6.56	6.3	5.8	5.65	5.47	5.44	5.86	6.44	6.02	5.72	6.01	5.95	1242
Lat 2 to 3 Lon 35 to 36	6.23	6.67	6.44	5.94	5.84	5.57	5.55	6	6.59	6.17	5.71	5.93	6.04	803
Lat 2 to 3 Lon 36 to 37	6.18	6.54	6.49	6.1	5.96	5.7	5.8	6.21	6.71	6.26	5.66	5.78	6.11	674
Lat 2 to 3 Lon 37 to 38	6.13	6.62	6.49	5.96	5.84	5.55	5.86	6.2	6.79	6.14	5.54	5.67	6.06	562
Lat 2 to 3 Lon 38 to 39	6.23	6.73	6.39	5.66	5.89	5.64	5.8	6.18	6.68	5.99	5.27	5.58	5.99	511
Lat 2 to 3 Lon 39 to 40	6.3	6.73	6.12	5.28	5.3	4.98	4.98	5.35	5.95	5.29	4.84	5.43	5.53	434
Lat 2 to 3 Lon 40 to 41	6.41	6.8	6.23	5.3	5.12	4.59	4.55	4.97	5.67	5.01	4.78	5.56	5.41	411
Lat 1 to 2 Lon 34 to 35	6.15	6.51	6.31	5.93	5.69	5.53	5.43	5.79	6.34	6.02	5.69	5.93	5.93	1515
Lat 1 to 2 Lon 35 to 36	6.2	6.67	6.44	5.94	5.76	5.38	5.21	5.55	6.34	5.97	5.54	5.88	5.9	1436
Lat 1 to 2 Lon 36 to 37	6.49	6.98	6.68	6.2	6.2	5.94	5.89	6.26	6.9	6.29	5.65	6.05	6.28	1179
Lat 1 to 2 Lon 37 to 38	6.3	6.85	6.58	6.02	5.99	5.68	5.72	6.11	6.83	6.21	5.47	5.74	6.12	912
Lat 1 to 2 Lon 38 to 39	6.07	6.67	6.39	5.89	6	5.78	5.89	6.27	6.84	6.28	5.39	5.46	6.07	361
Lat 1 to 2 Lon 39 to 40	6.02	6.44	6.11	5.68	5.87	5.58	5.63	5.97	6.39	5.88	5.12	5.3	5.82	261
Lat 1 to 2 Lon 40 to 41	6.11	6.51	6.17	5.62	5.46	5.01	5.03	5.38	5.87	5.48	5.08	5.43	5.59	194
Lat 0 to 1 Lon 34 to 35	6.24	6.58	6.39	5.86	5.6	5.39	5.25	5.6	6.14	5.97	5.7	6.02	5.89	1465
Lat 0 to 1 Lon 35 to 36	6.24	6.71	6.59	5.94	5.68	5.33	5.09	5.33	6.19	5.97	5.62	6.05	5.89	1848
Lat 0 to 1 Lon 36 to 37	6.48	7	6.73	6.16	6.11	5.82	5.66	6	6.78	6.22	5.58	5.99	6.2	1694
Lat 0 to 1 Lon 37 to 38	6.47	7.05	6.71	6.18	6.07	5.75	5.72	6.08	6.86	6.24	5.45	5.86	6.19	1327
Lat 0 to 1 Lon 38 to 39	6.07	6.69	6.45	6	6.12	5.72	5.86	6.25	6.86	6.36	5.39	5.48	6.1	504
Lat 0 to 1 Lon 39 to 40	5.78	6.22	6.15	5.9	5.9	5.6	5.7	6.04	6.5	6.17	5.39	5.34	5.88	225
North Avg.	**6.26**	**6.69**	**6.39**	**5.76**	**5.69**	**5.38**	**5.39**	**5.79**	**6.37**	**5.84**	**5.43**	**5.79**	**5.89**	**819**

Monthly Averaged Insolation Incident on Horizontal Surface (kWh/m^2/day)

Data : 1983 to 2005 (22-year Average)

Month / Lon & Lat	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Average	Average Elevation (m)
Lat 0 to -1 Lon 34 to 35	6.42	6.78	6.64	6.2	6.03	5.86	5.81	6.26	6.53	6.21	5.99	6.28	6.24	1346
Lat 0 to -1 Lon 35 to 36	6.19	6.68	6.46	5.74	5.5	5.36	5.24	5.58	6.08	5.79	5.42	5.9	5.82	2151
Lat 0 to -1 Lon 36 to 37	6.21	6.72	6.43	5.66	5.61	5.32	5.16	5.48	6.19	5.7	5.14	5.74	5.77	2287
Lat 0 to -1 Lon 37 to 38	6.06	6.69	6.25	5.52	5.24	4.76	4.66	4.91	5.81	5.5	4.88	5.46	5.47	1502
Lat 0 to -1 Lon 38 to 39	5.9	6.58	6.27	5.87	5.56	4.91	4.9	5.24	6.22	6.13	5.31	5.43	5.68	558
Lat 0 to -1 Lon 39 to 40	5.53	6.05	6.02	5.76	5.48	5.09	5.24	5.57	6.15	6.07	5.36	5.25	5.62	221
Lat 0 to -1 Lon 40 to 41	5.69	6.13	6.03	5.74	5.31	4.92	5.03	5.33	5.77	5.79	5.48	5.38	5.54	130
Lat -1 to -2 Lon 34 to 35	6.12	6.51	6.42	5.98	5.83	5.76	5.74	6.06	6.37	6.26	5.8	5.95	6.06	1449
Lat -1 to -2 Lon 35 to 36	6.1	6.58	6.49	5.95	5.69	5.53	5.48	5.81	6.3	6.08	5.6	5.82	5.94	1886
Lat -1 to -2 Lon 36 to 37	6.42	6.86	6.66	5.83	5.36	5.11	5.23	5.55	6.37	6.13	5.59	6.06	5.92	1490
Lat -1 to -2 Lon 37 to 38	6.41	6.94	6.41	5.58	4.95	4.37	4.26	4.55	5.72	5.77	5.23	5.81	5.49	1332
Lat -1 to -2 Lon 38 to 39	5.83	6.46	6.14	5.68	5.18	4.58	4.61	4.94	5.87	5.96	5.31	5.49	5.49	630
Lat -1 to -2 Lon 39 to 40	5.44	5.94	5.98	5.69	5.16	4.76	4.84	5.13	5.77	5.93	5.44	5.32	5.44	180
Lat -1 to -2 Lon 40 to 41	5.54	5.94	5.92	5.61	5.03	4.68	4.8	5.15	5.62	5.71	5.51	5.39	5.4	68
Lat -1 to -2 Lon 41 to 42	5.69	6.13	6.02	5.41	4.84	4.58	4.87	5.28	5.65	5.64	5.35	5.36	5.39	17
Lat -2 to -3 Lon 36 to 37	6.42	6.84	6.51	5.82	5.38	5.27	5.47	5.79	6.43	6.28	5.69	5.97	5.98	1285
Lat -2 to -3 Lon 37 to 38	6.29	6.77	6.32	5.55	4.91	4.5	4.54	4.86	5.88	5.99	5.5	5.77	5.56	1256
Lat -2 to -3 Lon 38 to 39	5.98	6.52	6.17	5.66	5.01	4.55	4.59	4.94	5.86	6.05	5.48	5.62	5.53	554
Lat -2 to -3 Lon 39 to 40	5.55	6.02	6	5.67	4.99	4.68	4.75	5.01	5.68	5.9	5.56	5.44	5.43	173
Lat -2 to -3 Lon 40 to 41	5.55	5.96	5.95	5.47	4.79	4.57	4.72	5.16	5.7	5.8	5.54	5.41	5.38	24
Lat -3 to -4 Lon 37 to 38	6.2	6.55	6.02	5.24	4.55	4.26	4.44	4.88	5.79	5.98	5.58	5.74	5.43	1198
Lat -3 to -4 Lon 38 to 39	6.18	6.57	6.04	5.32	4.59	4.32	4.37	4.7	5.58	5.85	5.57	5.79	5.39	695
Lat -3 to -4 Lon 39 to 40	5.71	6.2	5.95	5.43	4.75	4.55	4.61	4.87	5.51	5.76	5.55	5.54	5.36	188
Lat -3 to -4 Lon 40 to 41	6.24	6.57	6.51	5.6	4.8	4.75	4.91	5.63	6.3	6.4	6.27	6.15	5.83	1
Lat -4 to -5 Lon 38 to 39	6.08	6.43	5.92	5.15	4.32	4.16	4.28	4.63	5.46	5.75	5.65	5.73	5.29	632
Lat -4 to -5 Lon 39 to 40	5.8	6.07	5.7	5.15	4.58	4.49	4.58	4.86	5.46	5.56	5.55	5.63	5.28	54
South Avg	**5.98**	**6.44**	**6.20**	**5.63**	**5.13**	**4.83**	**4.89**	**5.24**	**5.93**	**5.92**	**5.51**	**5.67**	**5.61**	**820**
Country Avg.	**6.12**	**6.56**	**6.30**	**5.70**	**5.41**	**5.11**	**5.14**	**5.51**	**6.15**	**5.88**	**5.47**	**5.73**	**5.75**	**819**

Source : NASA (http://eosweb.larc.nasa.gov/)
Lat : Latitude
Lon : Longitude
' - ' : South hemisphere