4) Operation Data on PV Systems for Household

The expected energy use and the actual energy used from each of the two household systems which included a data logger are listed below. The data analysis methodology used to generate these figures are the same as those for the systems designed for use in clinics and schools.

For the household PV systems, Table 4-15 shows the results compiled from the operation data collected continuously at one home in the Turf together with the design values. The values in the "PV System Design" section are the basis of the design values used. In other words, each system uses one 25W PV module, and the design assumes 5.41 kWh/m^2/day (the figure for December, when the amount of solar irradiation on the tilted surface is lowest) as the amount of energy that would strike the PV module.

Table 4-15 Operating Characteristics of Household PV Systems

Item	Design Value	Actual Value Turf	Actual Value Sanyati
Irradiation on a tilted surface (kWh/m^2)	5.41	6.37	6.95
Storage battery charging current (Ah)	8.87	8.81	6.78
Planned supply capable current (Ah)	4.61	—	
Load current (Ah)	4.60	4.3	7.31
Load duration (h)	4.0	5.3	7.2
Maximum storage battery voltage (V)	(14.5)	14.40	13.20
Minimum storage battery voltage (V)	(11.5)	12.58	11.97

Details on the expected load is repeated below.

Planned load: 4.61Ah

Breakdown :

Type	Spec.	Lighting hour (h)	Current consumption (Ah)
Fluores. lamp	FL 7W #1	4 h	2.36
Fluores. lamp	FL 7W #2	0 h	0
Radio	9V / 5W	4 h	2.24
Total			4.60

a) Charging of the Storage Battery

Table 4-15 shows that the average daily charging of the storage battery was 8.81 Ah, which is close to the design value. The storage battery charging pattern for the household PV systems was completely different from that for the clinic systems. One reason for this is that the load was much greater relative to the panel size, so the storage battery was not normally in a fully charged state each day and it thus readily accepted the charging current from the panel. Another reason is that the charge controller installed in the system was faulty and had been bypassed. This meant that the PV module was never disconnected from the storage battery.

Using Equation 3-6 to verify the charging current a value of 6.37 kWh/m^2/day was assumed for the amount of solar irradiation (Q), to calculate the maximum possible charge, 8.36 Ah/day. Since the charging current falls as the battery voltage rises, the actual figure of 8.81Ah for the charging energy is reasonable.

b) Load Energy Use

According to the information from the data logger, the household energy usage was higher than that of the public facilities. Table 4-10 indicates an average daily energy usage of 4.3Ah, or 93% of the available energy supply. The average daily energy usage duration of around 5.3 hours also shows that the system was used as designed.

Also, from Table 4-10, it is indicated that daily average electricity consumption between August1997 to May 1998 was 2.83 Ah when the PV system was initially installed and December. This value is about 61 % of the maximum possible design electricity supply. Daily average electricity consumption time was 3.38 hours and shows a good consumption characteristic.

We note that when the system was first installed, the household sometimes ran the lamps or TV six or seven hours a day. We believe that this is the level of usage that they would actually wish to have, if possible. Since the 25Wp systems could not supply this level of energy, after initially running the battery down and having the controller disconnect the load for several days, the users began to heed the instructions given and limited their time to around 4 hours. After the initial overuse of the system, the users managed the system sufficiently well to avoid many disconnects by the controller.

Running a TV with the 25W system was not assumed in the initial design. However, it is now clear that people have a strong desire to watch TV and we cannot ignore this even with our small system of around 25Wp.

In the household in Sanyati where data collection was started from November, the load demand was extremely high when compared to the Turf household analyzed above.

As shown as Table 4-11, the average load demand during December, 1997 was 7.3 Ah/day and far above the design value. According to Table 4-11, the average load from November, 1997 to April 1998 was 4.64Ah which exceeds a design value a little bit but that is still significantly larger than the design value. The average load consumption time was about 4.64 hours per day,which is limite of 25W system.

Considering that the loads are high for the household systems in relation to the size of the panel, it is essential to minimize the power consumption of the charge controller while insuring proper charge control and over-discharge control is carried out to prevent damage to the battery. Many designs for charge controllers are not acceptable for these small 25Wp systems though they may be entirely adequate for larger systems. Therefore, a charge controller specially designed to suit the characteristics of a small system needs to be used.

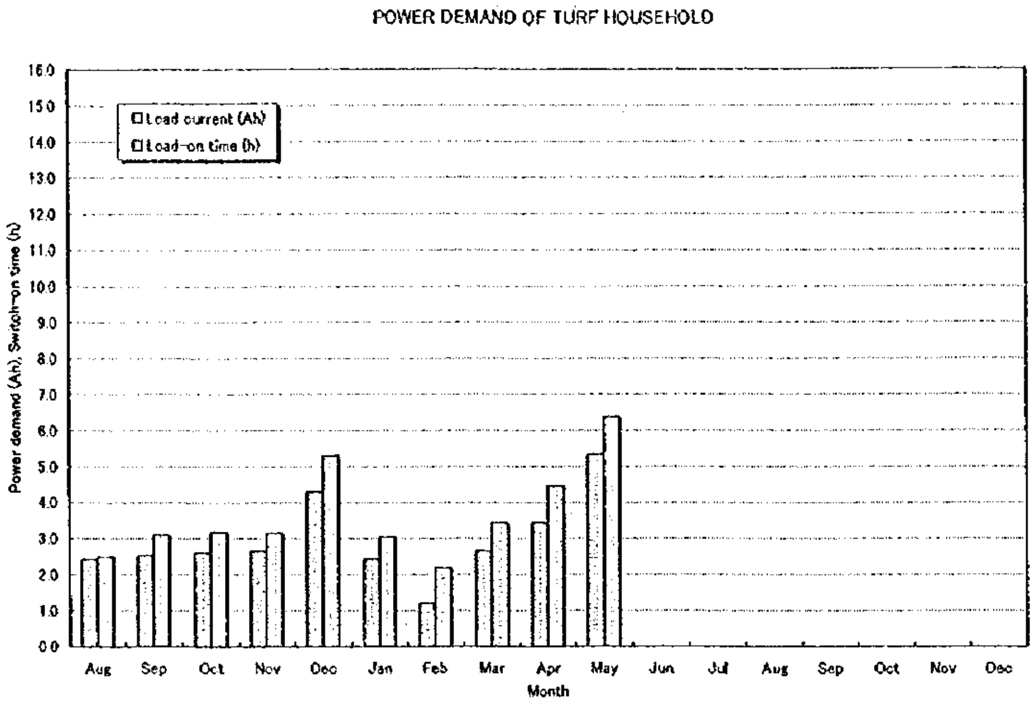


Figure4-31 Power Demand of the Turf Household

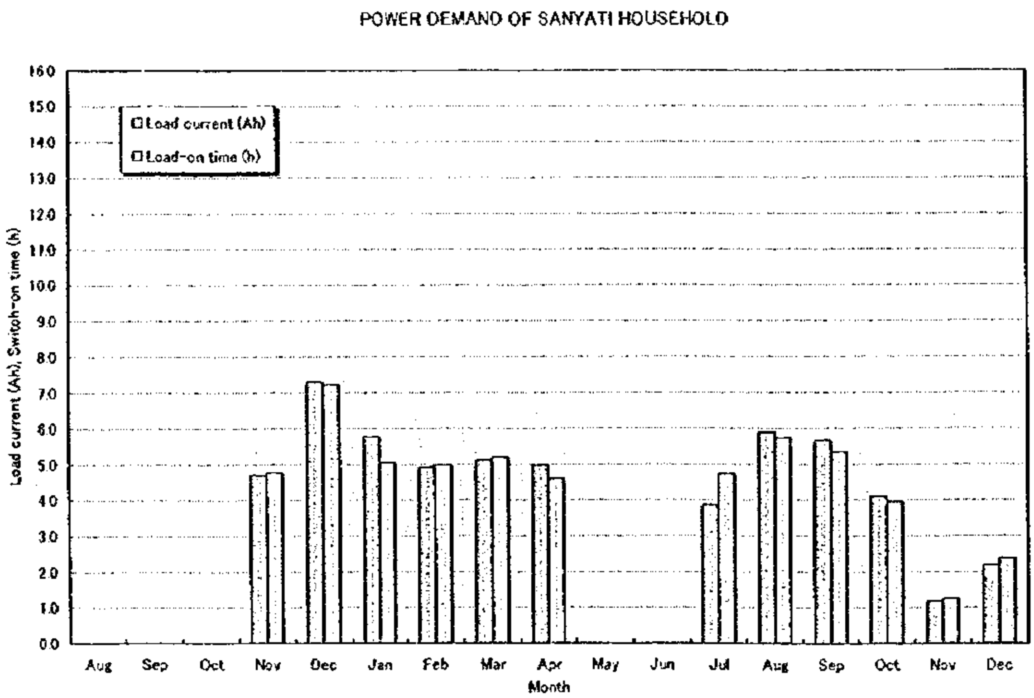


Figure4-32 Power Demand of the Sanyati Household

5) Behavior of Storage Battery Voltage

Methods for determining the operating characteristics of the storage battery in a small-capacity PV system are a) measure the specific gravity of the battery's electrolyte and b) measure the battery's voltage.

Specific gravity is measured by BUN personnel as part of the system's routine maintenance but is very difficult to use for an automatic control of battery charge and discharge. Measuring the voltage is the easiest way to estimate battery charge level and can be accomplished by using an automated measuring device. Virtually all charge and discharge controllers in use rely on voltage measurements to determine battery charge level.

However, variations in operating parameters, such as the charging current, the temperature of the electrolyte and the history of the battery can affect the relationship between terminal voltage and charge. In practice it is difficult to accurately determine the battery state of charge from the battery voltage alone.

Table 4-16 shows values for the maximum and minimum battery voltage obtained from the data loggers for 10 day periods.

From Table 4-16, it appears that the working voltage of the battery in each system is reasonable. The working voltage of the battery is different for the two types of controllers used and also is affected by the level of electricity consumption. Fig 4-33 to Fig.4-36 is graphical image of Table 4-16.

Battery voltage of the Turf Clinic system:

The maximum average value was 14.35 V (range13.99 V to 14.51 V) for the entire test period. Before replacement of the locally made charge controller by the improved JICA one, the maximum battery charge voltage was 14.12 V (range 13.99 to 14.21V). After replacing the controller, the maximum voltage increased to 14.39 V (range 14.11 to 14.51 V) in November and December. Before replacement of the local charge controller with the improved one from JICA, the maximum battery voltage was 14.1 V, considerably lower than the design value of 14.5 V even though the cut off set point was 14.4V. The reason is that the controller did not reconnect the battery once the cut off voltage was reached and the average battery voltage could not reach the design value. After replacement with the JICA controller, the voltage increased to 14.4 V or as intended in the design.

The average minimum value for the entire test period was 12.49V (range 12.86 to 11.53 V). The load was low during the period analyzed and the protection level of 11.5 V was not reached. Before November, 11 when a locally made charge controller was used, the average minimum battery charge voltage was 12.48 V (range 12.43 to 12.52 V), but, after November, 12 when an improved JICA charge controller was installed, the average minimum voltage increased to 12.75 V (range 12.64 to 12.86 V). This indicates that the charge controller is recharging the battery more completely than the locally made controller.

Fig. 4-33 shows the Turf Clinic's battery voltage. The data shows that the battery's maximum voltage is controlled at 14.5V in December, 1997 which is after the installation of the JICA-improved type charge.

From August 1998, when one year has passed from installing systems, voltage of batteries were decreasing, which means the life of local-made battery is almost over.

Table 4-16 The Maximum and Minimum Battery Voltage

	Turf Clinic		Tongwe Clinic		Turf Household		Sanyati Household	
Term	Max Volt	Min Volt	Max Volt	Min Volt	Max Volt	Min Volt	Max Volt	Min Volt
Aug/1-10	14.2	12.48	14.14	12.21	12.18	10.65		
Aug/11-20	14.21	12.48	14.17	12.34	12.48	11.9		
Aug/21-30	14.2	12.5	14.18	12.24	12.8	12.04		
Sep/1-10	14.19	12.52	14.17	12.27	12.84	12.06		
Sep/11-20	14.02	12.43	13.93	12.31	13.21	12.14		
Sep/21-30	13.99	12.49	14.14	12.25	14.21	12.41		
Oct/1-10	14.17	12.49	14.14	12.29	14.47	12.48		
Oct/11-20	14.11	12.46	14.18	12.2	14.46	12.51		
Oct/21-30	14	12.48	14.14	12.24	14.65	12.55		
Nov/1-10	14.17	12.47	13.97	12.24	14.56	12.59	10.51	8.5
Nov/11-20	14.35	12.68	14.06	12.17	14.3	12.59	13.79	12.19
Nov/21-30	14.11	12.7	14.01	12.1	14.44	12.63	13.4	12.09
Dec/1-10	14.45	12.82	14.12	11.99	14.7	12.59	13.39	12.04
Dec/11-20	14.51	12.86	14.11	11.86	14.38	12.58	13.04	11.91
Dec/21-31	14.44	12.81	14.13	11.65	14.1	12.57	13.17	11.95
Jan/1-10	14.42	12.71	14.06	12	14.44	12.60	13.35	12.02
Jan/11-20	14.47	12.64	14.07	11.96	14.60	12.64	13.08	11.92
Jan/21-31	14.43	12.70	13.99	10.88	14.75	12.70		
Feb/1-10	14.49	12.81	14.11	12.22	14.77	12.72		
Feb/11-20	14.46	12.76	14.04	12.21	14.73	12.59	14.33	12.14
Feb/21-28	14.49	12.77	14.09	12.11	14.64	12.55	14.40	12.16
Mar/1-10	14.49	12.77	14.12	12.09	14.43	12.56	14.41	12.16
Mar/11-20	14.44	12.59	13.92	12.02	14.52	12.51	14.17	12.17
Mar/21-31	14.47	12.62	14.14	11.91	14.61	12.49	14.37	12.18
Apr/1-10	14.45	12.60			14.35	12.47	14.38	12.19
Apr/11-20	14.44	12.53			14.04	12.49	14.38	12.18
Apr/21-30	14.46	12.47			14.56	12.56	14.40	12.20
May/1-10	14.46	12.47			14.06	12.51		
May/11-20								
May/21-31								
Jul/1-10								
Jul/11-20								
Jul/21-31	14.48	12.33	14.15	11.96			14.16	10.99
Aug/1-10	14.30	11.72	14.14	11.93			13.81	11.97
Aug/11-20	14.46	11.76	14.19	11.93			13.76	11.94
Aug/21-31	14.46	11.58	14.20	11.96			13.78	11.91
Sep/1-10	14.43	12.12	14.18	11.88			13.61	11.84
Sep/11-20	14.46	12.27	13.96	11.59			13.97	11.97
Sep/21-30	14.43	12.33	14.16	12.03			13.66	11.90
Oct/1-10	14.41	12.44	14.05	11.94			13.76	11.74
Oct/11-20	14.33	12.48	14.16	11.88			13.99	11.66
Oct/21-31	14.36	12.43	14.17	10.83			14.07	10.76
Nov/1-10	14.42	12.52	14.08	10.07			13.85	10.64
Nov/11-20	14.41	12.43	14.15	9.57			14.01	10.45
Nov/21-30			14.48	9.86			14.11	10.43
Dec/1-10			14.67	9.71			14.17	10.16
Dec/11-20								
Average	14.32	12.61	14.09	12.07	14.15	12.42	13.66	11.88

注) ▒▒▒ means the use of JICA-improved charge controller

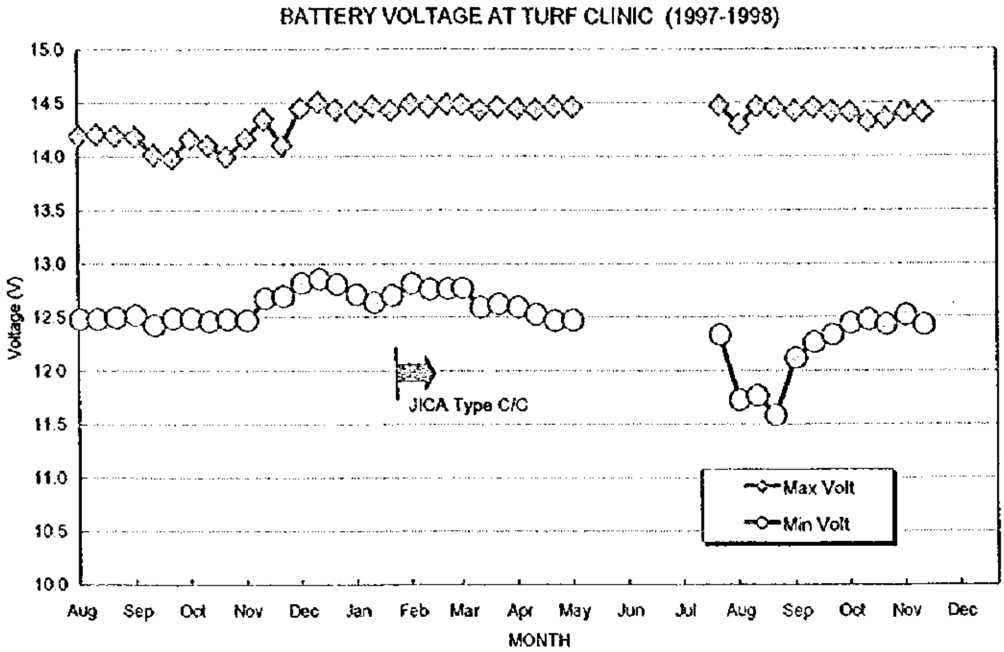


Figure 4-33 Battery Voltage of Turf Clinic

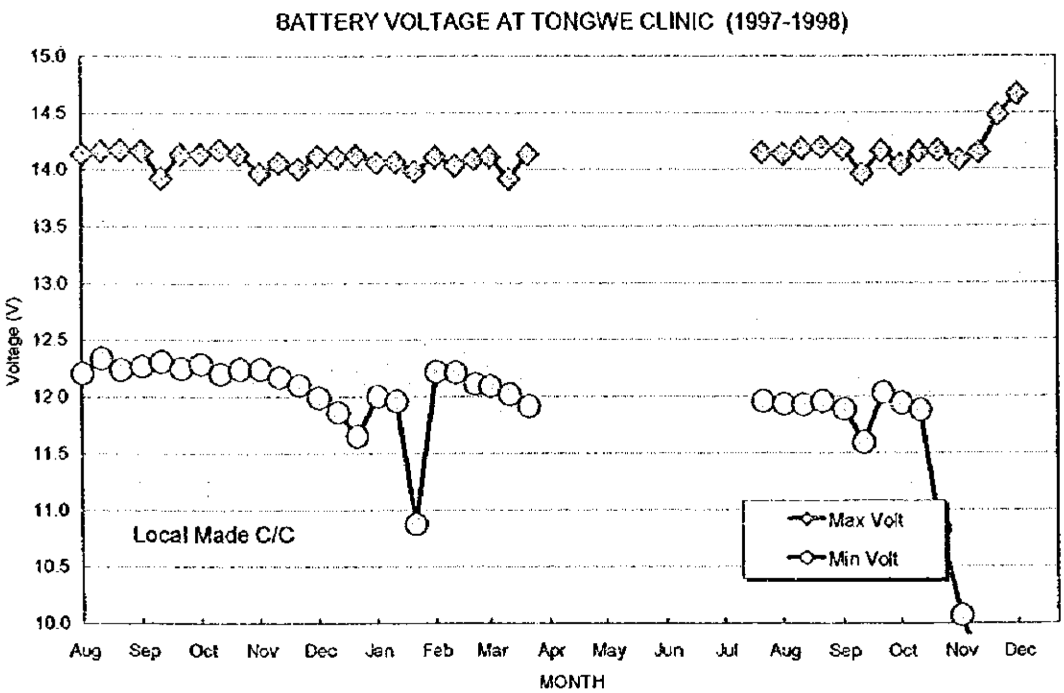


Figure 4-34 Battery Voltage of Tongwe Clinic

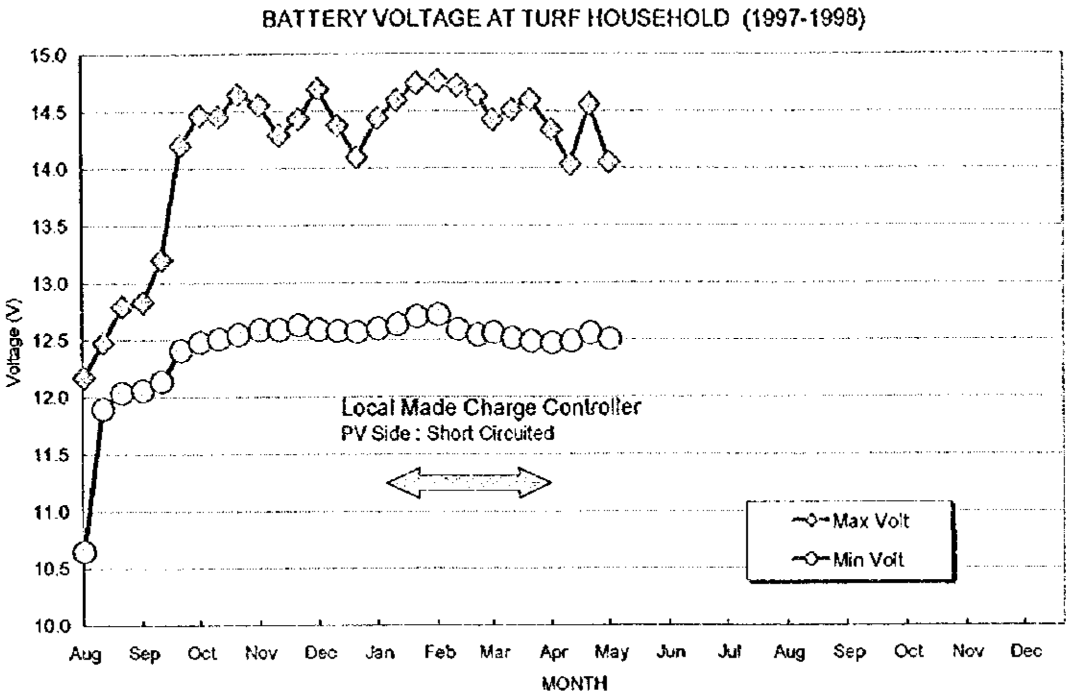


Figure 4-35 Battery Voltage of Turf Household

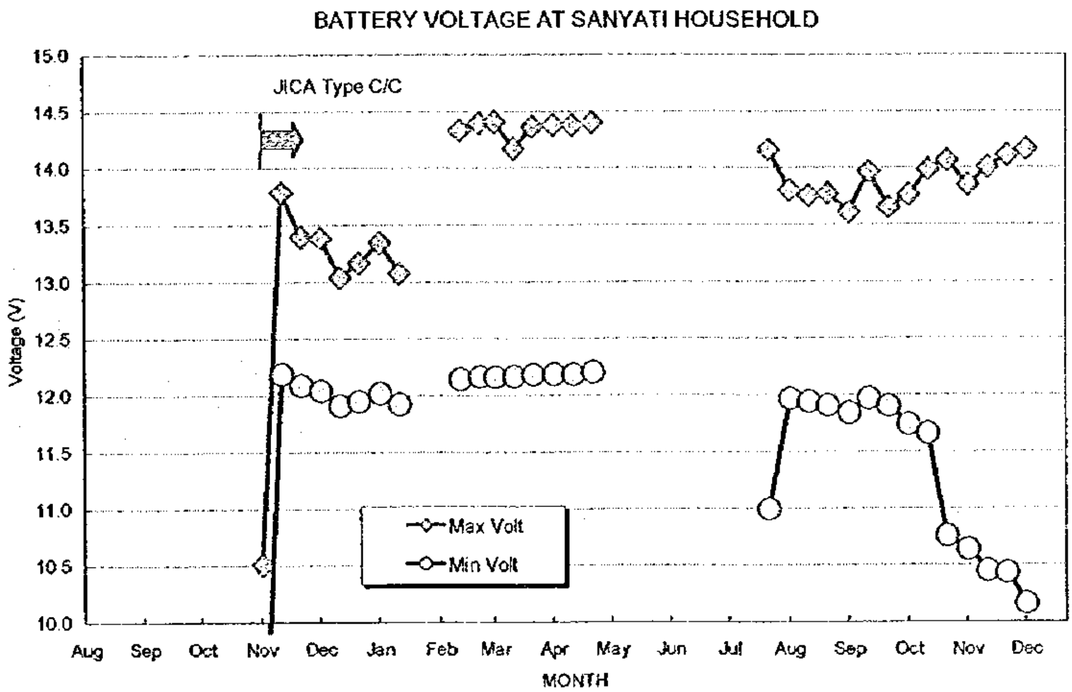


Figure 4-36 Battery Voltage of Sanyati Household

Battery voltage of the Tongwe Clinic system:

The maximum value: average maximum voltage over the period of analysis was 14.13 V (range 13.92 to 14.67 V). At this clinic, charging and discharging control are performed by a locally made charge controller. The charge cut off voltage of the locally made charge controller is 0.3 to 0.4 V lower than the specification value of 14.5 V and consequently the maximum battery voltage is below the design value. At present, there is no particular problem regarding maintenance and control of the system since the load is not large, but some problems concerning the recovery of charge in the battery may appear if the load becomes much larger.

The average minimum battery voltage for the analysis period was 11.76 V (range 9.57 to 12.34 V). The load level was much lower than expected and the LVD voltage of 11.5 V was not reached. Thus the LVD cutoff value was not a problem with the system operation in the same manner as the Turf Clinic system. However, the maximum voltage is considerably lower than the design value and battery charge may be insufficient when the load increases. That will also lower the minimum voltage and load disconnect may occur more frequently. Fig. 4-34 shows the Tongwe clinics' battery voltage. The battery maximum voltage controlled by local-made charge controller is not only 0.4V lower compared to targeted 14.5V, but also the value varies as well.

From October 1998, when one year has passed from installing system, battery voltage became abnormally low and the battery life seems to be almost over.

Battery voltage at the Turf Household system:

The maximum value: average maximum voltage during the analysis period 14.15V (range 12.18 to 14.77 V)

The minimum value: average minimum voltage during the analysis period, 12.42V (range 10.65 to 12.72 V)

A locally made charge controller was installed at this household. Immediately following the installation of the charge controller, a malfunction of the charge controller was experienced and the battery was connected directly to the panel, bypassing all charge control. We note that with the small 25Wp panel used in this system, overcharge damage could not occur with the battery used and electrolyte loss was not observed to be higher than for systems with operating charge controls.

Initially, the average maximum battery voltage was quite low compared to the design voltage level of 14.5 V. The cause was the malfunction of the charge controller component. After connecting the panel directly to the battery, the battery voltage recovered and the maximum voltage increased up to 14.77 V which is somewhat higher than the design level but not damaging to the battery.

Initially, the minimum battery voltage decreased to 10.65V, much lower than the protection level of 11.5V. This was due to the failure of the charge controller not allowing the battery to properly recharge after each day's use. After connecting the panel directly to the battery, the average minimum voltage rose to 12.72V which is well above the LVD setting. Since the load is high for this household system, it is important to determine how much the minimum battery voltage decreases as solar irradiation decreases during the rainy season.

Battery voltage of the Sanyati Household system:

The maximum value: average maximum voltage during the analysis period 13.78V (range 10.51 to 14.41V)

The minimum value: average minimum voltage during the analysis period 11.61V (range 8.50 to 12.20V)

At this household system, operational data acquisition began in November, 1997 when an improved JICA charge controller was installed. The average maximum battery voltage is recognized to be very low. One of the causes is that the voltage just after commencement of data acquisition was extremely low due to problems with the local controller which apparently did not properly disconnect the load at 11.5 V and allowed the battery voltage to drop to unacceptably low values. Even after replacement by an improved JICA one, the voltage did not recover to design values and remained close to the LVD value.

The main reason why recovery of battery voltage did not occur was simply that the load consumption of this household system consistently exceeded the design value. Two months load consumption of this household system in November and December showed 5.97 Ah average daily energy use which is about 30% more than the design value of 4.61

Ah. The average solar irradiation during the same period was 6.23 kWh/m²/day which is about 15% greater than the design value of 5.41 kWh/m²/day making the actual excess demand around 15%. The average electric power consumption time was 5.8 hours on average which was also significantly greater than the design value of 4 hours. After April 1998, the demand is stable because of the household learning how to use the load, and the load level has been matched to the supply level of the system. So, the battery maximum voltage from February is raised to 14.36V and the system had no further trouble.

We can say that from August 1998, when one year has past from installing systems, the battery voltage became low in all systems.

For the countermeasure for it, JICA is now preparing to change the local-made battery with better quality imported one.

This sample household is relatively wealthy with income from a large stand of cotton and has the means and desire to use more electricity than the small system installed by JICA can provide. They have requested a system size increase and are able and willing to pay an increased amount for more electrical service.

Fig. 4-36 shows the Sanyati Household battery voltage.

4.6 Monitoring by BUN

Monitoring was assigned to a non-government organization (NGO) named Biomass Users Network (BUN). In addition to once-a-month monitoring work, BUN is also expected to provide for the maintenance of the systems. The first monitoring assignment, primarily planned for checking the completion of system installation, was conducted jointly with the JICA study team. Later, BUN carried out monitoring work on their own and produced a report in August, 1998. Findings of the completion inspection and BUN's monitoring visits, including both problems found and the state of system utilization, are described below.

4.6.1 Inspection of PV Installation

(1) Installation work

It was found the method of making the holes needed to mount PV array support masts were so rough that the walls were often seriously damaged. Without having proper tools, the workers tried to punch the holes through the soft brick wall with a hammer and screwdriver, chisel or other inappropriate tool. The walls of Zimbabwe houses are easy to drill for mounting holes but using a percussion tool to make the holes leads to serious damage around the holes. Some workers repaired such damage with mortar after they installed the system, while others left damage untouched. Making the holes for PV array poles or conduit pipe should be done with a hand drill.

In many cases the PV arrays were mounted with too much tile and the tilt angle had to be corrected by removing the mountings and reweld them to the proper angle. Also, it was difficult for the installation workers to direct the arrays precisely toward the north. Though these errors usually were not large, unevenness was visible. It was found that some crews had neither compass nor inclinometer and were given a guidance by the inspection team. Those who install the arrays must have at least a compass, an inclinometer, and a level or plumb bob to check that the pole is vertical.

(2) Charge controller

A number of charge controllers were found to be prone to malfunction. In part this can be attributed to lack of post-installation inspections but, the fundamental cause lies in the manufacturing process. Locally-made charge controllers are manufactured by assembling parts procured from abroad. A visit to an assembly plant revealed that the plant workers touched the parts directly with their bare hands, and assembled them by manual soldering. Touching the parts directly with bare hands leaves body oils on the parts which can lead to poor soldering results and, ultimately, to bad connections. Also, if touched directly, some integrated circuits (IC) can be destroyed by static electricity carried with the worker. Thus, assembling the parts by touching them indiscriminately with bare hands is poor practice, because it can lower product quality and increase the rate of product failure.

A commonly used method to avoid touching the parts directly with the fingers is to have the workers use insulated tweezers for parts handling. Also, to prevent IC destruction by static electricity the workers need to wear anti-static working uniforms or wear writs grounding straps. These improvements cost little and need to be introduced immediately by the relevant manufacturers. Also, it is essential for good quality control to separate the functions of manufacture and inspection.

The other cause of malfunction was that the locally-manufactured charge controllers, employed at the beginning of the pilot project, consumed too much electricity by themselves to be used with a system having only 25Wp of panel capacity. To eliminate this problem, the charge controllers for all of the 25Wp systems installed in the 100 households have been replaced with JICA improved models, then monitored from November 1997 through January 1998. Entering the rainy season, load cutoffs attributable to lack of sunshine, as well as external noise induced by lightning, often triggered erroneous load cutoff of the first-generation JICA improved model, and many system outages were reported from January through February. As investigation results showed these troubles stemmed largely from a lack of noise resistance of the charge controllers, it was decided to improve their noise resistance. As a result, the first installation of the JICA charge controllers was replaced by a second-generation model which features outstanding noise resistance while retaining it's advantages over the local controller.

(3) Batteries

The primary concern about the local batteries used is the uneven quality of the battery cells. A battery consists of six 2V cells. Normally these battery cells have an electrolyte specific gravity in the 1.2-1.3 range. An examination unveiled that one out of every six had battery cells with lower than normal specific gravity. When the specific gravity is low, the voltage of the battery cell can rise quickly with limited charging at which point the electric current from the panel will be cut off by the charge controller even though the cell is not actually fully charged. As a result, lights were cut off within an hour at night by the controller due the limited charge available. The monitoring results showed that, in regard to the households, 32 batteries (29 by BUN, 3 by the study team) were removed for apparent failure in a year. Subsequent tests by the battery manufacturer indicate that not all the batteries had actually failed but at least 20 could not be restored to service. To solve this problem requires upgrading of the quality of the local manufacturing process to a level comparable to that used for good quality imported batteries. This will be expensive and take a long time to accomplish.

A primary maintenance requirement is to replace lost electrolyte with distilled water. During this pilot project, two types of batteries, deep cycle and automotive, have been installed at households for evaluation. According to the reports by field technicians since December 1997, the automotive batteries required distilled water once a month, while deep cycle batteries every other month.

(4) Fluorescent lamps and switches

Fluorescent lamps and wall switches were also found to malfunction in service. The failures of fluorescent lamps are due to the use of an inferior electronic ballast. Even the JICA study team found two defective lamps during its brief observation. Even a 1% defect rate is synonymous with poor product reliability and the defect rate for the fluorescent lamps was much higher than that. Many of the malfunctions of wall switches were caused by the fact that the installation workers left a loose wire connection. Another cause of wall switches trouble is contact failure because of poor quality of spring in the switch box.

4.6.2 Evaluation by Users

By August 1998, about one year after installation, the state of system utilization has become clearer. The users in Turf/Manyoni and Sanyati Districts both said they were very much satisfied with their PV systems, though most felt the system capacity too small. Survey results showed that 47 households in Sanyati and 21 in Turf/Manyoni desired capacity expansion. Table 4-17 shows operating conditions of the PV systems, which were summarized from the information gathered by field technicians during their monthly maintenance service visits. The graphs in Figs. 4-37 and 4-38 illustrate the average of the data contained in the aforesaid Table 4-17. Figs. 4-39 and 4-40 give updated data gained in April 1998. Nine months after installation, the April data confirmed that the early problems were cured and that 90% of the installed system have become completely trouble-free.

According to Fig. 4-37, which illustrates average conditions of PV-system operation, about one fourth of the households have experienced some trouble. As shown in Fig. 4-38, about half of the problems were system outages caused by an abnormal voltage drop in the battery due to a poorly functioning charge controller or poor-quality battery cells. Wiring and switch problems represented some 20% followed by the troubles with the lights and blown fuses. The cause of blown fuses is lack of knowledge about electricity. Fuses blowing in most instances were caused by uninsulated radio and TV wires. In most home people use wires as switches instead of actual wall switches. Field technicians are encouraging to insulate any wires used on electric appliances and user training.

The reported system outages included a few cases where charging became impossible as the charge controllers worked erroneously during a thunderstorm. Most of these problems can be attributed to the poor quality of the locally-manufactured parts such as controllers, battery cells and lights, as well as poor installation quality. In addition, some of the first-generation JICA improved model (OCD-02Z Model) controllers, which replaced the locally-manufactured charge controllers, also malfunctioned due to lack of electrical noise resistance and caused problems in many households. Based on such operating records, the initial JICA improved model was replaced with a mass-produced model (OCD-03Z Model) which was less influenced by noise. With regard to the battery cells, which are as important as the charge controller for a PV system, JICA judged that the locally-manufactured ones proved too unstable to keep the system running normally, and decided to replace the batteries with imported units.

Table 4-17 Monitoring Results of Household PV Systems

December 1997～ April 1998 : All system-equipped households covered

<Expressed in household numbers >

Item	Dec.	Jan.	Feb.	Mar.	Apr.	Ave.	Total
Favorable, satisfied	44	53	25	69	84	55	275
Too small system capacity	13	5	6	5	2	6.2	31
Having some troubles	27	34	11	15	8	19	95
<Causes of troubles>							
Charge controller & battery cells	12	23	2	6	2	9	45
Voltage drop	1	0	0	0	0	0.2	1
Fluorescent lamps or fuse	5	4	1	1	2	2.6	13
Wall switches or plugs	1	0	3	4	2	2	10
Loose connection	5	2	1	0	0	1.6	8
Causes attributable to users	3	5	4	4	2	3.6	18
No. of effective respondents	84	92	42	89	94	80.2	401

On top of the regular monitoring results provided by BUN technicians, the state of PV system utilization has been obtained from other sources, including downloading of data from data loggers, system completion tests, and surveys conducted at meetings held for local citizens. Those findings are summarized below.

- All clinics are very grateful for having PV systems installed.
- Many institutions are afraid that their panels will be stolen.
- Clinics find lighting very useful, not merely for consultation and treatment rooms where lights may be used for hours at a time, but also in stockrooms, toilets, etc. which are briefly in use from time to time.
- Benuhra School hopes to have all of its storerooms equipped with electric lamps.

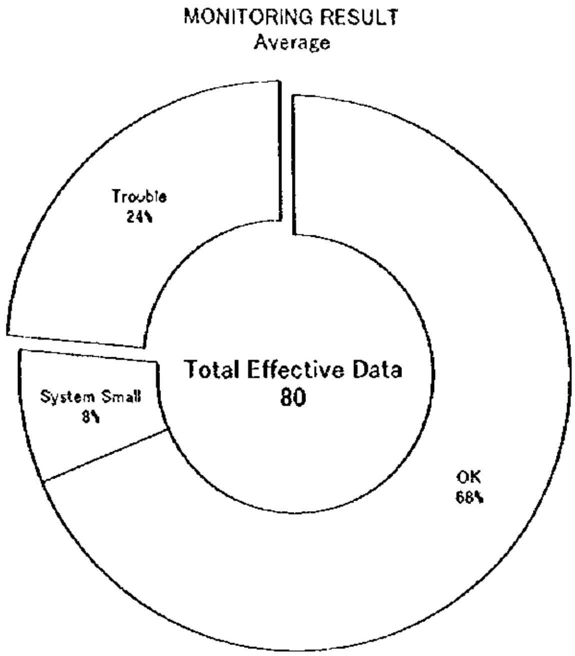


Fig. 4-37 PV System Operating Records (Average)

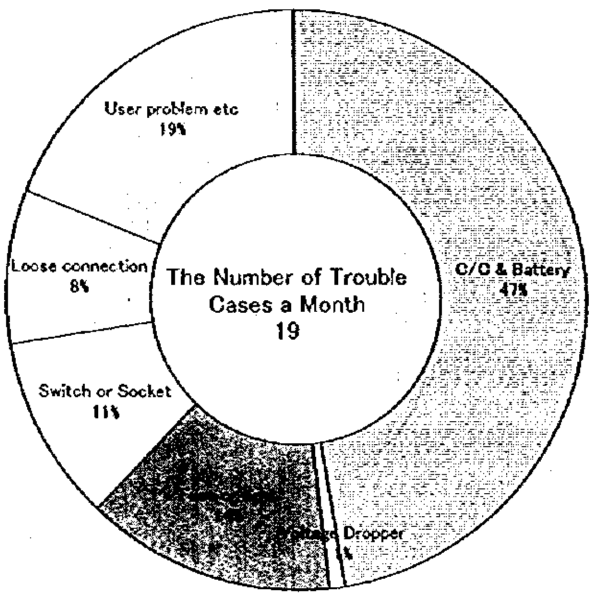


Fig. 4-38 Causes of Trouble (Average)

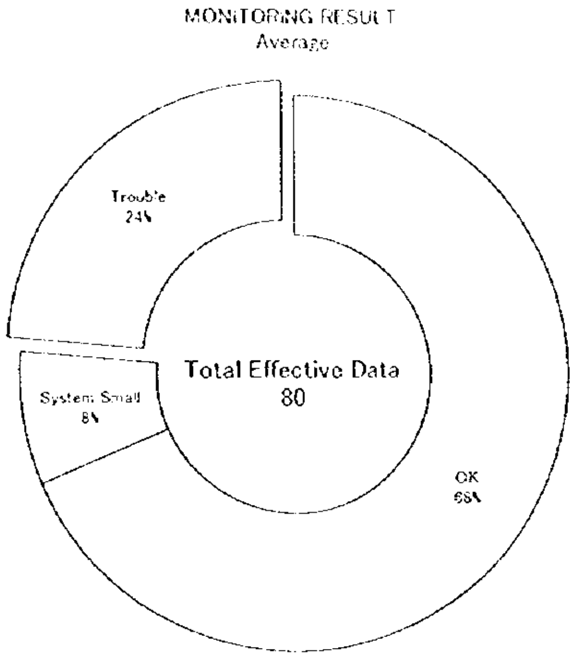


Fig. 4-37 PV System Operating Records (Average)

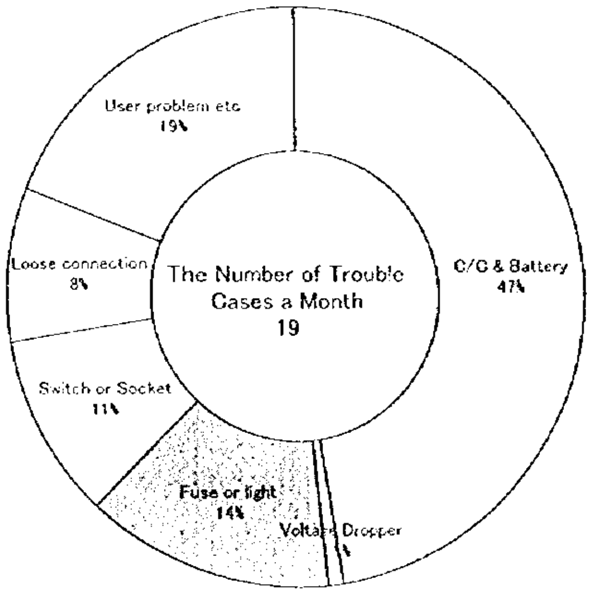


Fig. 4-38 Causes of Trouble (Average)

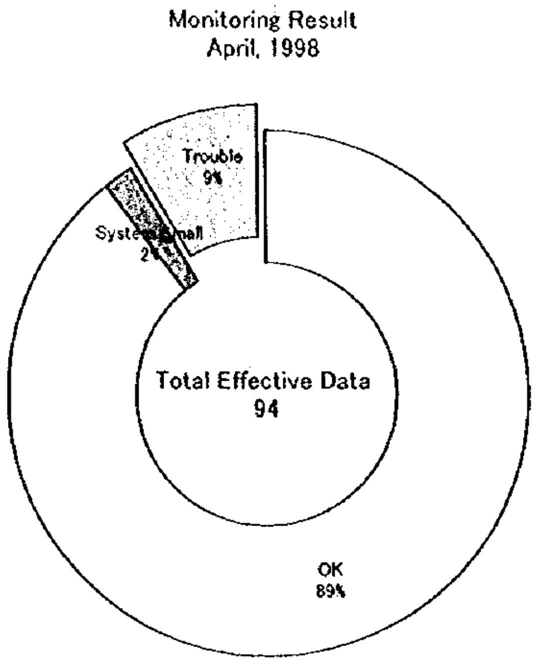


Fig. 4-39 PV System Operating Records (April 1998)

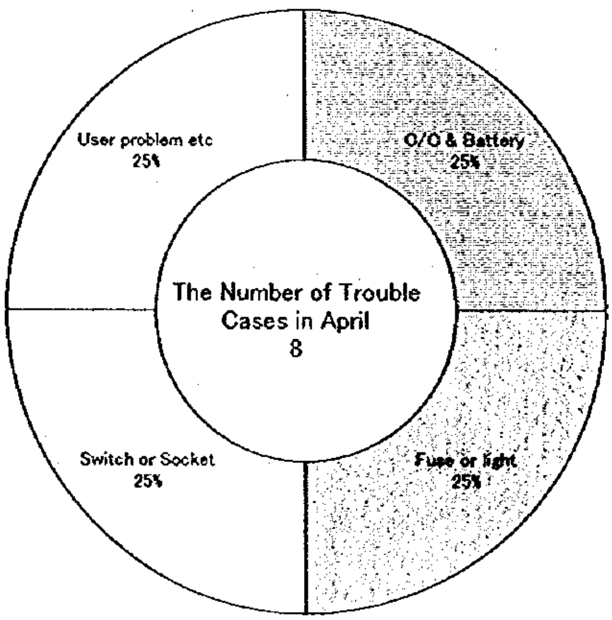


Fig. 4-40 Causes of Trouble (April 1998)

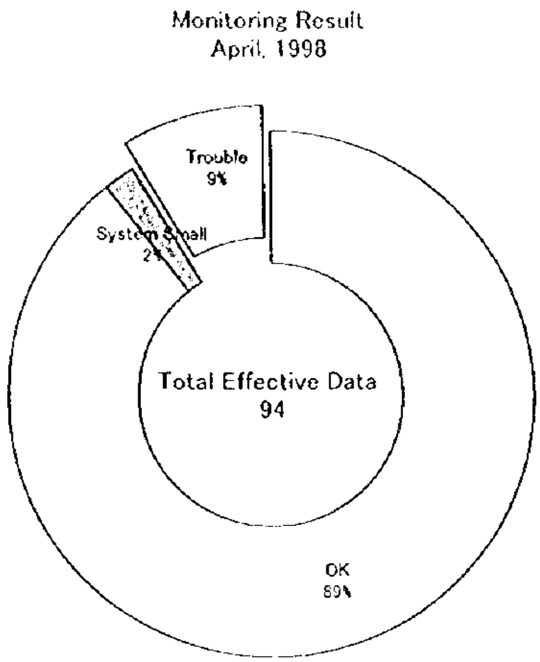


Fig. 4-39 PV System Operating Records (April 1998)

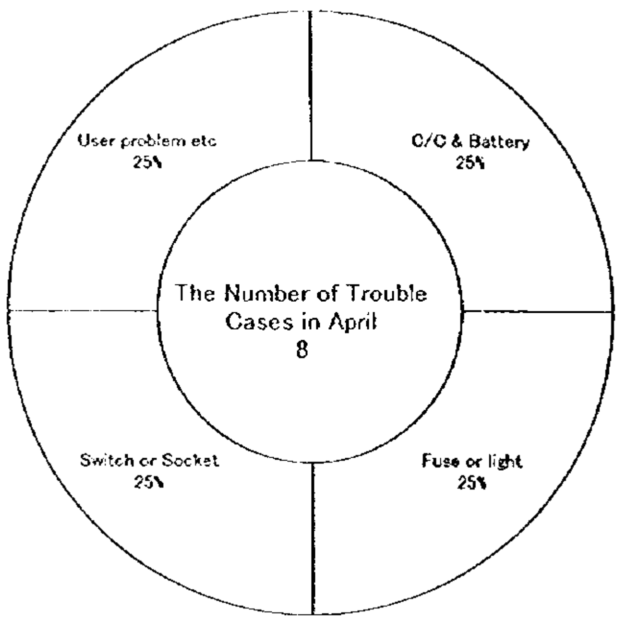


Fig. 4-40 Causes of Trouble (April 1998)

- While 25Wp systems have been installed at households for the pilot project, many of the system-equipped households, wealthy in relative terms, complained of the small capacity. The majority of the households had or wanted TVs. Few of the households appeared to be satisfy with lighting alone. In case PV systems are promoted by introducing a smaller capacity system first, it is recommended to also offer several higher capacity-variable options, easily possible in technical terms by making larger systems multiples of the basic small one, (e.g. 25Wp, 50Wp, 75Wp etc).
- In regard to the PV panel mounting, almost all the households preferred to have their system mounted on the roof in order to make theft more difficult. (Indeed, a panel was stolen from a pole in Turf while the family was out for a few days.)
- The amount to be paid under the JICA approach proved to be favorably accepted by the local people. In particular, many are farmers and have seasonal income so welcomed the opportunity to pay for their systems a year in advance.
- Also because the monthly payment is much lower than the GEF project, the local people prefer the JICA approach even if though it involves a much longer payment period.

4.6.3 Activities of Field Technicians

In order to maintain the PV systems installed for monitoring purpose, BUN trained six local young people in maintenance work and employed two of them as field technicians. One of them is responsible for Sanyati, and the other for Turf and Manyoni (Ngeji District). The field technicians visit the system-equipped households at least once a month, and record their findings as a daily record in a log book. Travelling by bus, they visit BUN's office in Harare once a month to make a report on the maintenance service tour. The items recorded on their daily log include the name of the household visited, date and time of the visit, outdoor temperature, weather on the day of the visit and the day before, specific gravity of battery electrolyte in each cell, electrolyte level, electrolyte temperature, battery voltage, battery terminal conditions, sunshine conditions, and user's comments.

The local technicians are provided by BUN with a kit of necessary tools with a tool box, as well as a bicycle for touring. The range of touring is about 25km (about 300km^2) in Sanyati and Turf alike. In the case of the technician resident in Turf, he is touring not merely Turf but also Manyoni, about 35km away from Turf. To get to Manyoni, he takes a bus with his bicycle tied on its roof. According to the daily reports, the field technicians tour the district, visiting all 50 systems scattered in the 25km-wide area in about a week (about 40-50 hours) if there are no problems. Naturally, more time is involved where troubleshooting and repair is involved.

The field technician in charge of Ngeji District has been touring reliably and has a good reputation among the users. Also, he is competent enough to solve most common problems. On the other hand, the female field technician in charge of Santyati is not so well liked by the users who complained of too infrequent visits. To make it worse, she caused technical problems, such as incorrect wiring after a voltage measurement. Additional training in her technical and general responsibilities appear needed.

4.6.4 Income and Expenditure of BUN

BUN earns its income from the connection charges (Z$750/household) collected from the users prior to the installation of the PV systems, and the annual electricity fees set at Z$900(Z$75/month)/year per household. The connection charge is collected before installation from local households which hope to be equipped with PV systems. This partially pays the installation cost and confirms their will and ability to pay. Government employees who are forced to move from time to time, such as policemen and teachers, were exempted from the connection charge on the grounds that they were not permanent residents. These users are required to pay Z$90 a month. Of 101 households, those special cases numbered only nine. If collections are 100% from the users, BUN's income should amount to Z$161,520 in the first fiscal year, and Z$92,520 a year from the second fiscal year onward. The collected money is to cover the maintenance cost, including that of battery replacement.

The balance sheet as of November 1998 is as shown in Table 4-18. While the installation of systems began July 1997, it was in December of that year before all the systems were installed. The collection rate of the PV connection fee was 100% (except government employees). Because PV system is installed to the user who paid connection fee. The connection fee is very important from the aspect of the stable income. On the other hand, the result of annual income was Z$57,225 to the plan of Z$92,520 and the collection rate was 63%. The results of collection rate by area were Sanyati with 47% and Turf/Manyoni with 79%. In the social survey before installation, the income of Sanyati was higher than Turf/Manyoni. However, the result for one year was opposite to our expectation.

As for this cause, many system troubles were reported on January and February in 1998 because of lack of noise resistance of the charge controllers. At that time, field technician in Turf/Manyoni visited each household enthusiastically. He was making an effort toward the solution and repaired the failed system. On the other hand, field technician in Sanyati area changed two times within one year and in case of the trouble, he could not repair the system due to a lack of experience. The users in Sanyati refused to pay for this period because they could not use the system for long. Thus, fee collection rate does not depend on users' income and depends on the reliability of the system and the ability of field technician. As for these solutions, needless to say, the system should be consisted of the reliability components. In addition, it is very important to train many trouble shooting concerned for field technician in the training course and on the job training.

Total expenditure for one year reaches Z$116,000 and this amounts exceeds the income plan. One of these causes was quality problem of battery and charge controller. Therefore, senior technician visited PV installation sites from Harare many times due to the solution of the problem. As the result, costs of senior technician and transportation exceeded the plan. Another cause was a problem of battery itself and BUN changed 64 batteries for only one year. Some of these batteries could be replaced by the maker guarantee, but the batteries damaged by a fault of the charge controller were replaced by the money that was collected from the user. Change of 64 batteries was a big miscalculation because we expected the battery lifetime of 2.5 years before installation. As this countermeasure, the JICA study team improved a charge controller and replaced all batteries from local battery to import one. The battery quality which was used in this study was very poor and its lifetime was extremely short. Hereafter, selecting the battery which has experience of long life, it is possible to manage the installed systems by using collected money from users.

Table 4-18 Balance Sheet of BUN (as of November 1998)

Income	Plan Z$	Result Z$	Expenditure	Result Z$
Connection charge	69,000	69,000	Field technicians' salary	25,498.42
Annual bill	92,520	57,225	Communications	2,886.56
Interest		13,926	Consumable supplies	33,580.76
			Field technicians' transportation expenses	5,205.70
			Senior engineer's transportation expenses	26,326.04
			Senior engineer's cost	14,000.04
			Administration expenses	3,000.00
			Other costs	6,220.06
	161,520	140,151	Total	116,717.58

Table 4-19 shows the five year-cash flow of the monitoring system which the JICA study team entrusted BUN. The income stated in the cash flow includes additional charges imposed on the users for their system capacity expansion done by the study team in August 1998. The charges for system maintenance service rendered to 12 public facilities by JICA study team are also taken into account. In February 1998, BUN visited the public facilities and recommended an appropriation for maintenance service in budgeting and a maintenance service agreement with BUN, though none of them has yet done so. On the cash out side, pay increases for the field technicians are assumed at a certain pace. Also, inflation is taken into consideration. A 10% non-payment rate and 15% contingencies are assumed on income and spending sides, respectively. If operated as prerequisite, the project should be financially stable as far as the first five years are concerned. However, the present charge collection rate was low with 63%. In order to raise collection rate, BUN will send a letter of reminder to the unpaid users. If the unpaid user does not pay money, the system will remove to new user who hopes the system.

Table 4-19 Projected Cash Flow for the First 5 Years

(Unit: Z$)

Item	Year 1	Year 2	Year 3	Year 4	Year 5	Total
Income						
Initial Fee	67,500					67,500
Periodic Fee (Standard)	82,800	82,800	82,800	82,800	82,800	414,000
Periodic Fee (Civil Servants)	9,720	9,720	9,720	9,720	9,720	48,600
Periodic Fee (Institutions)	12,000	15,600	18,720	22,464	26,957	95,741
Expansion Fee (Initial)		54,400	41,162	11,100		106,662
Expansion Fee (Periodic)		33,000	58,200	65,100	65,100	221,400
Unpaid Periodic Fee (10%)	-9,252	-9,252	-9,252	-9,252	-9,252	-46,260
Interest Income	14,238	66,746	18,595	10,025	2,817	112,421
Total Income	177,006	253,014	219,945	191,957	178,142	1,020,064
Expenses						
Battery Replacement		14,063	67,778	44,691	18,540	145,072
Controller Replacement			4,572	10,516	14,722	29,810
Panel Replacement		8,250	19,800	32,670	22,869	83,589
Miscellaneous Expenses	4,000	7,600	8,000	7,500	7,000	34,100
Field Technician Salary	24,000	26,400	29,040	31,944	35,138	146,522
Senior Technician Application: Household	10,000	24,000	24,000	30,000	36,000	124,000
Senior Technician Application: Institution	4,000	4,000	4,500	5,000	5,500	23,000
Administrative Overhead Application	2,000	8,000	9,000	11,000	13,000	43,000
Transport Cost	15,000	24,000	28,800	34,560	41,472	143,832
Projected Expenditures	59,000	116,313	195,490	207,881	194,241	772,925
Contingency 15% of projected expenditures	8,850	17,447	29,324	31,182	29,136	115,939
Net yearly Balance	109,156	119,254	-4,869	-47,106	-45,235	131,200

(Source) Biomass Users Network

4.7 Evaluation of Monitoring Results

The approach employed in JICA pilot project features that PV systems are owned, not by the users, but a managing organization, BUN in this case, and that the users pay the charge for electricity produced by the PV system. BUN is responsible for the maintenance and control of the PV system. If necessary, BUN replaces the system parts, while the replacement cost is covered from the electricity charge.

BUN employs local technicians who visit each installation at least once per month. In addition, to support the local technicians, a senior engineer is regularly sent from the Harare office.

This pilot project is designed to determine what problems will occur if this approach is employed in a larger scale future project for household rural electrification. It is not, however, intended to evaluate this approach from the monitoring results alone.

With almost a year having passed since the first systems were installed and the major problems peculiar to the initial stage have been solved. Actually, about a half year or so has passed since the PV-system operation has become stable. This point need to be taken into account in making the overall evaluation.

4.7.1 Management-related Subjects

(1) Managing organization: With this pilot project, management was entrusted to BUN, a NGO not only deeply involved in rural areas but also having technical experience in PV system installation through its participation in the GEF project. Through its involvement in the biomass effective utilization and PV system installation projects, etc., BUN has rich knowledge about the rural situations in Zimbabwe, and is superior in such points as local technician selection, employment, training and guidance, as well as the management of collected funds.

On the other hand, because BUN is a non-governmental organization and is often perceived as being an aid group for rural residents, it is hard to expect BUN to impose the same discipline on customers as official agencies. In the case of warnings, disconnects and removals for user contract violation, BUN lacks the respect afforded to an official agency. Also, partly because it knows so well about the actual financial state of farming villages, BUN is less likely to be cold blooded about collecting the user fees. In the case of GEF project, virtually no problems have been reported in the collection of charges for the 500 systems for which ZESA was responsible. With this pilot project, the rate of unpaid charges is assumed at 10%, partly because BUN is short of the compulsory power that ZESA or the Government can wield.

(2) Monitoring areas: Two areas, located some 200-250km away from Harare where BUN has its office, were selected as the monitoring areas. The two areas are about 100km from each other. One of them is Sanyati district, a communal land with commercial farms, where a relatively high income can be expected. The other is a farming village named Ngeji (Turf/Manyoni), a resettlement land, where settlements are relatively new, farms are not well established and are small and the expected income is lower than Sanyati.

Sanyati district has many more applicants for the JICA PV-system installation project than available systems. In Sanyati, the geographical distribution of the users is dense enough to permit easy access for maintenance service. On the other hand, because Ngeji (Turf area) could not raise a sufficient number of applicants early in the project, the monitoring area was broadened to include Turf and Manyoni. As a result, the geographical distribution is such as to require the local technician to take a bus when moving from one village to the other.

The relatively affluent Sanyati district also has some GEF-project participants, which means the residents were already informed of PV electrification before the JICA project. Accordingly, many hoped to have the lower cost JICA system installed. A problem was that few of them clearly understood that the capacity of the JICA system is about half that of the systems installed under the GEF project. Many users, having expected that they could use the JICA system in the same manner as its GEF counterpart, requested capacity expansion after the JICA system was installed.

With few GEF-project participants living in the resettlement area, Ngeji residents were poor in PV information and knowledge. Most of the experience was with poor quality amorphous systems bought at a low price and installed by the users so their experience with PV was both limited and not good. This lack of confidence made it difficult to get sufficient users for the JICA pilot project and a wide geographic area had to be included. This means that the local technician has to take considerably more time to complete the monthly visits than in Sanyati.

These two areas with different economic and social character were selected for the pilot project in order to help understand what economic and social factors would effect large scale PV based rural electrification. The results indicate that even with relatively low fees, the conditions in the area have a large enough effect that one area can have a long waiting list while another in the same district could be slow in responding.

(3) Number of users: Judging from the monitoring results, the number of users that a local technician can cover with a once-a-month inspection is 100-150 households. Because the expense incurred in providing the local technician change little with a greater number of users involved, it is desirable that the local technician cover the largest possible number of users. In carrying out full-scale PV-based rural electrification, it is recommended to secure, or develop, as many users as possible in a geographical range that a single local engineer can cover for maintenance service. Since this was not fully tested by the pilot project, it is proposed to start with 50 users per technician, then gradually increase the number of users covered by a local technician up to the maximum for each area technician.

(4) Office: The areas monitored in the pilot project are about 200-250km from Harare where BUN's office is located. This requires a 2.5-3-hour drive one way. In addition, the two project areas are located some 100km away from each other. Depending on road conditions, it usually took about two hours to visit one of the monitoring areas when starting from the other.

Conditions in the project areas are expected to be determined by the local technicians, who visit the users once a month who then report their findings to the office in Harare. However, to give management and technical guidance and to solve more complicated system problems required sending a senior engineer many times. The stocks of parts (batteries and charge controllers) are kept at the BUN office in Harare, then transported to the project areas when necessary. Due to the distance between the project areas and the office, the transportation cost represents a large portion of BUN's cash flow.

When a full-scale project is implemented, it is recommended to open a local office near the project areas. The local office must be staffed with resident senior engineers and retain a stock of suppliers, so that they can be ready for taking swift responses in emergency and delivered with minimal cost.

4.7.2 Staffing-related Subjects

(1) Local technicians: The local technicians assigned in the pilot project were chosen among four final candidates, two each from the Sanyati and Ngeji districts after they participated in the JICA PV technology training class at the Kwekwe technical.

The first local technician appointed for the Sanyati district resigned in four months for the reason of too low pay. Later, a female local technician was appointed and is currently in service. Because the work of the local technician is directly linked to the operational quality of the PV systems, to select a qualified local technician is a matter of vital importance. Experience in the pilot project confirm that serious and patient persons are most desirable.

Local technicians are provided with a bicycle each for visiting the users. But, they faced difficulties in performing their duties, particularly during the rainy season when roads get muddy and are sometimes flooded. Also, a bicycle appears inadequate for carrying a battery and a tool box simultaneously. As a result, local technicians would like to have a motorcycle. This desire cannot be met for various reasons, including initial cost, a fear of thefts, and the high fuel and maintenance cost involved. In many developing countries, a popular means of transport is the donkey, which appears optimal because it requires no fuel and can handle poor roads, yet can carry heavy objects as batteries. The problem is that few but the old and very poor people use the donkey as a transportation means in Zimbabwe and this is considered less attractive than the bicycle to the technicians.

(2) Senior engineers: During the pilot project, a staff member of BUN was assigned as the senior engineer, expected to instruct assist and supervise the local technicians. Under GEF project, he received his basic technical training in PV systems, then he joined the early stages of the JICA study effort during which the PV systems were installed. Also, when post-installation problems occurred, he collaborated with the JICA team in determining the causes and finding solutions.

Senior engineers are expected to instruct, assist and supervise the local engineers. They are expected to teach the local technicians how to render preventive maintenance and how to respond to the users needs. On the job training of the local technicians in troubleshooting and more complicated repairs is also a task of the senior engineer. During the latest pilot project, the senior engineer had few opportunities to instruct and supervise the local technicians partly because of the distance between his office and the monitoring areas made visits quite expensive. Once a full-scale project starts, the senior engineers are expected to be located at a local office near the project area, so they can effectively instruct and supervise the local technicians.

In implementing a full-scale project, the technical capability and experience of senior engineers can have a great influence on the usable life of system components, in particular the battery. Accordingly, the experience of the BUN's senior engineer is valuable, and should be put to best use.

(3) Administrative staff: BUN's Harare office is staffed with a manager, an accountant, a secretary-clerk, and the senior engineer introduced above.

The manager is responsible for the negotiations with the outside, including the JICA study team, DOE, RDC and ZESA, as well as liaison work with the secretariat of BUN (in London). The accountant is responsible for accounting project by project, and is engaged in the management of BUN's funds. The secretary-clerk is in charge of other office work.

In Zimbabwe, the market interest rates and inflation rates are so high that to use available funds effectively is essential in keeping a project afloat. In the latest project case, interest receipts accounted for 10% of the revenues.

With the approach employed in the pilot project, the monthly collections for PV system use includes the parts replacement cost for the future, particularly the battery replacement cost. This portion of the collected charge is deposited for each collection period and placed at interest, so that the necessary funds will be available when needed for buying new batteries for replacement. Because a full-scale project involves a much larger amount of funds, this form of fund utilization is expected to play a crucial role.

4.7.3 Technical Subjects

What technical characteristics of the PV systems installed in the pilot project are elsewhere detailed. Here, lessons learned in this area valuable for full-scale implementation is summarized.

(1) System capacity: Of the 100-household users, three fourths wanted capacity expansion. This clearly showed that 25Wp was too small. In order to meet the users' expectations, a PV system with a capacity of around 50Wp is desirable. At least if a smaller system is installed, it should allow easy capacity expansion. Other approaches may be practical but in any case the system size needs to be such as to fit the user's needs.

(2) Quality of PV system parts: During the pilot project, domestically manufactured parts were used as much as possible. Of the locally manufactured parts in use, the charge controller and battery were involved in most of the technical problems encountered. The problems related to the charge controller are now expected to be solved with its replacement by an imported unit which could be manufactured locally. As for the battery, the local battery makers are required to improve their manufacturing technologies and upgrade quality control efforts before their battery can be considered useable.

(3) System installation technologies: During the pilot project, several problems were learned out about the system installation. Before full-scale project implementation, it is necessary to locate qualified installation firms who receive adequate training and are examined through a practical test to be sure they are capable of providing the necessary installation quality. Workers should have access to the proper tools as well as know how to use them.

(4) Maintenance technology: In the beginning of the pilot project, the inexperienced local technicians did not have the confidence of the users but as the systems have become more stable as problems have been worked out, the level of experience has increased and confidence risen. Because a full-scale project has a much larger number of local technicians, it will be necessary to prepare a standard maintenance manual and establish some system to provide refresher and on-the-job training (OJT).

4.7.4 Financial Subjects

(1) Most recent balance: The five-year balance sheet prepared by BUN (Table 4-19) shows that some profit would remain in five years if capacity expansion is taken into account. Because this monitoring project assumes no increase in the number of users, the revenues should remain constant without capacity expansion. On the other hand, spending keeps growing due to inflation, which eventually erodes the profits. Therefore, after continuing for five years, this pilot project will close and the users will be expected to sign new contracts under different conditions than the pilot project. The preferred option would be for them to be included in a full scale project proposed on the basis of the results of the pilot project.

(2) Revenues: Given that interest receipts represent 10% of the total revenues, the battery replacement fund management can greatly affect the overall revenues. Also, while the rate of unpaid charges is estimated at 10%, the collection goal should still be 100%.

(3) Spending: Spending on expendable supplies, including panels, accounts for one thirds of total spending, which should be reduced during full-scale implementation by improved

system design and maintenance.

The remuneration for the local technicians and senior engineers is not high and should not be reduced. But, it is possible for one technician cover a larger number of users at the existing salary rate. Also, transportation cost represents nearly 20% of spending, which can be reduced by locating a local office near the target areas when a full-scale project is under way.

When combined, the administrative cost and office supplies cost totals about 10% of spending. This appears smaller than is the true case, because BUN divides these costs over other projects as well as the JICA pilot project. If the full-scale implementation is organized as an independent PV project, these costs are expected to pose heavier burdens, but can be subsidized by ZESA or the government in the early years if necessary.

4.7.5 Other

(1) Prevention of theft: Once an ESCO installs a PV system near the house of a given user, the contract specifies that the user is responsible for preventing theft and damage to the system.

During the pilot project, a panel theft occurred showing that there is some grounding in the fear. It is necessary to take some preventive measures and, if economically reasonable, insure the systems against theft. One of the lowest cost and most effective theft preventive measures is to install the system on the roof whenever possible.

(2) Measures for government officials not permanent residents: The users include nurses at medical clinics, government officials and others, who hope to install a PV system while they temporarily live in unelectrified areas. Later, if moving to an electrified area, they no longer need the PV system. But, if moving to another unelectrified area, they hope to bring the PV system with them or at least have access to a similar system in the new area.

Under the pilot project, these users were not required to pay the charge for initial connection. Instead, a fee system was employed which requires them to pay an extra amount of monthly charge, which, over a total of five years would cover the wiring cost. None of the users in the pilot project areas have left the area yet but this will be a problem in larger scale implementation, which must be faced.

(3) Anti-inflation measures: In Zimbabwe, inflation is high, exceeding 20%. Particularly recently, the Z$ has fallen as much as 50% against the US dollar which is likely to further fuel the inflation problem. Under the electricity supply service approach, the remuneration of the engineers, the purchase cost of expendable supplies, and the administrative costs of the office, etc. can directly be hit by inflation. The charge for use collected from the users should therefore be reviewed from time to time. In this light, the contract terms for large scale implementation should include a provision that the charges may be reviewed, perhaps annually, and changed if necessary.

4.8 Review of the Systems based on Monitoring Results

4.8.1 Power Expansion of the Existing 25W System

BUN, during its monitoring of the systems, found that most households expressed dissatisfaction due to the insufficient capacity of the 25W systems. In response, JICA was asked to consider raising the power to 50W for those households who wanted it. JICA agreed to provide 50 panels of 50Wp each for increasing system capacity. The plan was to change only PV panels and it was executed on August 1998.

(1) Existing PV system composition

PV module: 25W

Battery: 40 Ah, 12V (for 5 days use without any solar irradiation)

Charge controller: improved JICA type, rated current 10A

Permissible load energy use: 4.6 Ah/day

(2) The system composition after increasing panel capacity to 50Wp

a) System composition after capacity increase

PV module: 50W

Battery: 40 Ah, 12V (for 5 days use without any solar irradiation)

Charge controller: improved JICA type, rated current 10A

b) Review of permissible load amount

The condition assumed for solar irradiation on the slant surface (Total irradiation) is: 5.41kWh/m^2, coefficient Ksys: 0.409 (the same as in the existing system design), (the breakdown is: K1=0.9, K2=0.8, K3=0.95, K4=0.95, K5=0.92, K6=0.95, K7=0.8 and K8=0.9), and then the design calculation is performed by applying the equation 3-1 (Chapter 3).

PL = Pmod x Tq x Ksys=50 x 5.41 x 0.409=110.6(Wh/day)

Converting this into Ah delivered to a 12V battery,

Plah = PL/12 = 9.21(Ah/day)

The load can, of course, double over that available in the original 25Wp system. The problem is whether the existing battery can be used or not. The required battery capacity is calculated applying equation 3-3 (Chapter 3).

c) Calculation of required battery capacity

The assumed condition for required battery capacity is set forth as Kdod=0.8, load amount (PLah): 9.21, days without any solar irradiation: 5 days(Ksun=5).

Using these values then the required battery capacity, B is:

B >= Ksun x PLah/Kdod = 5 x 9.21/0.8 = 57.6Ah

And thus, B is beyond the B of existing battery, 40 Ah. Calculation is repeated by setting days without any solar irradiation to be 3 days,

B >= Ksun x Plah/Kdod = 3 x 9.21/0.8 = 34.6Ah

And thus, the 40 Ah battery can be used under that condition. The charge recovery characteristic is determined by applying equation 3-4, and the result is the allowable number of days effectively without solar irradiation would be 2.3 days. This means with the 50W modules and existing components should be adequate under Zimbabwe conditions of solar radiation.

d) Estimation of days without any solar irradiation

No long term data on the frequency of days with very low solar irradiation is available in Zimbabwe, but the data recorded by JICA data loggers shows only one period of 3 continuous low solar irradiation days. Even in a low solar irradiation day, solar irradiation of 2 kWh/m^2/day or so still remained. A system configuration with assumption of days without any solar irradiation to be 3 days, probably is reasonable.

e) Current capacity of charge controller

The improved JICA charge controller has a charge current-carrying capacity of 10A. Out put current of the 50Wp PV module to be used is 3A, therefore there is no problem with controller charging capacity.

(3) Operational characteristic of the system after power expansion

With a capacity increase to a 50Wp module, the following characteristic can be expected in case of the design condition of solar irradiation into slant surface found in December, 5.41 kWh/m^2/day.

- Maximum permissible load energy: 110Wh/day (9.2 Ah/day)
- Examples of available load equipment:

Simultaneous use of a 7W fluorescent light, 4 hours (2.36 Ah)
and a 20W TV set, 4 hours (6.68 Ah), or
Simultaneous use of a 7W- fluorescent lights, 3.5 hours each (4.1 Ah)
and a 20 W TV set, 3 hours (5.0 Ah), or
Simultaneous use of a 7W fluorescent light, 3 hours (1.77 Ah),
a 20W TV set, 3 hours (3 Ah) and a 5 W radio 4 hours (2.24 Ah),
and other similar combinations, are possible.

When solar irradiation is much larger, longer time usage is possible but battery life may be shortened because charging and discharging depth increases accordingly for the higher loading.

4.8.2 Future Programs for Local Electrification

It was clearly demonstrated that both the 25W systems for household use and 83W systems for public use as used in the JICA Pilot Project monitored in Zimbabwe, can play an effective role in rural electrification. It was also clearly shown that there exist numerous issues of concern for future projects such as making systems larger than 25Wp available, improving the unexpectedly poor quality of the locally made controllers and improving the very variable quality of the batteries. Other issues found where that the electrolyte supplies was inconsistent in quality, battery cells in new batteries often showed unacceptable variation in hydrometer readings, and finally several batteries are suffering from much larger voltage fluctuations than appropriate for their relatively new state. Additionally there is concern about liquid leakage due to inadequate design of the cell filler cap structure.

In order to resolve such issues cited above, to stabilize component and equipment supply, to provide for ease of maintenance and to promote local electrification, it seems most effective to design a basic system and to use components appropriate for ease of upgrading rather than to prepare specific designs for each user's requirements. To best meet a wide range of user needs, more than one standard design could be prepared.

(1) Preferable sizes of standard system

As many as 3 nominal sizes of systems 25Wp, 50Wp and 75Wp should be considered. The panel size need not be exactly that of the nominal value but should not be smaller. For instance, an 83Wp panel can be considered as being in the nominal 75Wp class. The system actually installed would be selected from the 3 standard systems in accordance with the load demand and ability of the recipient to pay.

(2) Specification of major components

Specification for major components in the standard systems is described below.

a. Charge controller

The improved JICA charge controller is designated as a standard one for all three standard systems. The features and specifications are as follows:

PV disconnection voltage (HVD):	14.5V
Load disconnection voltage (LVD):	11.5V
PV reconnection voltage (HVR):	13.0V
Load reconnection voltage (LVR):	13.0V
Self-consumption current:	15mA

Controlling relays are set as Normally closed at the charge control side and Normally open at the load side.

In this specification, the panel reconnection voltage (HVR) is set forth to be 1.5V lower than the HVD and the load reconnection voltage (LVR) is set at 1.5V higher than the LVD. This level of HVR is set to prevent chattering of relay contacts as well as providing for a stable control of the charge conditions. The level of LVR is also intended to prevent chatter of the relay contracts due to rapid switching while permitting the earliest reasonable reconnection of the load for customer convenience.

b. Battery

In the case of sites where regular maintenance is not available, low maintenance battery installation is important. Even the use of expensive sealed batteries may be appropriate. In the case of the system used in the Pilot Project where regular professional maintenance is available, conventional deep discharge, open cell batteries are the most economic type. To use an automobile battery is not recommended unless their short life is offset by very low cost in comparison to deep cycle batteries.

c. Fluorescent light

High efficiency and long life of both the electronic ballast and the bulb are very important. Safety is an important consideration also and a device, such as an integral fuse, should be included in the ballast to prevent damage should failure occur.

d PV module mount

The PV module mount used by the local installers for the Pilot Project was very poor. The mount is important in several ways to the proper acceptance of solar energy by the PV panel. It should be of strong design and not affected by common wind speeds and in the east-west direction it should be precisely horizontal. The angle of its inclination is preferably 17.5° , if not, should stay within an allowable range of 15 to 20° . The panel and mounting should be secure and very difficult to steal.

(3) System size of standard systems

For the proposed three standard systems, the specification is reviewed. Please refer Table 4-21.

Table 4-21 STANDARD PV SYSTEM CRITERIONS

ITEMS	PV SYSTEMS		
SIZE	25W CLASS	50W CLASS	75W CLASS
PV MODULE	25W	50W	75W
BATTERY(*)	20Ah / 12V (*30Ah / 12V)	40Ah / 12V (*60Ah / 12V)	60Ah / 12V (*100Ah / 12V)
CHARGE CONTROLLER	JICA IMPROVED TYPE HVD=14.5V, HVR=13.0V LVD=11.5V, LVR=13.0V CURRENT CONSUMPTION< 20mA	JICA IMPROVED TYPE HVD=14.5V, HVR=13.0V LVD=11.5V, LVR=13.0V CURRENT CONSUMPTION < 20mA	JICA IMPROVED TYPE HVD=14.5V, HVR=13.0V LVD=11.5V, LVR=13.0V CURRENT CONSUMPTION < 20mA
PV TILT ANGLE	17.5° N (15° −20°)	17.5° N (15° −20°)	17.5° N (15° −20°)
ANTICIPATED IRRADIANCE	5.41kWh/m²/day	5.41kWh/m²/day	5.41kWh/m²/day
AUTONOMY(**)	3 DAYS(**5days)	3 DAYS(**5days)	3 DAYS(**5days)
NECESSARY CHARGING PERIOD FOR BATTERY RECOVERY(***)	2.3 DAYS(***3.4 DAYS)	2.3 DAYS (***3.4 DAYS)	2.3 DAYS (***3.4 DAYS)
AVAILABLE LOAD CAPACITY	55.3Wh / 4.61Ah	110.6Wh / 9.2Ah	165.9Wh / 13.82Ah
EXAMPLE OF LOAD PATERNS	FL(7 W) x 1 x 2hs (1.18Ah) Plus TV(20W) x 2hs (3.34Ah) total = 4.52Ah	FL(7 W) x 1 x 4hs (2.36Ah) plus TV(20W) x 4hs (6.68Ah) total = 9.04Ah	FL(9W) x 1 x 9hs (6.75Ah) Plus TV(20W) x 4hs (6.68Ah) total = 13.43Ah
	FL(7 W) x 1 x 7hs (4.13Ah) Total = 4.13Ah	FL(9W) x 1 x 8hs (6.0Ah) Plus Radio(5W) x 5hs(2.8Ah) Total = 8.8 Ah	

Remarks: *,**,*** To prolong the autonomy up to 5 days the battery sizes and its charging period for battery recovery must be enlarged respectively.

4.9 Content of Technology Transfer

The capability to provide training in the installation, maintenance and operation of PV systems as used for rural electrification has been developed at Kwekwe Technical College. The College will provide short courses for technicians working in the field and will include PV technology in its standard electrical trades curriculum.

Technology transfer covering system design, monitoring, and system components has been accomplished though an "on-the-job-training" (OJT) approach through joint work with our counterpart technical personnel.

A workshop was held in conjunction with the second survey in Zimbabwe to introduce basic technical themes to interested individuals. The main technologies that are being transferred to our counterpart engineers are described below.

4.9.1 System Plans

1) Basic System Design Concepts

The basic equations and the loss coefficients used in system design were explained. Methods for processing the solar irradiation data needed for the above calculations, the methods for determining the characteristics of the main component parts and how to integrate them as a system were explained.

This was done in conjunction with the actual design of the systems for the Pilot Project. Since basic data on the characteristics of two of the main component devices that are particularly important for system design, the PV modules and the storage batteries, could not obtain in Zimbabwe, measures for obtaining this data through the use of locally available equipment were introduced and evaluated. Photo 4-24 shows how a data logger is set up.

- Measuring the current and voltage characteristics of PV modules:

The counterpart technical personnel were given guidance and hands-on experience in building a measuring circuit, setting up measuring equipment, performing actual measurements, and analyzing the data.

- Measuring the charge and discharge characteristics of storage batteries:

The counterpart technical personnel were given guidance and hands-on experience in building the necessary measuring circuit, setting up measuring equipment, performing actual measurements, and analyzing the data.

2) Characteristics of Component Parts

There was an exchange of ideas on the necessary characteristics for charge controllers. Guidance was provided on the use of PV IV curves and the charge-discharge characteristics of storage batteries, and ideas were exchanged.

3) Recommendation for PV system Installation

The accuracy of tilt angle of the PV modules has a big influence on maximizing the amount of electricity generated, and ideas were exchanged on topics such as methods for installing modules accurately.

4) Operation and Maintenance of PV systems

Regarding the operation and maintenance of the PV systems, ideas were exchanged on items that should be taught to users. The basic items to be taught to clinic staff were conveyed. Photo 4-25 shows one of our counterpart engineers explaining items requiring caution to clinic staff.

4.9.2 Monitoring

Methods for installing data loggers and evaluating method of data were explained to our counterpart technical personnel via OJT. Photo 4-26 shows one of our counterparts learning how to download data from a data logger.

Some of the actual items included in the technology transfer were the following:

- Basic theory of the data logger
- Setup and use of the data logger
- Hands-on training in designing and producing data logger interface circuitry, and installing it in a PV system
- Hands-on training in collecting data
- ands-on training in analyzing and producing graphs from data with the Excel spreadsheet software.

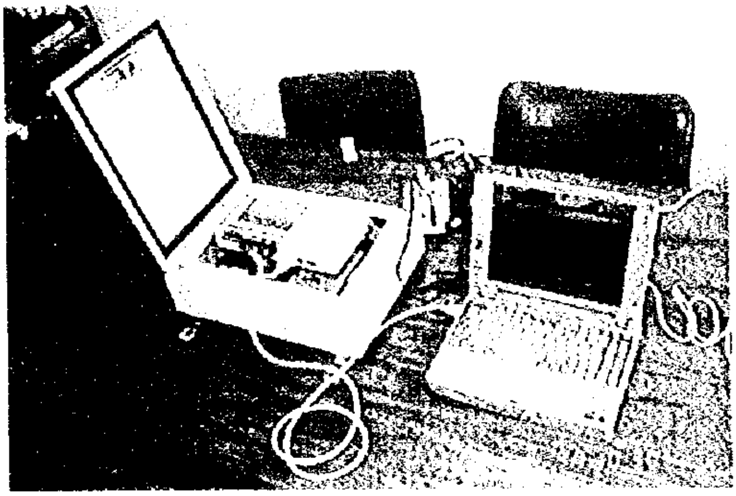


Photo 4-24 Setting Up of Data Logger

Photo 4-25 Explanation of Equipment Handling To Clinic Staff By Counterpart

Photo 4-26 Experiencing Data Down-Load

5

RESULTS OF SOCIAL INVESTIGATION

5.1 Objectives & Scope

In order to meet this Study's main objective of formulating a master plan promoting the electrification of rural areas in the Republic of Zimbabwe using photovoltaics, it was necessary to conduct an investigation of current socio-economic conditions in the country. In doing so, it was particularly necessary to identify the current electrification needs of both unelectrified and electrified households and public institutions in the rural areas, as well as forecast future demand for electricity in the same.

To forecast future demand of electrified households/public institutions (whether by PV or grid electrification), some of the specific data requirements included general living conditions, current consumption level/patterns, and levels and sources of income. For determining the affordability of PV systems, it was necessary to gather data on gross annual income, disposable income, expenditure patterns, and savings. For the PV-electrified households and institutions, in particular, it was also essential to gather data on actual experiences using the technology. To get data on unelectrified areas, meanwhile, a field survey was carried out by Southern Centre for Energy and Environment, a Harare-based NGO/research organization, using as a basis the information on the characteristics of rural Zimbabwe described in the next section.

5.2 Characteristics of Rural Zimbabwe

Agriculture is one of the major sectors of Zimbabwe's economy. Its value added production in 1996 totaled Z$ 5.1 billion (current prices) and accounted for the third largest share in GDP, following manufacturing (Z$11.2 billion, or 25% of the total), and finance & insurance (Z$5.3 billion, or 12% of the total). Export value of the country's agricultural products comprised roughly 30% of the national figure for the same year. The sector currently employs an estimated 1.22 million people, most of whom work in the communal land farms.

Zimbabwe is a high-lying country some 900-1,200 meters above sea level. The amount of rainfall can be described as modest, but agricultural production, particularly in the rural areas, is extensive (except for periods of drought), making it self-sufficient in terms of food supply. It also supplies food to neighboring countries. The national land is divided into 5 regions based on land characteristics and annual rainfall volume as shown in Table 5-1.

Table 5-1 Regional Classifications in Zimbabwe

Regional Classification	Rainfall Volume (mm)	Suitable Type of Agriculture	Area (km^2)	(%)
Region I	1,000 (1,700 m or higher) 900 (below 1,700 m)	Special crops, Multilateral agriculture	7,050	1.8
Region II	700-1000	Intensive farming	58,570	15.0
Region III	650-800	Semi-intensive farming	72,900	18.7
Region IV	450-650	Semi-rough farming	147,700	37.8
Region V	Less than 450	Rough farming	104,500	26.7
TOTAL			390,720	100.0

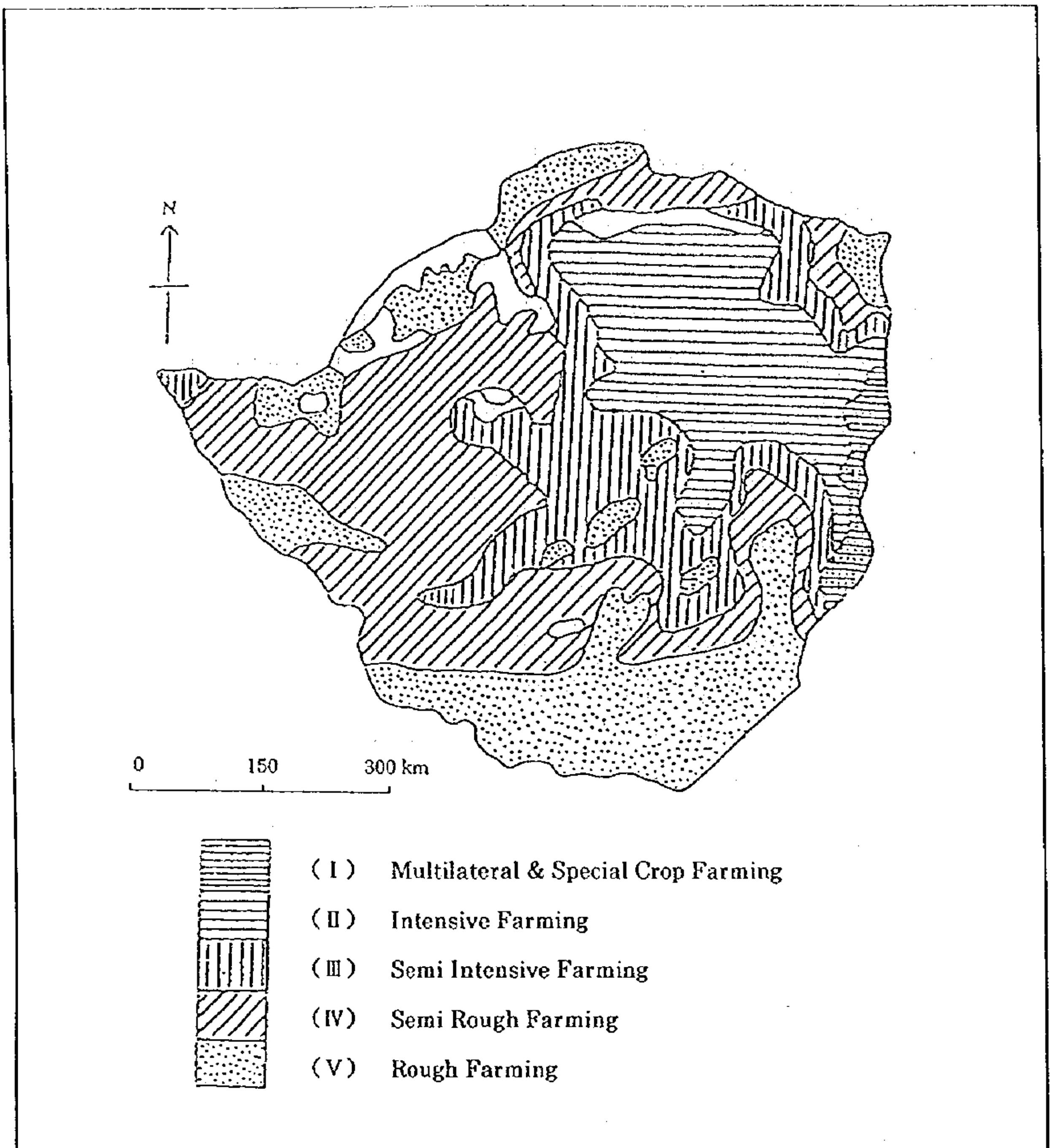
Source: N. D. Mutizwa & Mangiza (1985) Community Development in Pre-Independence in Zimbabwe University of Zimbabwe.

Soil in Region I is very rich, making it suitable for the cultivation of special crops and multi-crop farming. Along with Regions II and III, soil in Regions I has high concentrations of lime and kaolin, facilitating relatively high agricultural productivity. Soil in Regions IV and V, on the other hand, has high concentrations of either regosol (which is 90% sand and roughly 10% silt) or lithosol (which is basically made up of low-resistance gravel or rock). These regions suffer from low agricultural productivity.

Around 600-700 mm per year of rainfall is necessary for cultivation of maize, the main agricultural product of Zimbabwe. As shown in Table 5-1 above, areas classified under Region I receive a generous amount of rainfall every year, facilitating the cultivation of this important crop. Region I areas, which run mainly along the eastern border separating Zimbabwe and Mozambique, are also suitable for multi-crop farming, pomiculture, forestry, intensive livestock raising, and special crops such as tea, coffee, and macadamia nuts.

Areas classified under Region II, which receive about 750-1,000mm of rainfall, are suitable for intensive farming as well as intensive livestock farming. This region covers Harare City and peripheral areas. Meanwhile, areas classified under Region III, which receive about 650 - 800 mm of rainfall, are suitable for semi-intensive farming (mainly feed crops and cash crops such as maize and tobacco). It mainly covers the Midlands Province.

Region IV areas, which receive about 450-650-mm of rainfall every year, are suitable only for semi-rough farming. They are also suitable for stock farming, and cultivating drought-resistant crops. Agricultural productivity in these areas is not so high. Region IV mainly covers Matabeleland North Province, surrounding Region III. Meanwhile, Region V areas, which receive around 450-mm of rainfall or less, are suitable only for rough farming. Rough stock farming is the major activity in these areas. This region mainly covers the Matabeleland South Province, in the southern part of Zimbabwe. (See Figure 5-1)



Source: N. D. Mutizwa & Mangiza (1985) Community Development in Pre-Independence Zimbabwe University of Zimbabwe.

Figure 5-1 Agricultural Distribution Map of Zimbabwe

5.3 Classification of Zimbabwe's Farmlands and Characteristics

Most of rural Zimbabwe has a so-called double farming structure, where settlement farming (passed on by the English colonizers) co-exists alongside indigenous farming. There are five classifications of farmlands in Zimbabwe, namely: large scale commercial farms (LSCF), small-scale commercial farms (SSCF), communal land farms (CLF), resettlement area farms (RAF), and parastatal government farms (PGF). Table 5-2 summarizes some basic information about each farm type, including land area, the proportion of cultivated land to the total area, the number of individual farms, and average farm size for each farm type.

Table 5-2 Classification of Farmlands in Zimbabwe

	LSCF	SSCF	CLF	RAF	PGF
Total Area ('000 hectares)	10,740	1,380	16,340	3,290	420
Farming land (%)	33.4	4.3	50.8	10.2	1.3
No. of farms	4,835	8,500	1,000,000	56,800	55
Average size (ha.)	2,220	160	16	60	7,540

Source: Ministry of Agriculture (1995), Zimbabwe's Agricultural Policy Framework 1995-2020

(1) Large Scale Commercial Farms

LSCFs in Zimbabwe total around 10,740,000 hectares, or 33% of the national farm land area, and are owned by some 4,800 people (mostly Caucasian). Some 3,880,000 hectares of LSCFs are classified under Regions I and II, and thus have high agricultural productivity. In Region I alone, 59% of the LSCFs are occupied.

About 59% of LSCF's fall under Regions I-III, higher than the national ratio of 36% (See Table 5-3). The average size of LSCF's in Zimbabwe is larger than other farm types at 2,200 hectares (See Table 5-4).

Table 5-3 Division of Farming Land by Sector and by Region

(In %)

	LSCF	SSCF	CLF	RAF	PGF
Regions I and II	35	19	9	19	4
Region III	22	35	17	38	32
Regions IV and V	43	46	74	43	64
TOTAL	100	100	100	100	100

Source: Ministry of Agriculture (1995) Zimbabwe's Agricultural Policy Framework 1995-2020

Table 5-4 Trends in the Scale of Commercial Farms in Zimbabwe

(In 1,000 ha)

	No. of farms		Total Area		Average Farm Scale	
Year	LSCF	SSCF	LSCF	SSCF	LSCF	SSCF
1982	5,915	8,549	13,516	1,066	2.29	0.125
1983	5,481	8,653	12,347	1,075	2.25	0.124
1993	4,835	8,500	10,740	1,380	2.22	0.160

Sources: World Bank (1995) Zimbabwe Achieving Shared Growth

General Institute of Agriculture (1988) Agriculture in Tanzania and Zimbabwe

Most LCSFs are backed up by an organized labor force, a developed irrigation system (irrigation systems in LCSFs make up 84% of the national total of 150,000 hectares), and more than adequate funding. In spite of these, however, utilization of LSCF's remains disappointingly low at 4.2%. Currently, only 450,000 out of the total 10,740,000 hectares are being farmed by some 310,000 workers are farming.

Table 5-5 Trends in Irrigated Areas in Commercial Farms

	No. of farms		Irrigated Area (ha)		Average size (ha)		Irrigated Area (%)	
	LSCF	SSCF	LSCF	SSCF	LSCF	SSCF	LSCF	SSCF
1991	4,461	8,994	184,554	289	107.5	8.0	38.5	0.40
1992	4,396	8,369	125,972	212	98.4	8.6	29.1	0.29
1993	4,541	8,981	137,394	300	103.8	7.9	29.1	0.43
1994	4,601	8,981	172,886	277	108.3	8.3	34.7	0.37
1995	4,394		141,845		105.6		30.6	

Source: Ministry of Agriculture (1997), Agricultural Sector of Zimbabwe: Statistical Bulletin

Table 5-6 Trends in Crop Yield (1993-95)

	1993		1994		1995	
	Area ('000 ha)	Yield (Ton/ha)	Area ('000 ha)	Yield (Ton/ha)	Area ('000 ha)	Yield (Ton/ha)
Maize	1,238	1.63	1,401	1.66	1,409	0.60
Wheat	39	7.03	43	5.61	40	2.08
Millet	255	0.37	300	0.26	258	0.08
Sorghum	149	0.60	175	0.70	131	0.23
Cotton	170	1.10	170	1.00	150	0.67
Soybeans	52	1.93	51	2.13	71	1.08
Groundnut	114	0.59	134	0.50	164	0.32
Sunflower	118	0.41	119	0.41	140	0.16
Coffee	4	1.05	6	1.72	5	0.88
Tea	5	3.00	5	2.86	5	3.19

Source: FAO Yearbook (1995) Production (Vol. 49)

(2) Small Scale Commercial Farms

SSCFs total 1.38 million hectares, or about 4% of the national farm land area. There are about 8,500 individual SSCF's throughout the country, mostly owned by indigenous farmers, with the typical farm size averaging 160 hectares. About 19% of SSCF's are classified under Regions I and II, 35%, Region III, and the remaining 46% under Regions IV and V (See Table 5-2).

(3) Communal Land Farms

Many Zimbabwe farmers are given the right to cultivate CLFs (which belong to the state) through the Communal Land Act (whose predecessor was the Tribal Land Act during the British colonial period). Farmers are not allowed to possess these lands, but are given the right to use them subject to strict control by government-appointed rural committees, particularly on matters of land use and transfer of inhabitants. However, the succession of the right to use land is approved by notice by the heir.

There are about 16,340,000 hectares of communal lands in Zimbabwe, representing 51% of the national farm land area. They are classified under Regions IV and V, thus having low agricultural productivity. The yield of agricultural products per unit size of land, in fact, represents only 1/6-1/10 of the yield of commercial farms, due mainly to differences in the quality of the soil. To illustrate, in the cultivation of maize, LSCFs (where soil is rich) have an average yield of 4.5-5.0 t/ha, while CLFs produce only 0.5-1.0 t/ha. For the cultivation of sorghum, meanwhile, LSCFs have an average yield of 0.9-2.0 t/ha while CLFs produce only 0.2-0.5 t/ha. Some 10,000,000 farmers reside in CLFs, with each farm having an average size of 16 hectares.

(4) Resettlement Area Farms

The total area covered by RAFs in Zimbabwe is 3.29 million hectares, with the average size of an individual RAF being 60 hectares. About 43% of RAFs fall under regions IV and V, while 38% fall under Region III. The number of the resettled farmers as of 1996 was 62,000.

There are two basic types of resettlement in Zimbabwe. The first one involves granting a farmer the right to privately operate a farmland, at his own risk, but sharing the use of the pasture with other farmers. The second one involves the creation of a cooperative type of arrangement where a number of farmers share residence and in the tasks of cultivation and pasturage in a particular farmland. Currently, about 95% of RAFs are of the first type of resettlement, while the remaining 5% are of the latter type.

One basic government policy is to lend national farmlands to indigenous farmers. This is being done partly as a form of assistance to landless farmers and partly to decongest the overcrowded CLFs. Regarding the latter, the government usually offers compensation to the (mostly European) owners of CLFs to give up a portion of their land which it will then convert into resettlement areas for indigenous farmers.

(5) Parastatal Government Farms

PGFs, which are controlled by the government through the Agriculture and Rural Development Authority (ARDA), total some 420,000 hectares. About 64% of all PGFs in Zimbabwe belong to Regions IV and V, and thus have low agricultural productivity. The average farm size is rather big, however, at 7,640 hectares, with the total number of farms being 55.

5.4 Distribution of Agricultural Products

There are several organizations in Zimbabwe involved in the distribution of agricultural products. Their names and respective activities are summarized as follows:

Organization	Activity
Grain Marketing Board (GMB)	Purchase, storage, domestic sales, and export of grains
Dairy Marketing Board (DMB)	Purchase, storage, packaging of milk, manufacture, domestic sales, and export of dairy goods such as butter, cheese, and ice cream
Cotton Company of Zimbabwe (Cottoco) (formerly Cotton Marketing Board or CMB)	Purchase, winding, and spinning of cotton, domestic sales and export of linters and cotton seeds
Cold Storage Commission (CSC)	Purchase, slaughter of cows, goats, and sheep, domestic sales, and export of fresh meat

Table 5-7 shows trends in crop production volume, sales volume, and sales value for the period 1993-1996. Interestingly, sales volumes of the various major crops range from 10 to 100% of actual production levels. Of the total sales figures of the various crops during the 3-year period, some 74-95% were cultivated in commercial farms, while 5-25% were cultivated in small farms.

Table 5-7 Trends in Production, Sales to/through Marketing Organizations and Sales Value of Farm Products

Product	Item	Unit	1993	1994	1995	1996
Maize	Production	1000 tons	2,002	2,320	840 [4]	1609
	Sales Volume [1]	1000 tons	1,350	1,171	84	932
Wheat	Production	1000 tons	276	239	83	N. A.
	Sales Volume [1]	1000 tons	276	203	2	N. A.
Sorghum	Production	1000 tons	101	109	77	108
	Sales Volume [1]	1000 tons	25	23	13	4
Total crops	Sales value	Z$ million	4,130	5,575	5,352 [4]	10024
	Commercial[2]	Z$ million	3,075	4,549	5,071	8474
	Small size[3]	Z$ million	1,055	1,026	282	1550

Notes: 1) Annual sales volume and sales value figures cover periods beginning April & ending in March

2) Commercial = LSCF + SSCF + PGF

3) Small size = CLF + RAF

4) Production in 1995 dropped sharply due to a drought. Sales were not drastically affected, however, as prices simultaneously rose during the same year.

Sources: CSO (1996) "Quarterly Digest of Statistics", CSO (1995) Facts and Figures 1995, FAO Yearbook (1995) Production (Vol.49)

5.5 Contents of the Socio-Economic Survey

5.5.1 Survey Targets

(1) The survey will be administered to the following samples:

a. Two hundred (200) unelectrified, low-income households (with a monthly income of Z$2,000 or less) located in unelectrified villages. Of the 200, 100 were selected by the JICA Study Team for the installation of 25-watt PV systems for its pilot project

b. Two hundred (200) PV-electrified households located in electrified villages;

c. Fifty (50) unelectrified public institutions (i.e. clinics and schools) in unelectrified villages. From the 50, twelve (i.e. 10 clinics and 2 secondary schools) were selected by the Study Team for the installation of 165-watt PV systems;

d. Fifty (50) PV-electrified public institutions located in electrified villages.

(2) Selected Study Areas

For items the Study Team selected a and c above, Kadoma in Mashonaland West Province and Gokwe South in Midlands Province. For items b and d, meanwhile, the selected areas were the districts of Bikita, Bindura, Chimanimani, Gokwe South, Goromonzi, Gutu, Kadoma, Madziwa, Makoni, Murewa, Mutare, Mutasa, Shamva, and Zimunya) in the provinces of Manicaland, Mashonaland Central, Mashonaland East, Mashonaland West, Midlands, and Masvingo.

(3) Survey Methodology

The socio-economic survey was carried out by Southern Centre, which utilized a number of masteral students from the University of Zimbabwe Faculty of Social

Science to conduct the interviews. A questionnaire prepared by the JICA Study Team's social analyst and a DOE counterpart was utilized for said interviews, which were conducted face to face. Specific items studied are listed by category below:

a. Survey to the household and clinic

a) Unelectrified Households

- Composition of family
- Annual and monthly cash income
- Disposable income
- Lighting and heating expenses
- Other expenses
- Level of savings
- Monthly payments for PV system
- Demand for electricity
- Willingness to purchase PV system

b) Electrified Households

- Composition of family
- Annual and monthly cash income
- Disposable income
- Lighting and heating expenses
- Other expenses
- Level of savings
- Monthly payments for PV system
- Repayment conditions
- System configuration
- Extent of daily PV use
- Maintenance system
- Experience with system breakdown or trouble
- Level of satisfaction with PV system
- Future extension plan for PV systems

c) Un-Electrified Public Institutions

- Operating costs
- Lighting and heating expenses
- System configuration
- PV purchasing will

d) Electrified Public Institutions

- Operating costs
- Lighting and heating expenses

Maintenance management expenses for PV system
System configuration
Extent of daily PV use
Maintenance system
Experience with system breakdown or trouble
Level of satisfaction with PV system
Future extension plan for PV systems

b. Operating costs

Lighting and heating expenses
Maintenance management expenses for PV system
System configuration
Extent of daily PV use
Maintenance system
Experience with system breakdown or trouble
Level of satisfaction with PV system
Future extension plan for PV systems

(4) Survey of PV household in Kadome area by JICA team

Apart from the above mentioned interviews, a separate survey of areas selected by JICA for system installation was conducted by Southern Centre again using a questionnaire prepared by the JICA Study Team's social analyst and approved by DOE. Some of the items included were: composition of study area, residents' lifestyles, electric appliances being used, and PV electrification requirements. Figure 6-2 gives a clearer picture of the major items to be surveyed and their interrelations.

Monitoring survey by interview of PV electrified households in Kadoma district was carried out between January and February 1998.

Further monitoring by the JICA Study Team of increased capacity PV system households in Kadoma district was carried out in December 1998.

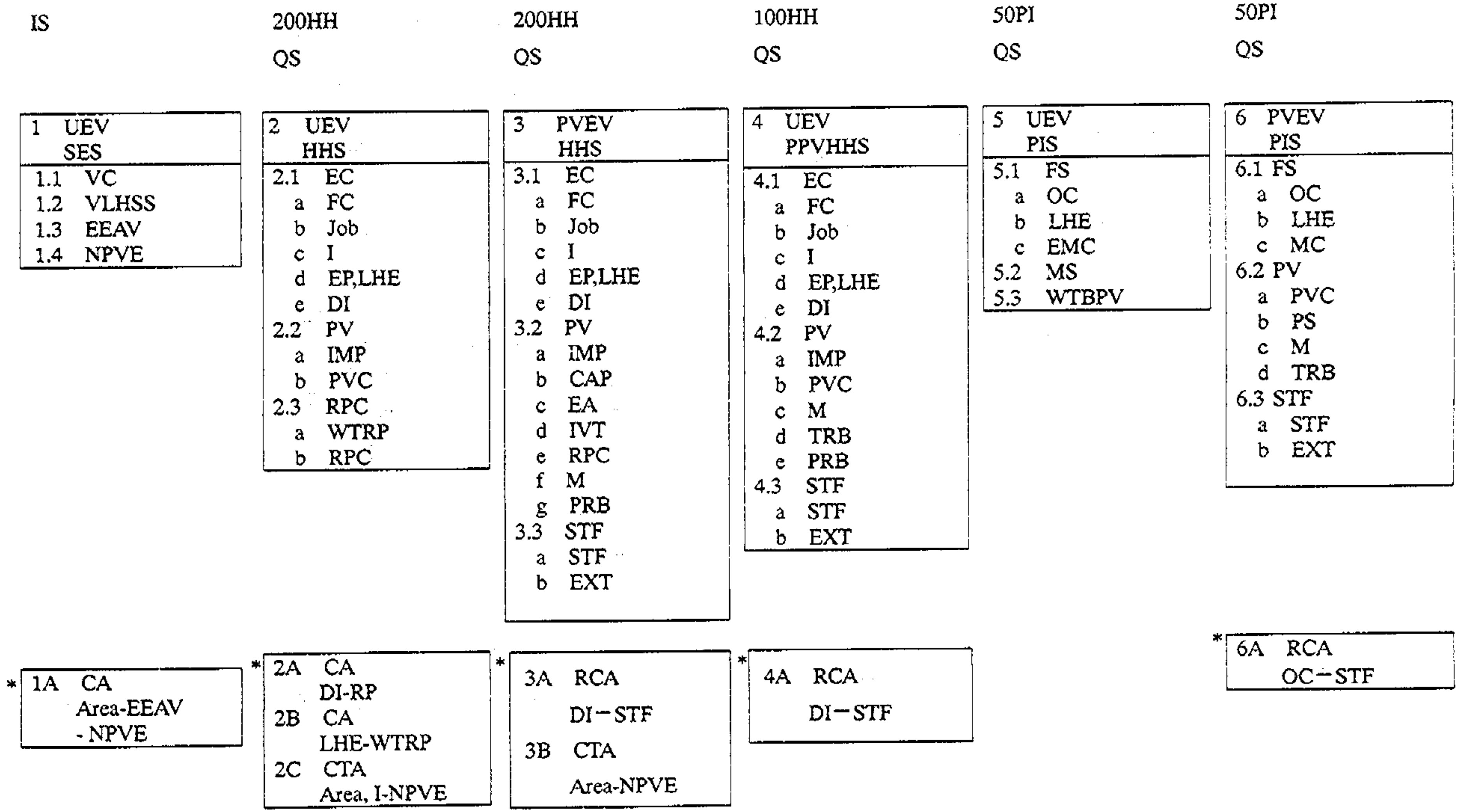


Figure5-2 The socio-economic investigation and the analysis (*) flow of the villages （1/3）

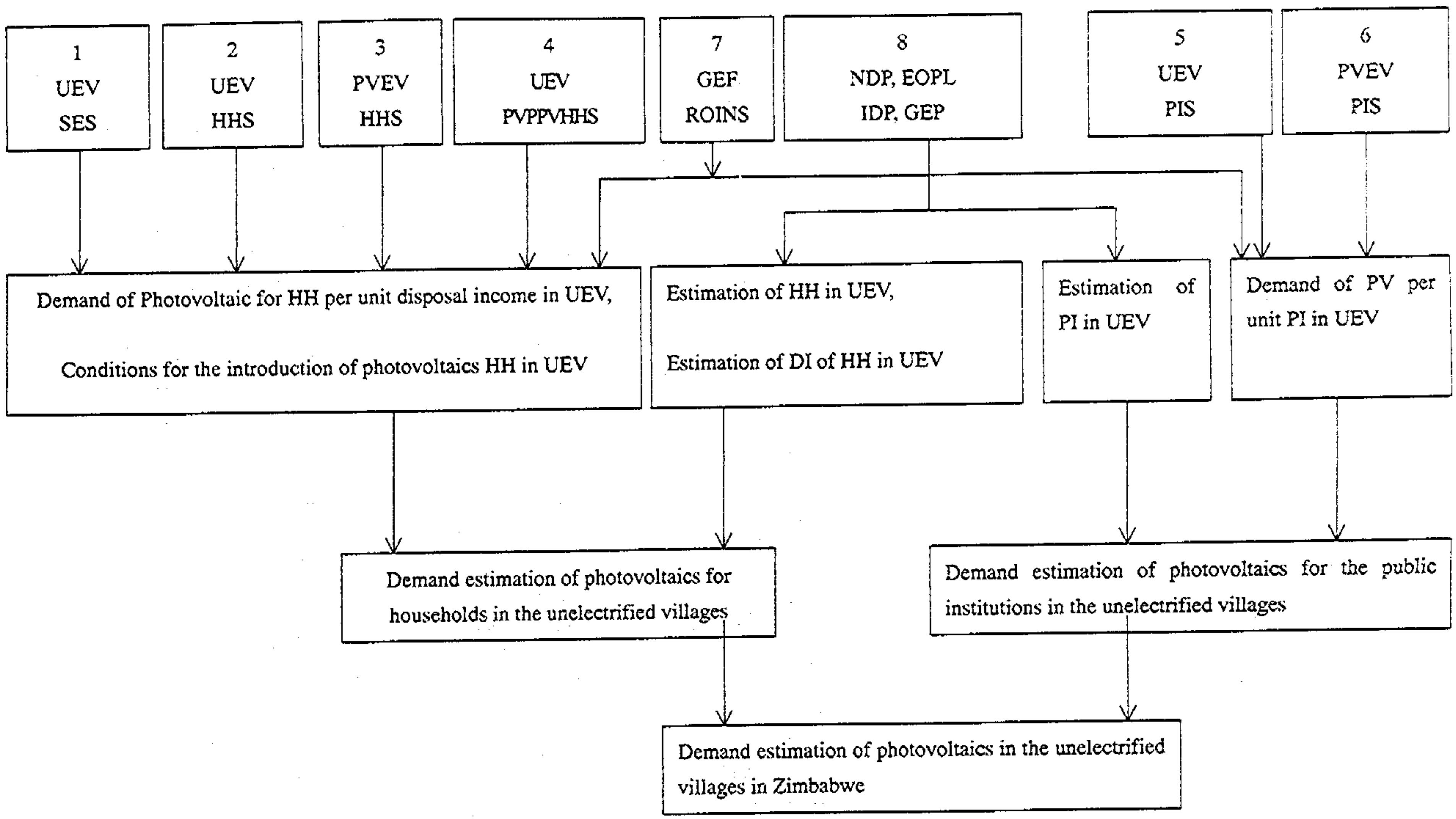


Figure5-2 The socio-economic investigation and the analysis (*) flow of the villages (2/3)

Note: Abbreviation list for Figure 5-2

AGDP	: Agricultural gross domestic products
CA	: Correlation analysis
CAP	: Capacity
CTA	: Cross table analysis
DI	: Disposal income
EA	: Electric appliance
EC	: Economic condition
EEAV	: Electric machines and electric appliances in the village
EMC	: Expected maintenance cost
EOPL	: Estimation of the population
EP	: Expenditure
EXT	: Extension plan
FC	: Family composition
FS	: Financial situation
GEF	: Global environment fund project
GEP	: Grid extension plan
HH	: Household
HHS	: Household survey
I	: Income
IDP	: Income development plan
IMP	: Importance
IS	: Interview survey
IVT	: Investment
LHE	: Lighting, heating, expenditure
M	: Maintenance
NDP	: National Development Plan
NPVE	: Necessity of PV electrification
OC	: Operating cost
OS	: Operating situation
PI	: Public institution
PIS	: Public institution survey
PPV	: Planned PV
PRB	: problem
PV	: Photovoltaic
PVC	: PC component
PVEV	: PV electrified village
QS	: Questionnaire survey
RCA	: Rank correlation analysis
ROINS	: Result of installation survey
RP	: Repaying
RPC	: Repaying condition
SES	: Socio-economic survey
STF	: Satisfaction
TRB	: Trouble
UEV	: Unelectrified village
VC	: Village composition
VLHSS	: Villages' living habitude by the social strada
WTBPV	: Willingness to build PV
WTRP	: Willingness to repaying

Figure5-2 The socio-economic investigation and the analysis (*) flow of the villages (3/3)

5.6 Survey Results

5.6.1 Targets Surveyed

A total of 492 targets (i.e. 441 households and 51 public institutions) were surveyed. Broken down, the total figure for households included 195 unelectrified, 185 PV-electrified, and 61 grid-electrified. An almost equal number of PV electrified and unelectrified households were surveyed.

Of the 51 public institutions, 31 were clinics (consisting of 18 unelectrified, 8 PV-electrified, and 5 grid-electrified) and 20 were schools (consisting of 18 unelectrified and 2 grid-electrified). The targets were located in six different provinces including Mashonaland West where 107 JICA PV systems were installed and Midlands where 5 JICA PV systems were installed. Roughly 82% of the targets were located in communal land farms.

A breakdown of the target households by province, sector, and level of electrification is shown in Table 5-8. 85% of unelectrified households were located in communal land farm areas while 9% were in resettlement farm areas. Meanwhile, of the PV-electrified households, 85% were in communal land farms while 10% were in resettlement areas. Half of grid-electrified households were in RAF areas, while the other half were located in urban areas.

Table 5-8 Distribution of Households by Province, Sector, and Model of Electrification

		Mode of Electification			
		Un-electrified	PV-electrified	Grid-connected	Sub-total
Manicaland	1. LSCF	2	0	0	2
	2. RAF	4	1	0	5
	3. SSCF	1	0	2	3
	5. CLF	41	33	11	85
	6. Urban	0	0	2	2
	Sub total	48	34	15	97
Mashonaland East	3. SSCF	1	0	0	1
	5. CLF	19	25	3	47
	6. Urban	1	1	8	10
	Sub total	12	26	11	58
Mashonaland Central	1. LSCF	1	0	0	1
	2. RAF	1	2	0	3
	5. CLF	18	11	3	32
	Sub total		13	3	36
Mashonaland West	2. RAF	13	17	0	30
	5. CLF	26	44	3	73
	Sub total	39	61	3	103
Midlands	5. CLF	32	28	4	64
	6. Urban	2	0	9	11
	Sub total	34	28	13	75
Masvingo	2. RAF	0	1	0	1
	3. SSCF	2	1	0	3
	5. CLF	30	21	6	57
	6. Urban	1	0	10	11
	Sub total	33	23	16	72
Total	1. LSCF	3	0	0	3
	2. RAF	18	21	0	39
	3. SSCF	4	1	2	7
	4. PGF	0	0	0	0
	5. CLF	166	162	30	358
	6. Urban	4	1	29	34
	Grand total	195	185	61	441

Note:

LSCF = Large Scale Commercial Farm PGF = Parastatal Government Farm

RAF = Resettlement Area Farm CLF = Communal Land Farm

SSCF = Small Scale Commercial Farm

Source: Zimbabwe field survey (1997)

5.6.2 Results of Household Survey

(1) Household size & income source(s)

The average number of people in households was 7.1. Table 5-9 gives a clearer picture of how this figure is distributed among the targets surveyed, along with a summary profile of the households' source(s) of income.

It was determined that most household heads and members engage in farming as their main source of income, accounting for 36% of the surveyed targets. The rest engaged in different kinds of salaried professions such as teaching, clerical/secretarial work, central/local government jobs, etc. Most households surveyed were found to engage exclusively in farming, i.e. household heads as well as members are farmers. A number of households, however, had members engaging in a combination of occupations, i.e. farming/salaried jobs. A few households, meanwhile, had all members earning income as salaried individuals.

Majority or 35% of the households surveyed had two income earners -- the household head and one other member of family. This was followed by households with only one income earner -- the household head -- accounting for roughly 26% of the sample, and then households with three income earners – the household and two household members, accounting for 21%. It was also observed that for almost half or 48% of the surveyed households, all members worked within the vicinity of the household, i.e. no member had to go far from the house to earn income. About 20% had one member going to the town/city to earn income, while 14% had two members.

Table 5-9 Job Profile of Households Surveyed

(1) General Job Profile

Rank	Household head	%	Household member	%
1	Farming	37.0	Farming	31.2
2	Teaching	21.5	Teaching	15.5
3	Service	9.1	Service	14.2
4	Business/Finance	7.5	Manufacturing	5.9
5	Transportation	3.9	Business/Finance	5.1
6	Government	3.2	Machine Operation	3.6
7	Office Director/Manager	2.9	Clerical/Secretarial	3.6

(2) Job Profile of Household Heads (According to Mode of Electrification)

Rank	Uncertified	%	PV electrified	%	Grid electrified	%
1	Farming	49.7	Farming	32.4	Teaching	21.3
2	Teaching	16.4	Teaching	27.1	Business/Finance	16.4
3	Service	7.2	Business/Finance	9.2	Farming	9.8
4	Transportation	4.1	Office Director/Manager	4.3	Transportation	8.2
5	Manufacturing	3.1	Government	3.2	Service	6.6
6	Business/Finance	3.1	Clerk/Secretary	1.6	Machine Operation	4.9
7	Machine Operation	3.1	Manufacturing	1.1	Manufacturing	4.9

(3) Job Combinations (Household Heads and Members)

Rank	Job of Household Head	Job of Household Member	No. of samples	(%)
1	Farming	Farming	93	15.2
2	Teaching	Service	37	6.0
	Teaching	Teaching	37	6.0
4	Own Agriculture	Teaching	28	4.6
5	Teaching	Farming	26	4.2
6	Service	Farming	23	3.8
7	Own Agriculture	Machine Operation	15	2.4
8	Service	Service	12	2.0
9	Teaching	Service	10	1.6
	Business/Finance	Teaching	10	1.6
	Farming	Government	10	1.6
TOTAL			301	49.1

(4) Number of Income Earners per Household

	Number of samples	% of Total
Head only	116	26.3
Head + 1 member	155	35.1
Head + 2 members	92	20.9
Head + 3 members	48	10.9
Head + 4 members	20	4.5
Head + 5 members	10	2.3
Total	441	100.0

(5) Job Location

No. of household members working far from household	Compositio n (%)
0	48.6
1	20.4
2	13.6

Source: Zimbabwe field survey (1997)

(2) Housing Characteristics and Sources of Energy

The general characteristics and sources of energy households surveyed are shown in Tables 5-10 to 5-13. There are basically two types of housing in the rural Zimbabwe. One is the modern type consisting of a square shaped building with plastered cement and/or brick walls, a slate roof, and about 3-4 rooms. The other is the traditional round-shaped house, with brick walls and a grass roof. Half of the surveyed households have both types of buildings in their compound, while 45% have exclusively modern type structures. The remaining 5% live in purely traditional structures (see Table 5-10).

Table 5-11 shows the kinds of appliances used by the surveyed households, their respective sources of energy, and the average length of usage per day. 90% own radios and use them from 3-6 hours daily. 45% own television sets, which they use for 2-4 hours, while only 10% own refrigerators. Majority of households surveyed also owns firewood stoves, candles, and wick lamps.

Energy sources utilized by the surveyed households are shown in Table 5-12. Average consumption of firewood was pegged at 310 kilograms per month. For unelectrified households, this figure was 337 kg/month, while for PV-electrified households, it was 326 kg. For grid-connected households, meanwhile, it was 113 kg. In terms of cost, the average for all surveyed households was Z$30.8/m. 61% of the households surveyed were found to be consuming firewood at no cost. This figure was slightly higher at 69% for unelectrified households. 55% of PV-electrified households consumed firewood at zero cost, while 43% of grid-connected households enjoyed the same.

Average monthly consumption volume and cost for paraffin was pegged at 14.1 liters and Z$28.7, respectively. Food was regarded as the most important priority, followed by money, water, health and education. Electricity placed sixth. In terms of energy source preferences, PV came out on top as most households regarded it as being the most easily available and the least-cost option to them. (See Table 5-13).

Table 5-10 Housing Characteristics & Types of Structures per Household

	Traditional structures only	Modern structures only	Traditional & Modern
(%)	5	45	50

Rank	Modern – Traditional	Share of Total (%)
1	1 - 0	29
2	1 - 2	13
3	1 - 1	9
4	2 - 0	8
5	2 - 1	8

Source: Zimbabwe field survey (1997)

Table 5-11 Appliances Owned by Surveyed Households

Appliances	(%)	Length of Usage/Day (in number of hours)	Source(s)
Radio	90	3-6	Battery, PV, grid
TV	45	2-4	PV, battery, grid
Refrigerator	10	3-6	Paraffin oil, grid
Wick lamp	90	2	Paraffin oil
Candle	90	2	Candle
Lighting	56	3	PV, grid
firewood stove	99	6	Firewood
Mill	1		Diesel oil
Pump	Rare	24	PV, wind
Generator	Very rare	2	Diesel oil

Source: Zimbabwe field survey (1997)

Table 5-12 Light and Fuel Expenditures of Surveyed Households

Electrification	Units	UE	PV	Grid	Average
Expenses for light and fuel	Z$/m	61.3	117.9	162.3	97.3
Firewood	Z$/m	(27.3)	(35.4)	(30.6)	(30.8)
Diesel and other fuel	Z$/m	(17.2)	(36.2)	(121.6)	(37.8)
Paraffin	Z$/m	(16.8)	(46.3)	(10.1)	(28.7)
Lighting	Z$/m	(10.0)	(17.1)	(0.7)	(11.6)
Others	Z$/m	(6.8)	(29.2)	(9.5)	(17.0)
Dry battery	Z$/m	47.2	15.5	15.2	28.6
PV	Z$/m	0	34.8	0	---
Grid electricity	Z$/m	0	0	122.3	---
Wood consumption	Kg/m	337	329	113	310
Paraffin consumption	l/m	7.2	22.0	4.2	14.1
Lighting	l/m	4.3	8.1	0.3	5.7
Others	l/m	2.9	13.9	3.9	8.4

Source: Zimbabwe field survey (1997)

Table 5-13 List of Household Priorities and Preferences for Energy Source

Rank	General	Energy Source
1	Food	Photovoltaic electricity
2	Money	Firewood
3	Water	Paraffin oil
4	Health	Grid electricity
5	Education	Generator electricity
6	Electricity	

Source: Zimbabwe field survey (1997)

(3) Income and Expenditures

Gross Total Annual Income (GTAI) in end-1996 of rural households surveyed (according to mode of electrification) are shown in Table. To come up with a more realistic figure for average, six samples with income higher than Z$200,000/y were excluded from the calculations.

Average GTAI for unelectrified households in 1996 was Z$26,121. This figure was clearly lower than PV-electrified households, which posted an average of Z$42,196. For grid-connected households, meanwhile, it was Z$48,941. The difference of GTAI between UE and for PV-electrified households is accounted for by the big number of households with income lower than Z$10,000. Some 62.7% of unelectrified households fell under this category, while it was 60.7% for PV-electrified households. Less than half, or 47.5% for grid electrified had incomes falling below Z$10,000. No relation between provincial GTAI and electrification ratio of each province was observed.

Average monthly expenditures of unelectrified households was Z$1,624, while PV-electrified households spent an average of Z$2,577 a month. This figure was slightly higher for grid-connected households which posted an average of Z$2,807. The average for all households surveyed was Z$2,178. To arrive at this figure, samples with monthly expenditures over Z$16,700 were excluded from the calculation (see Table 5-17).

Average accumulated savings at the end of 1996 was Z$4,246 for unelectrified households, Z$6,246 for PV-electrified households, and Z$5,988 for grid-connected households. The overall average was Z$5,354. It should be noted that these figures dropped to Z$1,654, Z$3,320, Z$1,805, Z$2,352 at the end of May 1997 when preparations for the planting season began (see Table 5-18).

Table 5-14 Gross Total Annual Income* of Households in 1996

Mode of Electrification	UE	PV	Grid	Average	Mode
GTAI (Z$)	26,121	42,196	48,941	35,798	10,000

*Excluding 6 households with income higher than Z$200,000

Source: Zimbabwe field survey (1997)

Table 5-15 Number of Income Sources of Rural Households

Number of income sources	1	2	3	4	5
%	35	39	18	5	1

Source: Zimbabwe field survey (1997)

Table 5-16 Major Sources of Income of Rural households

Rank	1	2	3	4	5
Job	Agriculture	Salaried	Small Enterprise	Income in kind	Borrowing
%	38	34	8	7	3

Source: Zimbabwe field survey (1997)

Table 5-17 Monthly Expenditures of Rural Households

Mode of Electrification	UE	PV	Grid	Average
Z$/month	1,624	2,577	2,807	2,178

Source: Field survey in rural Zimbabwe in 97

Table 5-18 Savings of Rural Households

Mode of Electrification	UE	PV	Grid	Average
End,-1996 (Z$)	4,246	6,246	5,988	5,354
End-May 1997	1,654	3,320	1,805	2,353

Source: Zimbabwe field survey (1997)

5.6.3 Survey Results for Households with PV Systems

(1) PV Systems Installed

Table 5-19 shows the number of PV systems installed beginning 1989 (according to capacity). These figures are shown graphically in Figure 5-3, where a notable increase in number of installations can be noted beginning 1993 (increasing at an annual rate of 60% until 1997, when the GEF project started. It should be noted that the total figure for 1997 was based on the rate of installation for the first 7 months of that year. Figure 5-4 shows the number of systems installed under the GEF project alone.

Table 5-19 PV Systems Installed (1989-1997)

Year / Capacity (watts)	1989	1990	1991	1992	1993	1994	1995	1996	1997*	Total
Less than 20	0	0	1	0	0	1	3	4	0	9
20-39	0	3	0	1	4	6	13	22	39	88
40-59	2	1	3	0	3	3	7	15	8	42
60-79	2	0	0	4	3	5	11	11	5	41
120 and above	0	0	0	0	1	0	0	0	0	1
Total	4	4	4	5	11	15	34	52	52	181

*Projected annual total based on installation rate between January and July

Source: Zimbabwe field survey (1997)

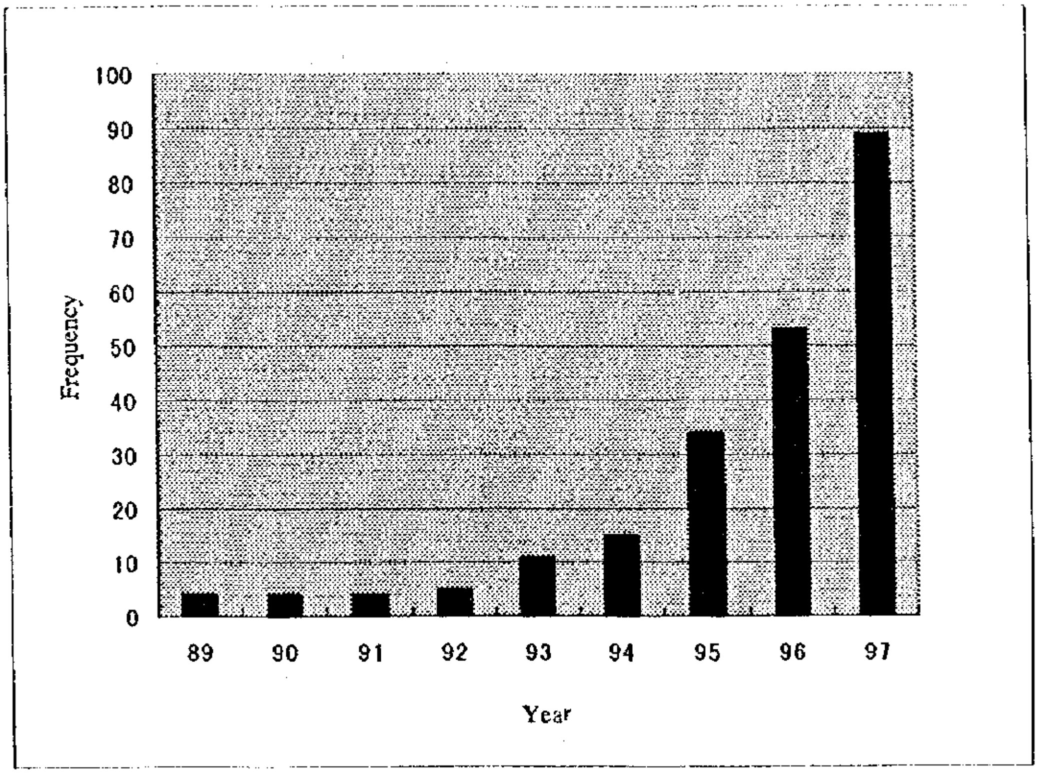


Figure 5-3 Trends in number of PV installed in study areas
Note: Figure for 97 is an annual base one converted from actual result obtained during the first seven months
Source: Field survey in rural Zimbabwe in 97

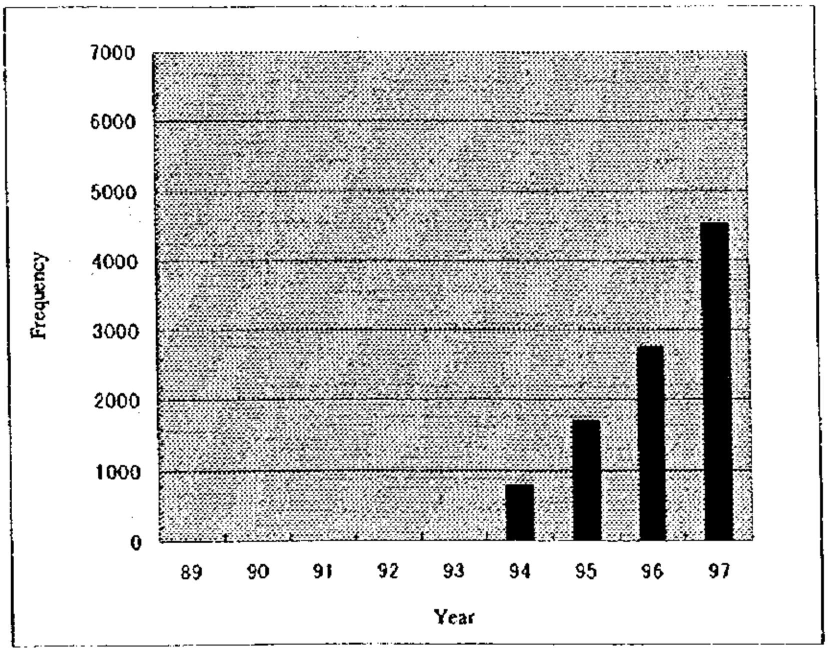


Figure 5-7 Trends in number of PV installed by GEF project
Source: GEF Annual Report 1997

Ninety-three of households with PV systems had electric lights (fluorescent tubes/incandescent bulbs). Around 89% owned radios/radio cassette players, while 78% owned black and white television sets. Most households normally begin using their system from six in the evening and use it for an average of 3.5 hours (see Figure 5-5).

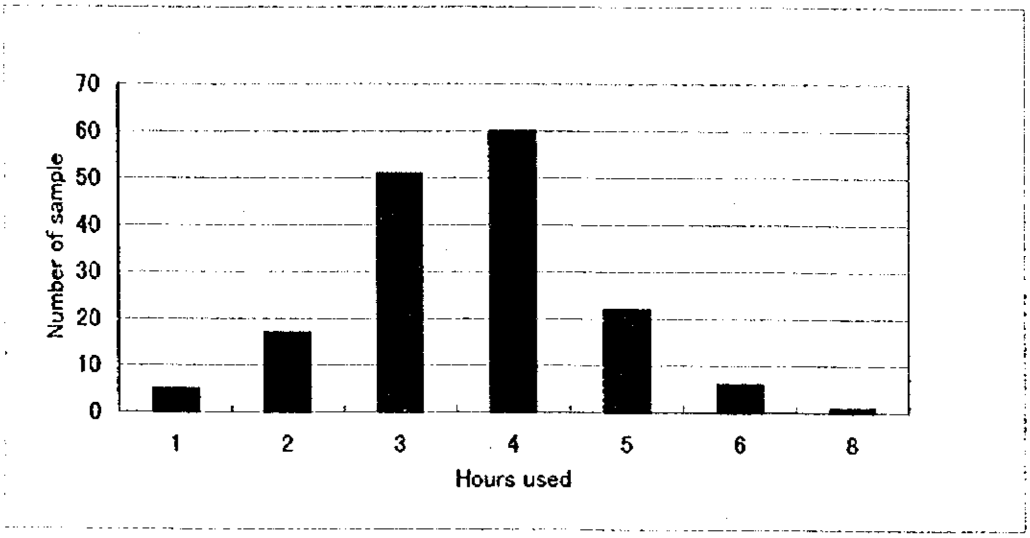


Figure 5-5 Distribution of hours PV used

Source: Field survey in rural Zimbabwe in 97

(2) System Cost and Payment Terms

A little over half of the households surveyed bought their PV system on installment, making an initial down payment and then paying the balance over an agreed upon period of time. The other half bought their systems via one-time payment. About 35% of the households that bought the systems on installment had to pay the balance for 5 years, while 31% had a 2-year repayment period. 77% of the households who bought their systems on installment made their payments on a monthly basis, while the rest paid annually and semi-annually. This is explained by the fact that most of the household heads who bought PV systems are salaried persons.

About half of the PV systems bought cost less than Z$5,000 while the other half cost between Z$5,000 and Z$10,000 resulting in an average Z$7,070. Average repayment amount was calculated as being Z$290/month. The lowest annual income of among all the households that purchased PV systems was pegged at Z$10,000.

(3) Maintenance Fees and Problems Encountered

Maintenance of the PV system is typically carried out by a member of the household, with the average annual maintenance fee being Z$100. This is roughly equivalent to the fee charged for repairing a broken system. Number of system shutdowns (after installation) averaged around 1.5, and the average period for each shutdown was 10 days.

Major problems encountered (listed according to frequency) include: low water level in the battery, voltage fluctuations during use, inoperable of system due to lack of sunshine during daytime, wrong inclination/ breakdown of pole, breakdown of PV panel, corrosion of the battery terminal, and shorter available hours for use.

(4) Change in Daily Life after Installation of PV System

Following are the changes in daily life noted after the PV systems were installed (listed according to rank):

Changes in Lifestyle	%
1. Entertainment hours became longer	23.1
2. Completing homework became easier for school children	16.3
3. Knitting, sewing, and similar activities could be done at night	15.6
4. Interest in the outside world became greater	14.1
5. Dinner time became more enjoyable	10.4
6. Cooking at night became easier	5.7
7. Increased safety against intruders/animals at nighttime	5.6

Items 1 and 4 are the natural results of having access to radio/television, while the rest can be attributed to lighting during nighttime. A separate interview of school teachers revealed that the frequency and volume of homework in rural schools in Zimbabwe is quite considerable – with assignments given out 4 or 5 days a week for secondary school students, and 3 to 4 days a week for primary school students. It was estimated that it takes about 3 hours a day for secondary school students to complete their assignments, while it half of that time or 1.5 hours for primary school students. The installation of PV systems thus contributes significantly to students' improved performance.

(5) Level of Satisfaction with the PV Systems

Roughly 63% of PV-electrified households expressed satisfaction with their decision to buy the PV systems. Roughly 22% showed satisfaction with PV while commenting that the benefits of using the PV system were offset by the limited capacity of the systems and the burden of repaying the loan. Less than 10% expressed dissatisfaction with their systems. No correlation between level of satisfaction and amount of disposable income was noted. On the whole most rural households seemed to regard the PV systems as having brought them substantial benefits.

(6) PV Expansion Plans

It was learned that most PV-electrified and unelectrified households would like in the future to use the following appliances (listed according to popularity): refrigerator (19%), TV (15%), fluorescent light (13%), radio cassette (9%), radio (9%), battery charger (7%), electric frying pan (5%), incandescent light (5%), electric fan (5%), food processor (3%).

There is a rather obvious desire by most households to use refrigerators, which cannot be run on a small-capacity PV system. Currently, about 38% of grid-connected households own refrigerators, while only 5% of PV-electrified households, and 3% of unelectrified households do. For the latter, the refrigerators are run on paraffin.

For small, say 25-watt systems, most (roughly 66%) of unelectrified and PV-electrified households prefer to use them for 1 fluorescent light and 1 outlet for radio/TV. Only a small percentage wanted to use the system exclusively for lighting, i.e. 2 fluorescent lights.

5.6.4 Price Sensitivity Analysis of PV Systems in Rural Areas

A Price Sensitivity Analysis was conducted to determine the appropriate PV system price in rural Zimbabwe. Survey targets were asked what price level they felt was: (a) payable; (b) payable (but rather cheap), (c) too expensive; and (d) too cheap. The responses were then collated from low price to high price: (a) and (c), from high price to low price : (b) and (d)and plotted as curves on a graph. The minimum acceptable price (P_1) is the intersection of curves (a) and (d) while the maximum acceptable price (P_4) is the intersection of curves (b) and (c). Based on these, the acceptable price range, i.e. between P_1 and P_4, can be established.

Calculations yielded the acceptable price range for small PV systems as being between Z$142/month to Z$ 258/m. Table 5-20 summarizes the results of calculations both for households and public institutions.

Table 5-20 Price Sensitivity Analysis Results in Unelectrified and PV-Electrified Areas

	Unit	Households	Clinics	Schools
Highest acceptable price (P_4)	Z$/month	258	740	786
Lowest acceptable price (P_1)	Z$/month	142	340	446
Payable price	Z$/month	306	326	550
Payable investment	Z$	945	1,050	4,310

Source: Zimbabwe field survey (1997)

For households, the acceptable range is below the payable price of Z$306 – presumably due to the lack of awareness about PV of the unelectrified households surveyed. For clinics, meanwhile, the acceptable price range is between Z$340 to Z$740, higher than the actual figure of Z$326. This is again presumed to be cause of the lack of awareness by unelectrified clinics. Unlike households and clinics, the payable price of PV systems for schools is within the computed range.

No relationship was found among a) GTAI and fees considered "acceptable" for PV systems, b) monthly expenditures and acceptable fee, and c) monthly expenditures and fuel expenses.