8

FRAMEWORK OF RECOMMENDED PV SYSTEM-BASED RURAL ELECTRIFICATION

8.1 Consideration of PV System-based Rural Electrification Approach

Most of the conventional photovoltaic (PV) based rural electrification projects under way in developing economies worldwide have been oriented toward the sale of PV systems. This sort of marketing-oriented projects heavily depends on the efforts of the firms which intend to sell PV systems and/or provide relevant installation and maintenance services. But, experience shows that this approach has some problems. For example, many users lack knowledge of PV systems. Without knowing how to maintain the battery, they often damage their batteries. Also, remoteness makes it hard to obtain distilled water necessary for refilling the battery. Given these problems actually experienced in PV projects, the pilot project rests on the basic rule that electricity will be supplied to the users for a fee while the PV systems themselves will be owned by the project implementer. The fee to be collected from the users includes not only the cost of the system but also the charges for maintenance/inspection visits and repairs when needed. However, because the systems are installed as a pilot project with no assurance that the project will continue after five years, a contract term with users is set for five years. What to do with the system after five years will be considered when the time comes according to the options available at that time. Effectively, this is a term-limited electricity supply service. The approach employed in pilot project was compared with the sales-oriented projects. Its results are described below.

(1) Potentials of including lower income user classes

The problem is PV systems are expensive. With the sales-oriented approach, a PV system must generally be paid for over 3-5 years in installments. Thus, due to the high monthly payments, those who can afford PV systems are limited to rather affluent households. In comparison, the pilot project assumes a 20 year payback for the investment and additionally features that the system provider evenly spread the cost of maintenance of the systems, a cost which often cannot be met by low income households because it usually is a relatively large lump sum whose timing cannot be predicted.

Since the depreciation period is set in relation to the system life (20 years) and maintenance costs evenly included in monthly fees, the users' monthly cost burden is predictable and can be low enough so that a much larger percentage of rural households can participate in solar based rural electrification.

(2) Maintenance/inspection

Under this pilot project, the maintenance/inspection visits are carried out by local technicians who regularly tour among their users. Because local technicians are not merely trained in PV-system repair/operation but in preventive maintenance as well, they can prevent problems from developing. In comparison, a sales-oriented project requires the users to make the maintenance/inspection of their systems. Those who are knowledgeable to some extent can help prevent a system failure by refilling battery liquids or through proper system use. But, the likelihood is that though rural households are most in need of PV systems, they are the least likely to have the knowledge or capability (or interest) to properly maintain them and system reliability is poor with frequent power outages and battery failures.

(3) Repairs/replacement of system parts

In addition to regular maintenance/inspection works, repairs and replacement of parts where necessary are included in the fee under this pilot project. In comparison, a sales-oriented project requires the users to repair by themselves or pay professionals for repair or replacement services. It is common for users to decide to purchase repair components which are cheaper than those originally supplied causing poor system performance and early battery failure.

(4) Installation sites

A sales-oriented project allows dealers to supply PV systems no matter where their users live so far as the users have the money to buy one. In comparison, the pilot project concentrates users in 50 household clusters so a local technician can easily visit each site on a monthly basis.

(5) Post-grid electrification response

If the system-equipped households are reached by an extended grid in the future, the approach of the pilot project allows the user to turn back the PV systems to the project where they can be reallocated to other users. In comparison, the systems purchased under a sales-oriented project will be useless unless the users are able to sell them to others.

As described above, both the marketing-oriented and system-provided approaches have their own advantages and disadvantages. But, given such advantages as the potential for making PV systems available to the middle and low income classes, the high system reliability made possible by providing periodic maintenance & inspection services and its flexibility in switching users over to grid supply in the future, the electricity supply service with the system owned by the implementation company is recommended as the more viable option for the promotion of PV system-based rural electrification.

8.2 Organization Responsible for PV System-based Rural Electrification

It is clear that sustainable, large scale rural electrification using solar PV is best done by a soundly funded public or semi-public organization (an Energy Service Company -- hereinafter referred to as an ESCO). Therefore, it was decided to take that approach for the pilot project, where an ESCO is responsible for the ownership and installation of PV systems for households. Electricity generated from these systems is supplied to the users and electricity bills include the system rent and maintenance/inspection/repair charges.

8.2.1 Requirements for ESCO as a Supply Organization

A successful large-scale PV-based rural electrification project requires an ESCO, a well-established electricity supply organization with a stable management and financial foundation. The ESCO is required to satisfy the following requirements as an electricity supply organization.

(1) Decentralized management units which allow centralized coordination

PV systems installed in users houses require swift and economical responses in the event of mechanical troubles, spare parts supplies, customers services, etc. Therefore, the ESCO is required to have branch offices in various spots near the concentrations of users. At the same time, the ESCO must have a centralized sector responsible for negotiations with the government and overseas aid organizations, fund-raising, assets utilization, specification and purchase of materials and equipment, staff training, service/cost sharing coordination among the decentralized management units, etc.

(2) Marketing ability

The cost to manage and sustain this organization heavily depends on the maintenance charges collected from the users and it is also deeply related to the degree of geographical concentration of the users. Thus the ESCO should have a strong market development ability, so that it can concentrate as many users as possible within a given district.

(3) Technological capabilities in PV power generation

The ESCO is required to have or be able to economically obtain the technological capabilities necessary for performing system design, selection and quality inspections of component parts, making tests upon the completion of installed systems, and post-installation maintenance services.

(4) Motivation to maintain systems satisfy users' requests

System reliability depends on quality of design and maintenance. An organization responsible for PV system-based rural electrification is required to provide the users with highly reliable electricity supply and take a decisive posture toward making the necessary periodic inspections. In an ESCO, the bills paid by the users are the only revenue source for the organization. To keep that revenue stream coming, the best efforts must be made to win users' satisfaction through the provision of reliable electrical service which in turn depends mainly on consistent and quality maintenance.

(5) Financial capability to afford capacity expansion

A major finding of this pilot project is that, once PV systems have been successfully in operation over six months, a growing number of unelectrified households in the vicinity want PV systems and many existing users want to expand the capacity of their system. To realize effective rural electrification, the ESCO must always be able to meet the requests for system installation from new users and for capacity expansion from existing users within a given district.

(6) A good grasp of billing and bill collection

To collect and manage the fee collection from the widely dispersed users requires decentralized management. In addition, the collection method must be flexible enough to meet the financial conditions of the users who tend to earn their incomes seasonally as they are farming families. Bill collection should be arranged for the convenience of the users to match their income patterns. The staff in direct contact with the users must have the up to date information about the payment status of their customers.

(7) PV-based rural electrification as the primary objective and service as it primary product

An ESCO must have the supply of PV-generated electricity service as its primary company objective. The requirements for successful PV rural electrification are different from those for other electrification forms and an organization not dedicated to PV-based rural electrification tends to have consistently poor results in providing quality service to its customers connected to PV systems. Likewise, an organization mainly organize just to increase the number of PV systems to be installed can hardly satisfy the basic requirement for rural electrification; that is, a sustained and highly reliable electricity supply.

(8) Authority to disconnect when fees are not paid

Consistent fee collection does not occur if customers are not disconnected for non-payment of fees. Users must sign a contract clearly stating that the ESCO will disconnect the system if the fees are not paid. Also, the ESCO must carry out the disconnection according to the terms of that contract. If disconnects are not consistently made for non payment of fees, the rate of collection can plunge to a level so low that the ESCO cannot financially survive. At the least, the ESCO would lose the confidence of the users who honestly do pay their bills. At the same time, disconnection of systems and/or collection of overdue bills must be made with consideration of the income timing conditions in the district. In general, advance payment up to one year ahead should be the preferred mode of collection.

8.2.2 Evaluation of Candidate Organizations for ESCO

Both existing and newly-formed organizations can be candidates for fulfilling the ESCO role. The former include the Zimbabwe Electricity Supply Authority (ZESA) which is currently responsible for electricity supply, Rural District Councils (RDC) which are local administrative organizations, and the NGO currently responsible for the JICA system of this preliminary project under the DOE supervision. By analyzing their advantages and disadvantages, the major candidate organizations for the ESCO were evaluated.

(1) ZESA (Zimbabwe Electricity Supply Authority)

In 1997 ZESA agreed to install 500 household PV systems under a scheme quite similar to this pilot project. To introduce, manage and maintain a PV based rural electrification project with a much larger number of independent PV systems to be installed, will require a larger staff including additional management staff as well as both PV-system experts and maintenance personnel.

These new staff will have functions completely different from those of the regular ZESA staff and effectively, if acting as ESCO for a PV-based rural electrification project, ZESA will be required to set up a new, independent management organization for solar electrification. In specific terms, it appears necessary to create a subsidiary independent of ZESA, provisionally named "ZESA Solar." During its early days, the subsidiary can be subsidized or extended financial aid by the government and international aid organizations. Later, however, the subsidiary will be able to perform operation and maintenance on its systems fully financed by the collected fees. ZESA Solar does need to be kept consolidated with ZESA in the areas of basic policy, accounting and upper management, but it is recommended that it perform its services completely independent of ZESA.

(2) RDC (Rural District Councils)

Rural district councils (RDC) are local administrative organizations which cover individual administrative jurisdictions across Zimbabwe, and are responsible for policy-making in such issues as rural area development, including determining the electrification necessary to local residents. RDCs have shown their ability to manage decentralized districts as local government units. However, though the RDCs have been given the authority to provide improvements in health, education and public services, RDCs are not empowered to offer an electricity supply service. Also, RDCs do not have necessary technical skills and manpower for directly providing an electrical supply service. In their capacity of a local government organization, RDCs have only a limited discretion over financial decisions and its budgets, which in particular means difficulties in both personnel recruiting and dismissal and a lack of flexibility. RDCs are also subject to the geographical limits of their administrative jurisdiction. A small or poor jurisdiction may be unable to install sufficient systems to allow efficient management and maintenance of a PV-based electrification project. As each RDC must act independently of the others within its own area and budget, economies of scale would be lost and there would be inefficient duplication of facilities, personnel and efforts.

(3) NGO (Non-governmental Grganizations)

This JICA pilot project is managed by a NGO with a good record of performance. Also, several other NGOs in Zimbabwe have installed PV systems and thus contributed to their dissemination. But these NGOs cannot cope with the large number of systems envisioned for full scale rural electrification using PV systems. To revamp existing NGOs and enlarge their financial and geographical coverage enough to meet this PV-based rural electrification project can involve many risks. Further, such an approach is likely to cost substantially more than creating an expert group as a subordinate unit of existing local government organizations. Yet, NGO members can participate in the project as local or senior engineers under the ESCO.

(4) Cooperatives

In some countries, such as the Philippines and the U.S., cooperatives have been playing a key role in electrification of rural areas. The success in such countries is largely the result of the existence of supervisory and supporting organizations (NRECA in the U.S., NEA in the Philippines) which provide a wide range of roles from regulating and supervising the contents of cooperatives' activities to extending them training, funds and technical assistance.

At present, no supervisory organization exists over such cooperatives in Zimbabwe. The need to establish such a supervisory organization is limited, particularly if it is to be specifically for the promotion of PV-based rural electrification.

In general a cooperative based system lacks the management ability, technological capability and financial stability required for the sustained maintenance of PV-based rural electrification.

As in the case of RDCs, the employment of a cooperative based system, unless established on a national scale, can block the possibility of cross subsidizing from affluent areas where electrified households are concentrated to less affluent areas with many unelectrified households, which are maintenance-cost-intensive areas.

(5) Newly-formed private organizations

Given the lack of prior successful experience and the lack of development of the market, it appears too early to establish a new private organization specifically for PV-based rural electrification. Private firms can act as the principal organization responsible for such a project only after large numbers of PV systems have been installed and data have been gained on actual costs and risks involved in PV based rural electrification. Even in that case, close government involvement would be necessary in both finance and management. Accordingly, an organization under the control of the provincial or national government appears to be most appropriate.

(6) New or existing government organizations

Except the case to use part of ZESA's organization, it is not recommended to use existing government organizations, or form a new government organization, for a PV-based rural electrification project. Government organizations lack flexibility and will not be able to make the necessary organizational or operating changes which will be needed as VP based rural electrification evolves and expands especially during Phase 1

The various elements discussed above are summarized in Table 8-1.

Table8-1 Characteristics of Candidate Organizations for ESCO

Functions	ZESA Solar	RDC	NGOs	Cooperatives	New private organizations	Existing government organizations
Decentralized management plus centralized coordination	○	○	△	×	×	○
Ability to develop users	○	△	○	△	○	×
PV-system technological capacity	△	×	○	×	△	○
Motivation of long-term supply	○	×	△	△	○	×
Low-cost capital raising	○	△	△	×	×	○
Local staff managing capacity	○	○	△	×	△	△
Quality control capacity of system installation	○	○	△	△	○	△
Bill collection and accounting capacities	○	○	△	×	○	△
Authority of organization	○	×	×	○	○	×
Will and ability to disconnect unpaid users	○	△	△	×	○	△

As clearly noted from Table 8-1, a ZESA subsidiary is optimal to fulfilling the overall role of ESCO.

8.3 PV-based Rural Electrification Project

8.3.1 Number of Households Subject to PV-based Electrification

The numbers of electrified and unelectrified households in Zimbabwe were surveyed in 1992. Since then, electrification has been in progress in urban areas, but the electrification rate in rural areas has changed little to date. The 1992 survey results showed unelectrified households numbered 1.50 million nationwide, and 1.30 million in rural areas. At present, unelectrified households reach an estimated 1.50 million in rural areas.

Table 8-2 Household Electrification Rates by Province (1992)

Province	Household	Electrified		Unelectrified	
		%		%	
Mashonaland West	232,340	21.13	49,093	78.87	183,247
Mashonaland Central	177,011	9.03	15,984	90.96	161,009
Mashonaland East	219,516	8.74	19,186	91.25	200,308
Manicaland	320,944	13.49	43,295	86.5	277,617
Masvingo	231,727	11.22	26,000	88.76	205,681
Midlands	247,723	24.21	59,974	75.79	187,749
Matabeleland South	108,815	10.12	11,012	89.84	97,759
Matabeleland North	116,115	15.47	17,963	84.39	97,989
Major City Harare	364,136	64.4	234,504	35.55	129,450
Bulawayo	145,962	91.83	134,037	9.16	11,910
Total	2,163,289	28.24	610,913	71.74	1,551,944
Area Wise Urban	763,706	71.65	547,195	28.32	216,282
Rural	1,399,583	4.55	63,681	95.43	1,335,622

From the results of a socioeconomic survey (1997), an assumption was made as to the size of fee which would be affordable and the number of households within this range determined. With annual bills charged for a PV system assumed at Z$1,426, or Z$3,353 (see Section 5.7 of Chapter 5) the percentage of and the number of households were obtained for which the bills would remain below 4% of their annual income. This figure was chosen because a social survey on rural society showed that unelectrified households spent about 4% of their annual income on kerosene and batteries used as the alternatives to electricity.

Here, estimations are made for the years 1997 and 2017. (The estimation for 2017 assumed a population growth of 3%, rural population at 58%, and annual income growth at 3%)

Table 8-3 No. of Households affording a PV System

Payable bills	Share of affordable households		No. of affordable households	
	1997	2017	1997	2017
Z$1,426/year	14.8%	46.8%	222,000	1,123,000
Z$3,353/year	3.7%	15.4%	55,500	370,000

The estimation results suggest that the households which can afford the annual cost of around Z$3,000 (the potential customers) reached an estimated 50,000 as of 1997, and would outnumber 300,000 by 2017. This suggests that affordability will not be a limiting factor in developing PV rural electrification at a rapid rate.

8.3.2 FY-Basis Electrification Project and Staffing

Examined here is the case where 15,000 systems will be installed during a five year long Phase 1, and a total of 150,000 systems installed in two decades.

Systems will be installed first in a limited number of areas. Then, while expanding the capacity of the organization, installation efforts will be gradually extended nationwide. The size of staff, number of offices, centers, etc. which will be needed for the electrification project are estimated as well.

Table 8-4 PV System Installation Plans

Phase 1	Year	1st	2nd	3rd	4th	5th
No. of installed systems/year		1,000	2,000	3,000	4,000	5,000
Accumulated No. of installed systems		1,000	3,000	6,000	10,000	15,000

Phase 2	Year	6th to 10th	11th to 15th	16th to 20th	total
No. of installed systems／year		6,000	9,000	12,000	
No. of installed systems/5 years		30,000	45,000	60,000	
Accumulated No. of installed systems		45,000	90,000	150,000	150,000

After establishment of ESCO, their offices and centers are planning to increase year by year (refer to Table 8-5)

First year, national management center and two local management offices are established. Two district management centers will cover 1,000 users. Local technician is basically in charge of 50 users, therefore, 20 local technicians are necessary. Also, senior engineer takes care of five local technicians. So, four senior engineers are necessary. During first phase, 10 local management offices will be established and they cover 15,000 users. When local management offices increase, district management center will be established. Then, local technician is in charge of about 100 users and senior engineer takes care of about seven local technicians.

Second phase is from sixth year to twentieth year. Second phase is divided in three five-year plan. In final five-year plan, number of annual PV installation reach 12,000. Then, local technician will be in charge of 200 users, senior engineer takes care of 10 local technician, and 35 local management offices will be established. Final accumulated users will become 150,000. Number of total technician and engineer is 750 of local technicians, 75 of senior engineers.

Figure 8-1 shows number of annual PV installation and accumulated number in first phase and second phase.

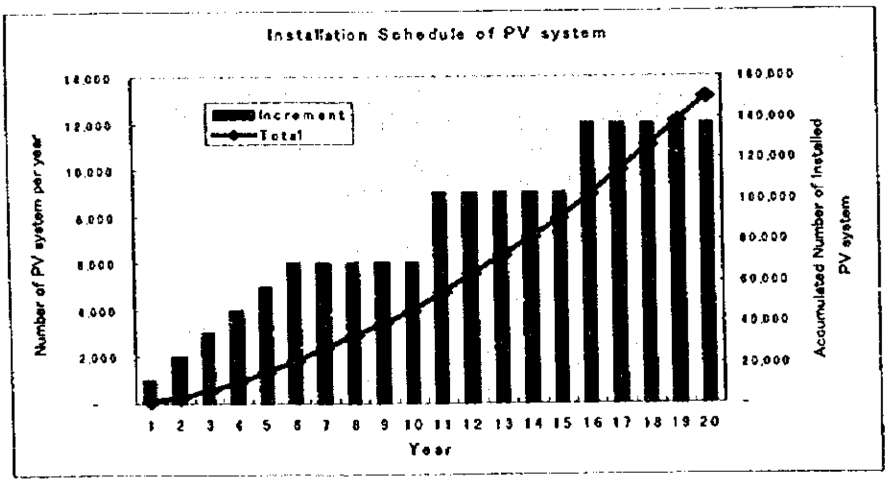

Figure 8-1 Installation Schedule of PV System

Table 8-5 No. of Households Subject to PV-based Electrification and Offices and Centers Required

Phase 1 Year	1st	2nd	3rd	4th	5th
No. of installed systems/year	1,000	2,000	3,000	4,000	5,000
Accumulated No. of installed systems	1,000	3,000	6,000	10,000	15,000
No. of customers／No. of local technicians	50	60	75	83	100
No. of local technicians	20	50	90	120	150
Local /senior engineers	5	6	6	7	7
No. of senior engineers	4	8	15	17	21
Local management offices	2	4	6	8	10
District management centers			1	1	1
National Management Center	1	1	1	1	1

Phase 2 Year	6th to 10th	11th to 15th	16th to 20th	Total
No. of installed systems/year	6,000	9,000	12,000	
No. of installed systems/5 years	30,000	45,000	60,000	150,000
Accumulated No. of installed systems	45,000	90,000	150,000	
No. of customers/local technicians	120	150	200	
No. of local technicians	375	600	750	750
Local /senior engineers	10	10	10	
No. of senior engineers	38	60	75	75
Local management offices	20	30	35	
District management centers	3	5	7	
National Management Center	1	1	1	

Table 8-6 Estimated Staffing Requirements for Offices and Centers

	Local management offices (LMO)	District management centers (DMC)	National Management Center (NMC)
Manager	Concurrently held by a senior engineer	1	1
Senior engineers	2 ～ 3	1 ～ 2	2 ～ 4
Office clerks	1	2	3 ～ 5
Drivers	1	2	2
General labor	1	1	1
Total	5～ 6	7 ～8	9 ～13

Table 8-7 Expected Staffing Requirements (Last Fiscal Year of Every 5 Years)

FY	1st~5th	6th~10th	11th~15th	16th~20th
NMC	1	1	1	1
Manager	1	1	1	1
Senior engineers	2	3	4	4
Office clerks	3	4	5	5
Drivers	2	2	2	2
General labor	1	1	1	1
DMC	1	3	5	7
Managers	1	3	5	7
Senior engineers	2	5	7	10
Office clerks	2	6	10	14
Drivers	2	6	10	14
General labor	1	3	5	7
LMO	10	20	30	35
Manager				
Senior engineers	21	38	60	75
Office clerks	10	20	30	35
Drivers	10	20	30	35
General labor	10	20	30	35
Managers	2	4	6	8
Senior engineers	25	46	71	89
Office clerks	15	30	45	54
Drivers	14	28	42	51
General labor	12	24	36	43
Local technicians	150	375	600	750
Total	218	507	800	995

8.3.3 How to Manage ESCO

Under this project, PV systems will be located, not scattered over a broad area, but within a concentrated district of 50-100 users where a local technician can visit every month to provide necessary maintenance service. Where 10-20 districts could be developed in an area, a Local Management Office (LMO) would be established, and senior engineers assigned to supervise the local technicians. The LMO is responsible for billing (including maintenance charges) and management of spare parts inventories. A province having several Local Management Offices would be provided with a District Management Center (DMC) to render more efficient broad-area management. A National Management Center (NMC) must be present from the beginning. The NMC directly supervises the Local Management Offices in the areas where a District Management Center is absent (see Figure 8-2 "ZESA Solar Simulated Organizational Chart").

Table 8-8 Roles by Part

	Setting requirements	Contents of services/works
PV system users	More than 50 users exist in an accessible area by a local engineer every month.	To use electricity produced with PV system. To pay the bill for system installation. To pay the electricity rate. To replace consumable supplies, like fluorescent lamps. To prevent thefts and damage to the system.
Local technicians	To reside in the same area as PV system users to be served.	To provide system maintenance. To instruct users how to properly use the system. To collect maintenance charges and replace parts, if necessary. To locate new users within the service area
Senior engineers Assigned to local management office.	A senior engineer assigned for every 5-7 local technicians.	To give local technicians technical guidance, and check maintenance conditions. To check claims and instruct how to handle them. To judge the time of battery replacement. To check system installation work
Local management offices (ZESA: Sub offices)	Established in an area with 10-20 groups of users developed.	Staffed with 2-3 senior engineers and 1-2 office clerks. Responsible for collection/management of electricity bills, claims handling, management of supplies, replacement of local technicians, payment to local technicians.
District management centers (ZESA: Area/ District offices)	To manage 4-5 local management offices.	Responsible for bill collection within the districts, information gathering for claim handling, inventory management of spare parts & component parts for new users.
National Management Center (ZESA: Harare Main Office)	Ultimately to manage 7-8 district management centers across the country.	To act as the window while negotiating with the government. To prepare plans to promote electrification in all areas. To design the specifications of systems and component parts. To check quality, procure and deliver parts. To prepare local/senior engineers training and educational programs, fund-raising plans, budgeting, financial settlements, PR activities.

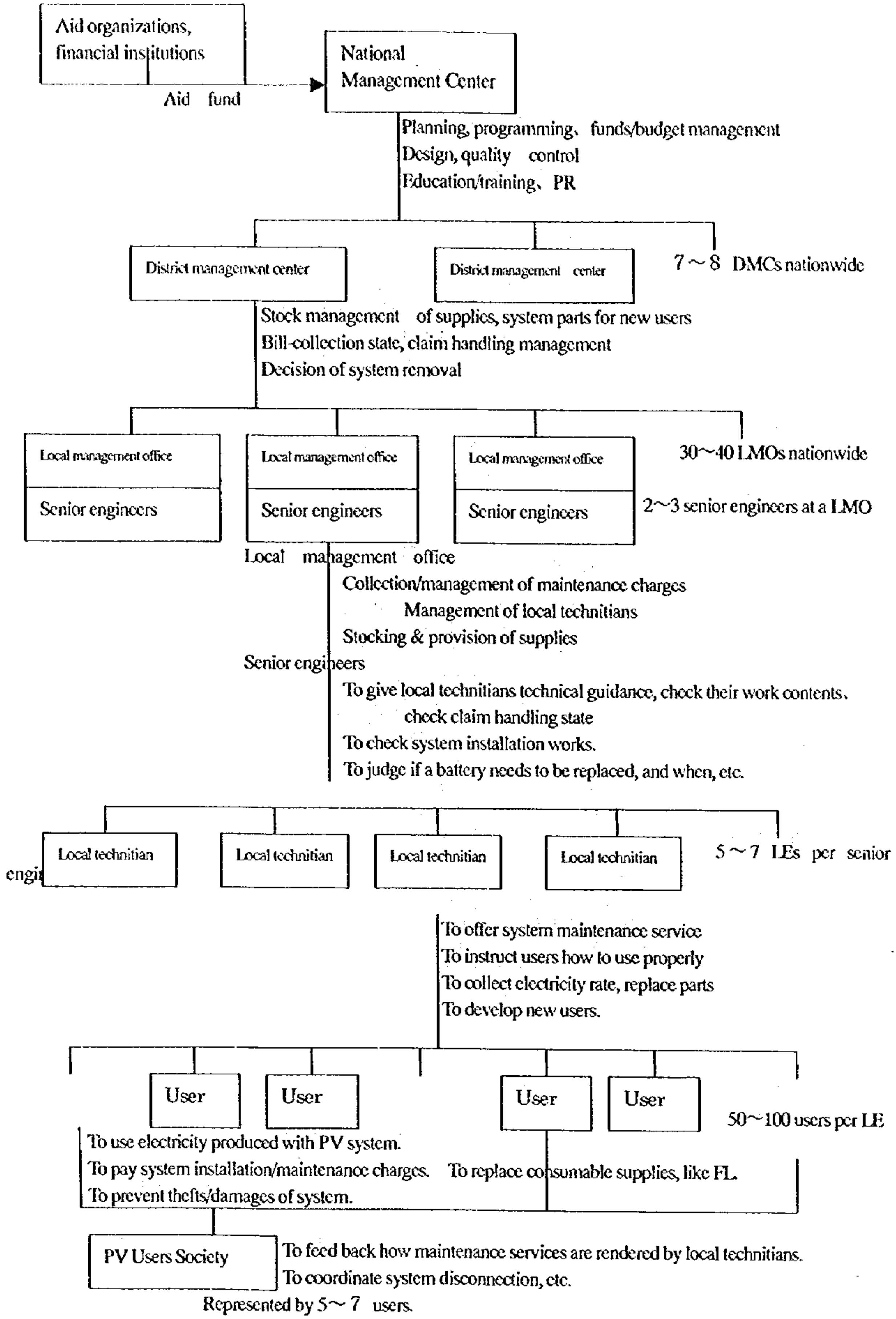

Figure 8-2 A Stimulated Organizational Chart of ZESA-Solar

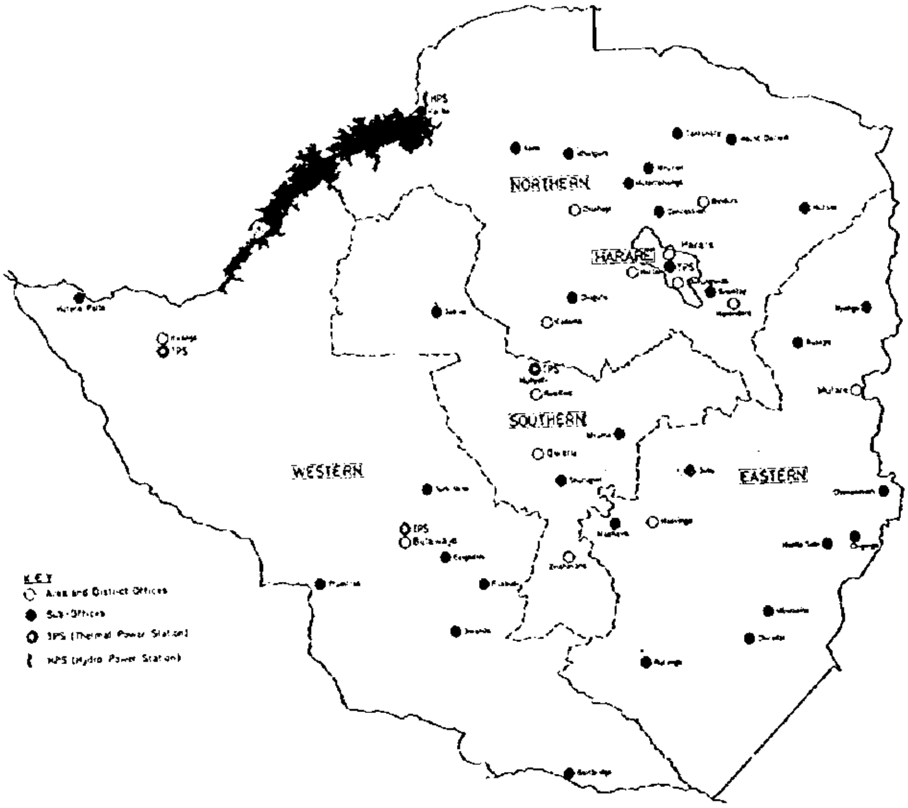

Figure 8-3 ZESA Area Offices and Sub Offices

Area	Province	Area and District Office	Sub Offices
Northern	Mashonaland West	Chinhoyi, Kadoma	Karoi, Mhangura, Chegutu, Mutorashanga
Northern	Mashonaland Central	Bindura	Centenary, Mount Darwin, Mvurui, Concession
Northern	Mashonaland East	Harare, Marondera	Mutoko, Bromley
Eastern	Manicaland	Mutare	Nyanga, Rusape, Chimanimani, Chipinge, Middle Sabi
Eastern	Masvingo	Masvingo	Gutu, Mashava, Chiredzi, Rutenga
Southern	Midlands	Gwelu, Kwekwe	Gokwe, Mvuma, Shurugui, Zvishavane
Western	Matabelelan d South		Esigodini, Plumtree, Gwanda, Beitbridge
Western	Matabelelan d North	Bulawayo, Hwange	Victoria fall, Turk Mine

8.3.4 Staffing Requirements and Training

(1) Local technicians

Because the users involved in "Phase 1" are those who have less than four years of operational experience, they must be visited by a local technician at least once a month. Once their operating experience exceeds five years, the number of visits by a local technician can be reduced to once every other month. For "Phase 1", it appears necessary to have a local technician visiting the users every month.

A local technician must be assigned to every 50 systems during the initial project period, with the average per technician expanding to 100 systems a few years later. Accordingly, a district consisting of about 1,000 systems requires some 10-20 local technicians. Given the target that a total of 15,000 households shall be equipped with PV systems during "Phase 1," some 200 local technicians must newly be secured and trained during the five years of "Phase 1." In addition, on the assumption that some technicians would resign or be found disqualified during the five-year Phase 1, an additional 30 technicians need to be trained. Specifically, "Phase 1" requires a training center where some 50 local technicians can be trained every year. The training system already established by the JICA study team at Kwekwe Technical College is recommended as appropriate for training the local technicians.

For successful rural electrification, it is also essential to regularly check the technical competence of local technicians and senior engineers and give them re-education or retraining periodically, so that they can keep their capabilities at a sufficient level.

(2) Senior engineers

A senior engineer needs to be assigned for every 5-7 local technicians. The post of senior engineer, who is expected to supervise the local technicians and make repairs which are beyond local technicians' capacity, must be held by an engineer who is given broad-range training, from system operation and theory to the skills to pursue causes of trouble. Given the target size of 15,000 systems during the "Phase 1," some 5-10 senior engineers need to be trained every year. At present, few local organizations are able to offer such training. If the PV trainers at Kwekwe Technical College are given the necessary training, they would be able to offer the higher level training necessary for senior engineers.

(3) Screening and training of local technicians and supervisor's capacity

It is local technicians, responsible for periodic system inspections, who directly act as the liaison between the users and the ESCO. Usually the technicians are the only representatives of the ESCO visible to the users. To ensure swift responses to troubles and minimize the cost of access, the technicians must reside within the same area as their users.

Qualities required for local technicians include; faithfulness, capability and will to perform necessary work with minimal supervision, be responsive to training, have a polite manner with the users, be honest, and be capable of winning the users' confidence through competence and reliability.

For these reasons, it is important for the ESCO is to be capable of screening qualified candidates and training them to be competent technicians who not only are able to offer top-quality maintenance service but also can maintain good customers relations by acting as competent representatives of the ESCO in both technical and organizational terms.

The organization is also required to have the capacity to monitor, support and supervise the technicians. This task falls on the senior engineers who are given the needed education/training, then assigned to Local Management Offices to supervise, support and assist the local technicians as necessary.

8.3.5 On-site Management and Control

(1) Management policy

PV systems are owned and given the necessary maintenance by the ESCO. Wiring from the controller and appliances, including lights, are owned and managed by the users. This is the same approach used in grid delivered electricity systems. The electric utility owns the facilities involved in power production and distribution up to the interior distribution center in the customer's house. By taking this approach, it becomes possible to initially select the best components and to replace failed components with the proper units.

The ESCO provides individual districts with maintenance services through local technicians who are ESCO employees and residents in their respective districts. A district is defined as an area where the local technician can economically visit all the users at least once a month.

To sustain the employment of a local technician requires at least 50 users. Therefore, until some 50 households in a given district agree to receive such service, no PV systems will be installed in the district. A single local technician can properly serve up to around 100 users, (in a densely-housed district). If a district contains more than 100 would-be users who hope to install PV systems, the district is divided into two, each treated as a single district. (In Phase 2, a single local technician is expected to serve up to 200 customers, each to be visited every other month, on the assumption that technological advances, such as improved batteries, and more experienced users would reduce the needs for maintenance visits to once every other month.) Local technicians need to be provided with appropriate means of transport, such as bicycles, and arrangements made for covering the cost of public transport within larger districts (usually buses) where needed.

(2) Contract between the ESCO and users

As in the case where electricity is supplied from a grid, a user is required to sign a contract which stipulates that the user agrees to pay the charge for system installation.

Further, under a maintenance service contract with an ESCO, the customer agrees (1) not to modify the equipment belonging to the ESCO, (2) to keep the PV panel out of the shade, (3) to allow free access by the ESCO technician to the system, (4) to pay agreed upon fees by the specified date, and (5) to use the system in accordance with the guidelines published including that any new load should not be connected to the system unless a prior written consent is given by the ESCO.

On its part, the ESCO is required under the contract (1) to maintain the electricity supply, and (2) to replace all failed components without added cost to the user excepting wiring after the controller and appliances owned by the user. Also (3) the ESCO is entitled to disconnect or dismantle the PV system if the user does not follow the terms agreed.

(3) Feedback from users

For the ESCO it is very important to have a means to get feedback information from the users about the quality of the service rendered by the local technician. Under this pilot project, individual local technicians are required to collect users' comments during their visit. The technicians include the comments in their visit reports, which are submitted to their senior engineers. One problem is the limited frequency of local technician's visits to a user. It was also found during this pilot project that users' requests were not always correctly conveyed through the local technicians' report, particularly if the comment reflected unfavorably on the technician. The functions of the feedback system are to convey the users' complaints and requests to the manager of the ESCO and to inform the users of the ESCO policies, particularly if the billing and service arrangements are changed. To implement this feedback system, it is recommended to form a user's committee in each district comprised of 5-7 users, who will collect users' complaints and requests and directly convey the information to the manager of the ESCO. This helps get around one of the problems of the ESCO approach which is having only the local technician as the interface between the company and the customer. A user's committee can greatly improve public relations and make the ESCO more responsive to the needs of the users as well as acting as a form of supervision on the local technician.

(4) Initial cost (system installation charge)

The charge for system installation has the same significance as the charge for connecting to a grid.

While this charge is useful in confirming the users' ability and willingness to pay for electrification and helps offset the cost of wiring the house and installing the system.

The amount of the system installation charge should be determined by taking into account a wide variety of factors, including system size, system cost, the source of funds for installation, government policies, and what is an affordable amount for the users. Ideally, the installation charge should cover the installed components which will become the property of the user, i.e. the wiring after the controller, the lights and any other appliances provided during the installation.

8.3.6 ESCO Management Cost

(1) Personnel expenses

It is the personnel expenses that are expected to make up the greater part of the management cost. Particularly because this type of project involves a large number of local technicians, their unit cost can have a great impact on the management cost. In Zimbabwe's rural areas, where few opportunities of employment are available, labor costs are low and such jobs as are available are almost exclusively for males. The tasks of the local technician are practical for females as well as males making the number of possible applicants much larger. As the work load of the local technician rises (with increasing numbers of systems to maintain) and the competence of the technician increases the salary can also increase The number of higher level staff will be small and their pay rate not so critical as that of the numerous local technicians. During the start up phase, it may be appropriate for ZESA to second existing employees to the ESCO providing effectively a management subsidy to the ESCO. In the long run, however, direct employment by the ESCO will be necessary. To subsidize startup personnel through a government subsidy can also be viable. Also, the purpose of the Rural Electrification Fund (REF) includes salaries of personnel involved in rural electrification and this could be used for management subsidy.

(2) Material Costs

Major material costs include the consumable supplies used by the local technicians and replacement costs of failed batteries and charge controllers. The Battery's life greatly depends on the manner of battery use and the quality of periodic maintenance performed. Also, these costs vary depending on the types and quality of batteries and charge controllers used. Because the ESCO is expected to use domestically-manufactured products as replacement parts as much as possible, it is essential to require domestic manufacturers of PV-system components to bring the quality of their products to an acceptable standard. To this end, technical guidance should be given to them by the ESCO and stringent quality acceptance tests performed.

(3) Administrative costs

Administrative costs include: the costs incurred in bill collection, inventory control, claim handling; the maintenance and operating cost of vehicles to deliver materials and transport senior technicians; fuel costs; the education & training costs of staff; ; and the maintenance & management costs of offices themselves. These administrative costs should be included in the service charge collected from users. In case the collected charges are insufficient to cover administrative costs, ZESA would be expected to make up the short fall as the parent company of the ESCO.

8.3.7 Fee Setting

In principle, the fee charged to the users should be set by taking into account the recovery cost of the initial equipment investment, administrative costs of ZESA-Solar, maintenance cost, and the cost of replacing failed components belonging to the ESCO. Since the ESCO is allowed to provide PV systems of different sizes depending on the different needs and payment abilities of different users; a different fee would be charged based on the actual cost of installing, supporting, maintaining and repairing that system. The different needs should be met by setting a standard module size and assembling the standard modules to fit the needed requirements. ESCO would also be allowed to install more than one system per customer if requested.

As a minimum, the operation and maintenance (O&M) cost should be fully recovered from the users. In practical terms, reflecting the government's policies to promote and subsidize specific rural electrification projects, the fee is set in two ways, in one case with the whole or part of initial capital investment included, and in the other case the initial investment is not included. In Chapter 9, several different cases are analyzed along with their effect on the fee that would have to be charged.

8.4 Components of PV Systems and their Installation and Maintenance

8.4.1 Components of PV Systems

In order to make PV systems marketable, it is essential to set standard system specifications to make the procurement and installation processes easier. Based on the results of the pilot project, three system sizes, namely 25Wp (operating a fluorescent lamp and a power point), 50Wp (three lamps and a power point), and 75Wp (five lamps and a power point), are proposed. Users can select which system they want depending on their household needs and ability to pay. Also, it is important to determine whether it is better to procure the system components from overseas or from domestic sources. Of particular concern are the battery and charge controller as their quality will have a crucial impact on system reliability and life cycle cost.

Table 8-9 Standard PV Systems

Items	PV systems		
System size	25Wp-class	50Wp-class	75Wp-class
PV module	25Wp	50Wp	75Wp
Battery	20Ah / 12V	40Ah / 12V	60Ah / 12V
Charge controller	JICA improved model HVD=14.5V, HVR=13.0V LVD=11.5V, LVR=13.0V Consuming current < 20mA	JICA improved model HVD=14.5V, HVR=13.0V LVD=11.5V, LVR=13.0V Consuming current < 20mA	JICA improved model HVD=14.5V, HVR=13.0V LVD=11.5V, LVR=13.0V Consuming current < 20mA
PV Mount Direction & tilt angle	17.5° N (15° ~20°)	17.5° N (15° ~20°)	17.5° N (15° ~20°)
Design Solar radiation	5.41kWh/m²/day	5.41kWh/m²/day	5.41kWh/m²/day
Design no-sunshine days	3 days	3 days	3 days
No. of days torecharge battery	2.3 days	2.3 days	2.3 days
Allowable load	55.3Wh / 4.6Ah	110.6Wh / 9.2Ah	165.9Wh / 13.8Ah
Examples of simultaneously usable loads	A 7W-FL lamp (1.18Ah) & a20W-TV .34Ah) on for 2 hours each.Total 4.52Ah	A 7W-FL lamp (2.36Ah) & a 20W-TV (6.68Ah) on 4 hours each Total 9.04Ah	A 9W-FL lamp on for 9 hours (6.75Ah) & a 20W-TV on for 4 hours (6.68Ah) Total 13.43Ah
	A 7W-FL lamp on for 7 hours (4.13Ah) Total 4.13Ah	A 9W-FL on for 8 hours (6.0Ah) & a 5W-radio on for 5 hours (2.8Ah) Total 8.8Ah	

Note) If the design no-sunshine days are assumed at 5 days, instead of 3 days in the table above, the systems' battery capacities would be as follows: 30Ah for 25W-class, 60Ah for 50W-class, and 100Ah for 75W-class systems. The hours required for recharging amount to about 3.4 days, respectively.

(1) Battery

Zimbabwe-made batteries are available in two types; those designed for road vehicles, and "deep cycle" batteries intended for solar use. According to the monitoring results of this pilot project, automotive batteries need a check of battery liquids every month. On the other hand, deep cycle batteries require a battery check only every other month. Different types of batteries therefore result in a different term for technician visits. Where periodic visits by a maintenance technician are made, batteries with open cells are preferable to the maintenance-free batteries or sealed type. To properly perform preventive maintenance, it is essential that each cell be checked individually and that is impossible with a maintenance-free or sealed battery. Maintenance-free or sealed batteries are best used where the sites with PV systems are installed are not accessed regularly by trained technicians. The employment of automotive batteries cannot be recommended unless it is clear that their short life is acceptable both economically and in reliability of service.

Selection of battery capacity depends to some extent on the solar climate. No long term data are available on the frequency of cloudy days or their duration in Zimbabwe. The data collected by the JICA survey show that low sunshine days can continue for three consecutive days. Even a low sunshine day does not mean total loss of solar irradiation, rather a level of around 2kWh/m^2/day (about 25% of peak hours). Therefore, no power outage problems should be caused if the system is designed on the assumption that no-sunshine days would continue for three consecutive days.

The usable life of a battery greatly depends on not merely its quality but the manner of its use. For example, comparing repeated discharging of 30% of battery capacity with repeated discharging of 75% will have a different effect on battery life. In one actual case, data showed that the number of times of cycling with a 30% discharge level was 1,200 times before battery failure, but only 400 times when deep cycled to 75%.

While the pilot project employed locally made batteries, they have proved too short-lived to be acceptable. Under present conditions, PV systems are acceptable for remote areas only if their components are of sufficient quality to function for at least several years. For locally made batteries to be practical significant improvement in quality control and manufacturing technology needs to be made by the local companies.

(2) Charge controller

In order to cover a wide range of systems from 25Wp to 75Wp, the JICA improved model is taken as the standard. Its special features and specifications are as follows.

PV disconnect voltage(HVD) : 14.5V
Load disconnect voltage (LVD) : 11.5V
PV reconnect voltage(HVR) : 13.0V
Load reconnect voltage (LVR) : 13.0V
Current consumption : 15mA
Relay of control is in normally closed on the PV side, and normally open on the load side.

With the specifications above, the PV reconnect voltage (HVR) is set lower than the HVD by 1.5V, while load reconnect voltage (LVR) set higher by 1.5V, than the LVD. The level of HVR is designed to eliminate excessively frequent on-off activity by the relay while still allowing stable charge control for the battery. The level of LVR is designed to promote a proper recovery of a battery by delaying reconnection of the load until at least partial recharging has taken place.

The charge controller of the JICA improved type, as employed in the pilot project, has a charging capacity of 10A. Given that even the maximum output current of a 50Wp PV module is about 3A, the capacity is more than sufficient. In practical terms, the employment of a charge controller of around 10A is recommended, because smaller capacity controllers would have to be changed in the case of a system capacity expansion.

For the small-capacity system of 25Wp, the charge controller must be selected carefully because consumption of the charge controller itself can put a heavy burden on the system. During the pilot project, a very low consumption charge controller was developed and installed. But, many switching errors occurred resulting in a loss of confidence in the controller by users and technicians alike. Since the pilot project was intended to determine the acceptability of the equipment used, to install a newly developed controller was not an inappropriate action since replacement could be quickly effected (as was the case in the pilot project). However, for full scale rural electrification, it is vital that charge controllers with a long and stable field experience be used.

(3) Fluorescent lighting apparatus

The local-made fluorescent lamps employed in the pilot project have had a failure rate of only 1%. Improvements can reasonable be left tot he manufacturer. For safety reasons, a fuse should be included in the fluorescent light or at least in the circuit to each light.

(4) PV module support frame

It is optimum if a module is given a tilt angle of 17.5 degrees, but in any case the angle must be set within the allowable range of 15°-20°. Also, concerned about possible thefts, almost all users prefer a module mount attached to the wall or roof of their house. A straw-thatched house in the traditional style generally has walls too weak to mount the module. However, the module can be installed through the thatch roofing if poles are erected upright inside the house, then penetrating the roof.

8.4.2 Procurement/Distribution of Component Parts

System component parts will be procured through the National Management Center (NMC). With system design, as well as specifications and standards of component parts set by the technical staff of the NMC, necessary parts procurements will be carried out periodically and suppliers will be selected thorugh competitive tender. Successful bidders must deliver the parts to a designated District Management Center, where they are given an acceptance inspection. The parts delivered to a District Management Center are then forwarded, under its control, to individual Local Management Offices for use in each district.

8.4.3 Stocks of Parts

(1) Stocks of major supplies at District Management Centers

In order not to cause unacceptable delays in system repair, every district should have sufficient supplies available. Particularly, it will be hard to transport batteries individually from Harare to the user site swiftly and without excessive cost. Therefore, individual District Management Centers are required to keep supplies of all component parts and extra sets of PV systems, the latter for new users. While in storage, batteries should be charged periodically or connected to a continuous float charge system.

(2) Supplies of lights and fluorescent bulbs needed users

Users are required to purchase replacement lights bulbs themselves. Therefore those materials must be available near the users. One option is to send lights and bulbs with the local technicians on their visits so he could sell them to users. But, this option would put an extra burden on the local technicians in terms of both product transport and accounting. Also, because the local technicians will visit their users only once a month, inconvenience can be caused to the users. A more viable option is to consign the sale of lights and bulbs to the shops. located in each individual district.

8.4.4 Installation/Maintenance of System

(1) Installation by trained & certified installation-service companies

Generally, if a rural electrification project has a growing number of users, the amount of installation works will also swell rapidly, and it won't be practical to handle such work by the ESCO staff alone. Then, it becomes necessary to contract for such installation works to private installation service companies such as those developed under the GEF project. One of the problems found by the JICA pilot project is that the installation service companies did not have a satisfactory technical capability or the proper tools to perform a satisfactory installation. Therefore, under the "Phase 1" project, it is recommended to give contractor installation service companies extensive training which includes the requirement that they pass a practical examination for certification. Moreover, during "Phase 1," installation work by contractor companies should be supervised on site by senior engineers from the Local Management Office.

(2) Use of proper tools

It has been observed that many of the problems arising after PV systems were installed under the JICA pilot project stemmed from either misunderstanding of the technical requirements for PV systems (e.g. an installation site not properly selected to avoid shade), lack of proper tools or improper use of the proper tools.

To ensure good installation quality during Phase 1, the majority of the installation service companies contracted to do installations will need to be given general training, on both the theory of PV system installation and on-the-job training specifically including how to properly use tools. Installation-service companies must be required to have a set of proper tools available for their use. The tools can either be owned by the company or. is also reasonable for the ESCO to sell or lease the proper tools to such companies. In the latter case, consideration must be given to the cost so that the sales price or rental charge of the tools should not be excessive.

(3) Maintenance of the system

Maintenance of the system is provided by local technicians. Periodically, at first once a month, local technicians visit their users to check the systems, take necessary preventive measures, and confirm that the users do not make any modifications to the system without permits nor use electric appliances which are not designated to be connected. Users on their part report their experience with the system to the local technicians. Problems and requests, if any, should be communicated to the ESCO through the local technicians. Also, senior engineers must regularly tour the districts covered by local technicians, and supervise them. If troubles occur which are beyond the local technicians' capacity, the senior engineers will help the local technician solve the troubles. Particularly, the replacement of a battery needs the approval of a senior engineer.

8.5 Summary

So far, the recommended framework for PV system-based rural electrification has been examined from various aspects (e.g. how to develop the market, the organizations responsible for rural electrification projects, management methods, target households, fee-setting). What's made clear by the results of the pilot project is that even if users are provided with a system, its maintenance and management involves many difficulties because they live in rural areas distant from support. In order to use PV systems in remote rural areas, what should be emphasized again and again is that the after-sale care is absolutely essential. Without such care, an expensive system will be out of service for an extended period which undermines users' confidence in PV systems, thus producing a negative market effect. If PV power generation is to be promoted as a suitable means of electrification, the organizational/management systems discussed in this chapter are important considerations.

9

PV System-Based Rural Electrification Project

9.1 Background of the Project

9.1.1 Needs for Rural Electrification

As of 1998, unelectrified households in Zimbabwe numbered an estimated some 1.5 million. ZESA, responsible for electricity supply in Zimbabwe, currently plans to extend its grids in hopes to electrify all the so-called rural service centers (RSCs) nationwide by FY2007. This project, initiated in FY1997, is expected to make electricity available in 413 RSCs by FY2007. Its total cost is projected to reach Z$460 million.

However, because ZESA's project covers only RSCs and their vicinity, those electrified under the project will be limited to an average about ten shops, including restaurants, groceries and slaughterhouses, and an additional about 5-10 affluent households nearby. Naturally, the number could grow if the number of affordable households multiplies. For the present, however, rural electrification extension is likely to remain at around 10,000 households nationwide. Thus, even when ZESA's rural electrification project is over, the number of unelectrified households is expected to remain unchanged from now, or can even grow larger. For the present, to enable such unelectrified households to receive electricity by extending grids cannot be justified for economic reasons. For one thing, such unelectrified households are widely scattered. For another, their electricity demand is limited to lighting and TVs, and is therefore too small to justify a massive investment.

Such being the situation, it has been under consideration to electrify such scattered rural households using solar photovoltaic (PV) systems. ZESA on its part has been considering how to make PV systems popular among unelectrified households in rural areas. The latest survey results on rural society (see 5.6) clearly showed that rural households' electricity demand would be limited to lighting and TVs/radios, which could fully be covered with a 50Wp-class PV system for each household.

9.1.2 Rural Electrification by making PV Systems Popular

As outlined in Chapter 8, the proposed project proposes that rural electrification is carried out through the use of PV systems on each household. In order to allow the largest number of rural users to be able to afford the systems and to insure that long term maintenance and sustainability will be possible, the approach used is not that of selling PV systems to rural households. Instead of urging unelectrified rural households to buy PV systems, a public or semi-public organization having a solid economic foundation acts as Energy Service Company (hereinafter referred to as ESCO) and furnishes each household a suitable sized PV system to be installed inside or next to their house. Then, the ESCO collects, from the system-equipped households, a fee which includes sufficient money to pay the capital cost of the systems and for its maintenance.

Under the JICA Pilot Project, PV systems were installed in both individual households and public facilities, but only the former has been provided with maintenance & inspection services. This was the case because public facilities, such as medical clinics, have thus far no budgets for buying maintenance & inspection services. Therefore, during the study, the systems installed at public facilities were checked by the study team, which toured such facilities as often as every 3-4 months or so. What was found by the touring team was that personnel at few public facilities checked the battery liquid level at all. Also, it was found hard to obtain distilled water for refilling when necessary. Several public facilities even had charged batteries brought in from outside. From these findings, it is clear that, in the long run, PV systems are be maintained better under the ESCO approach, where the PV system is rented to supply electricity, rather than selling PV systems directly to the users and placing maintenance responsibility on the households. Moreover, the proposed ESCO-led PV electrification system makes PV systems affordable to the lower-income class than ever, because it assumes a capital cost recovery period as long as 20 years instead of the 3 years commonly required under sales schemes..

9.2 Objective and Basic Policy of the Project

9.2.1 Objective and Significance of the Project

The objective of this project is rural electrification in Zimbabwe. To that end, the use of PV electrification systems is proposed. Based on the findings of the JICA-sponsored Pilot Project, proposals will be made for the PV-system management arrangement, the bill collection method, and overall institutional setting for the development of PV electrification. Action programs for the Zimbabwe government, relevant private firms and others will be proposed as well.

9.2.2 Basic Policies to Spur the Development

The proposed rural electrification plan is characteristic in the point that fees are collected in return for the security of "electricity supply" (not the purchase of solar systems) to currently unelectrified households. This plan does not involve electrification for institutions such as clinics and schools. Reason why institutions are out of scope that it is not easy to set up PV maintenance budget for institutions during this survey. Requirements which must be considered include the selection of districts and households where PV systems should be introduced, rate-setting policies, and a recommended management system to best implement a PV electrification system for rural Zimbabwe. Basic policies relevant to how to implement this unique project are described below.

(1) Districts and households where PV systems are to be introduced shall be selected by taking into account the local economy and such factors as if they are concentrated geographically to permit easy maintenance and if local technicians can be secured.

(2) Electricity rates shall be set by taking the cost for PV system installation and continuing maintenance and the residents' ability to pay into account. In addition, the payment method shall be decided by fully reflecting the users' opinions.

(3) For long-term success in PV based rural electrification, cooperation at all levels -- user, component suppliers, implementers and Government -- are required. Recommendations are made for policies for Government, private organizations and others concerned with PV based rural electrification later in this report.

These are the basic policies to be applied for pursuing the objective of this project, or the "promotion of PV system-based rural electrification."

9.3 Size of the Project

Because how many households are in need of rural electrification is an important element which sets the upper limit on the size of this project, an overview is given below.

9.3.1 Number of Unelectrified Households

The number of electrified and unelectrified households in Zimbabwe was surveyed in 1992. Since then, electrification has advanced in urban areas, while an electrification has remained virtually unchanged in rural areas. The 1992 survey results show that unelectrified households numbered 1.5

million nationwide, and 1.3 million in rural areas. At present, rural areas contain even larger numbers of unelectrified households, which now include an estimated about 1.5 million. In principle, they are the target households for this rural electrification project.

Table 9-1 Household Electrification Rates by Province (1992)

Province	Households	Electrified		Unelectrified	
Total	2,163,289	28.24%	610,913	71.74%	1,551,944
Urban	763,706	71.65%	547,195	28.32%	216,282
Rural	1,399,583	4.55%	63,681	95.43%	1,335,622

9.3.2 Number of Households that can afford Systems

As already discussed in Chapter 5, those capable of paying a fee of Z$3,000/year numbered 50,000 households in 1997, and are likely to outnumber 300,000 households by 2017.

The households capable of paying a fee of Z$1,500/year numbered 200,000 in 1997. It is clear that the fees which need to be charged under and ESCO are low enough so that the number of households which need and can afford systems is not a limiting factor for this project..

9.4 Specific Contents of the Project

9.4.1 Tartget of the Project

Given that some 1.5 million rural households are left unelectrified at present, the primary target of this project is set as that 10% of currently unelectrified rural households, or about 150,000 homes, shall be electrified in two decades through PV electrification. This target number also appears to be reasonable from the number of households which can afford the necessary fees. The target of 150,000 households in two decades is to be pursued in two phases; one phase during the first five years and the second during the remaining 15 years. The first phase is designed to underscore the penetration of PV systems and provide for strengthening of the management organizations, with 15,000 households be electrified. The second phase is designed for full-scale implementation of PV systems for rural electrification, with the remaining 135,000 households be equipped with PV systems in 15 years.

9.4.2 Criteria for Selecting Candidate Districts for the First Phase

(1) Introduction method

A recommended method for PV system introduction is to designate 1～2 local management offices in an area (province) as a model case first, then select around ten districts of users in the vicinity of each designated office. Each district shall consist of a minimum of 50 users to be equipped with PV systems. This method will help to reduce the market development, operation and management costs and insure that maintenance can be provided at the lowest possible cost..

(2) Criteria for selecting candidate districts for first phase

The first phase shall be started by selecting the districts where density of candidate households is high enough for there to be a high probability of having sufficient households apply for systems. Also, given that the maintenance service is rendered by ZESA (ZESA-Solar), the districts to be selected are those accessible by ZESA for touring maintenance services. In specific terms, these would be districts located within 20-30km from ZESA rural offices, or within 20-30km of ZESA rural service centers. An economic analysis confirmed that PV electrification would be advantageous even in a village situated 1km away from grids and consisting of about 50 households, so long as electricity demand should be limited to lighting and TVs/radios as is true now. Assuming that electricity demand could almost triple in the future, it is reasonable to select districts more than 5km away from the grids.

(3) Criteria for selecting households to be equipped with PV systems

The households to be equipped with PV system shall be selected among those which are currently unelectrified and "not-poor." In specific terms, the selected households shall be capable of paying around Z$1,500~3,000 yearly (such households numbered 50,000~ 200,000 in 1997, and are likely to outnumber 300,000~1,000,000 by 2017).

Table 9-2 Density of Unelectrified Households by Province

Province	Area	No. of unelectrified households			Household density
	km^2	Urban areas	Rural areas	Total	Households/ km^2
Mashonaland West	60,467	23,699	158,633	182,332	3.02
Mashonaland Central	27,284	7,058	153,261	160,318	5.88
Mashonaland East	24,934	4,548	196,182	200,730	8.05
Manicaland	34,870	9,210	268,774	277,984	7.97
Masvingo	44,310	6,529	199,243	205,772	4.64
Midlands	58,967	17,549	170,426	187,975	3.19
Matebeleland South	66,390	5,145	92,977	98,121	1.48
Matebeleland North	73,537	4,347	93,432	97,779	1.33

Tale 9-3 Poor & Non-Poor Household Ratio

Province	Poor & non-poor ratio			Housing density Households/ km²	
	Poorest	Poor	Non-poor	Unelectrified	non-poor and unelectrified
Mashonaland West	48	20	31	3.02	0.93
Mashonaland Central	46	20	34	5.88	2.00
Mashonaland East	60	14	26	8.05	2.09
Manicaland	62	13	25	7.97	1.99
Masvingo	57	12	32	4.64	1.49
Midlands	46	17	37	3.19	1.18
Matebeleland South	45	17	38	1.48	0.56
Matebeleland North	55	13	32	1.33	0.43

The shares of poor households are borrowed from WAPCOS Report

From above table, the candidate provinces for the first phase electrification should be Mashonaland Central, Mashonaland East and Manicaland.

Figure 9-1 shows areas already electrified (blue circle), to be electrified by 2001 (green circle) and by 2007(red circle).

(4) Mutoko, Mashonaland East (in December, 1998)

The study team visited the ZESA branch (Depot) that is managing Mutoko, Mashonaland East as the candidate area of the first phase. The results of survey are as follows.

Number of the electrified households in Mutoko is 1,860. The electrification ratio is around 15% and the number of the unelectrified households becomes 12,400. The areas of jurisdiction are involved Murewa, Mutoko, Mutawatawa, Macheke East. The ZESA management center in this area is located in Marondera. There are many high income families in these areas who produce saleable crops and wash for gold.

The work of Mutoko Depot are the extension and maintenance of the distribution line, reading of the watt-hour meter, the publication of the bill, the collection of the charge and so on. Total personnel are 28 and two out of 28 reside in Murewa. At present, the reading meter of 1,860 households is done by one person. After the extension plan of distribution line will be complete, the meter reader will increase to two.

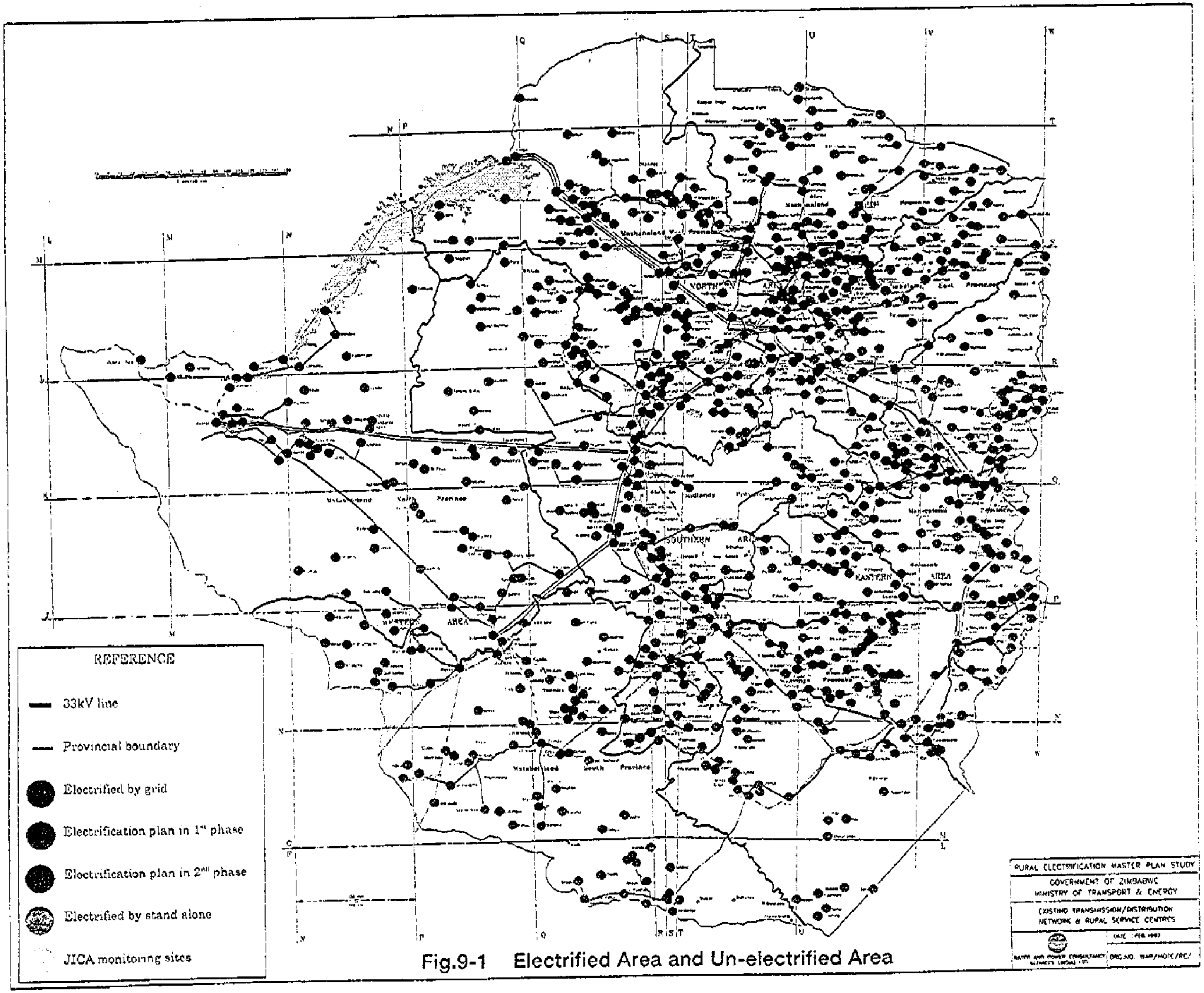

Fig.9-1 Electrified Area and Un-electrified Area

The electric power consumption of one customer is about 500 kWh/monthand average electric rate is Z$200/month. After meter reading, a bill is mailed to the users and the user pay in Depot or the center. Generally, the grace period of 30 days is given to the unpaid user. However, the grace period of 60 days is giving in these areas because of poor transportation. If user does not pay within two months, electricity will be cut off by ZESA.

The average salaries of the Depot staffs are Z$25,000/month with engineer, Z$18,000/month with technician, and Z$3,000 with meter reading worker. There are several vehicles including pickup and six wireless telephones which cover the whole area approximately and Mutoko Depot has mobility. Also, Mutoko Depot has the stockyard which can be used for spare parts and the repair of the equipment.

As the first candidacy area which implements the first phase from the point of the charge collection system, the solvency of the residents, the stable management basis, the mobility of Depot, it is judged that Mutoko is adequate area.

9.4.3 Functions Required for PV-system Management Organization

To succeed in large-scale rural electrification by virtue of PV electrification requires an ESCO, a firmly-established organization responsible for electricity supply, which can satisfy specific requirements. ESCO functions are already described in chapter eight, they are:

(1) Decentralized management units with central administration for policy and high level tasks.

(2) Ability to develop users through public relations and marketing

(3) Technological capability for PV electrification

(4) Motivation to provide good service by maintaining systems and meeting users' needs

(5) Financial capability to afford capacity expansion in the future

(6) A good capability of billing and bill collection

(7) Primary organizational task is PV-based rural electrification

(8) Authority to disconnect when fees are unpaid

Among existing candidate organizations, ZESA (Zimbabwe Electricity Supply Authority) can be cited as the best that can satisfy all the aforesaid requirements. ZESA is authorized to supply electricity to both urban and rural areas and has been growing both in power production and transmission/distribution sectors. Yet, if responsible for the management and maintenance of a rural electrification project which involves large numbers of independent PV systems ZESA must increase its personnel, both with PV-system experts and maintenance staff. Further, ZESA as a whole does not have as its primary responsibility either PV electrification or rural electrification. Therefore, to best implement PV-based rural electrification, it appears better for ZESA to set up a new mostly independent organization (provisionally named "ZESA- Solar" for convenience). Office of ZESA Solar, personnel, management policy, office work processing, etc. owns jointly existing ZESA organization but account sector of ZESA Solar should be divided from existing ZESA.

9.5 Supporting Programs for Project Implementation

The latest findings show that to implement the proposed project requires some supporting programs. Included are quality improvement of locally made PV-system equipment, the establishment of technical centers, introduction of test facilities for PV-system equipment, setting of product standards including the introduction of a certificate system, the establishment of engineer and technician training centers, and improvement of stock control and distribution functions. The flow of supporting program is shown as Figure 9-2

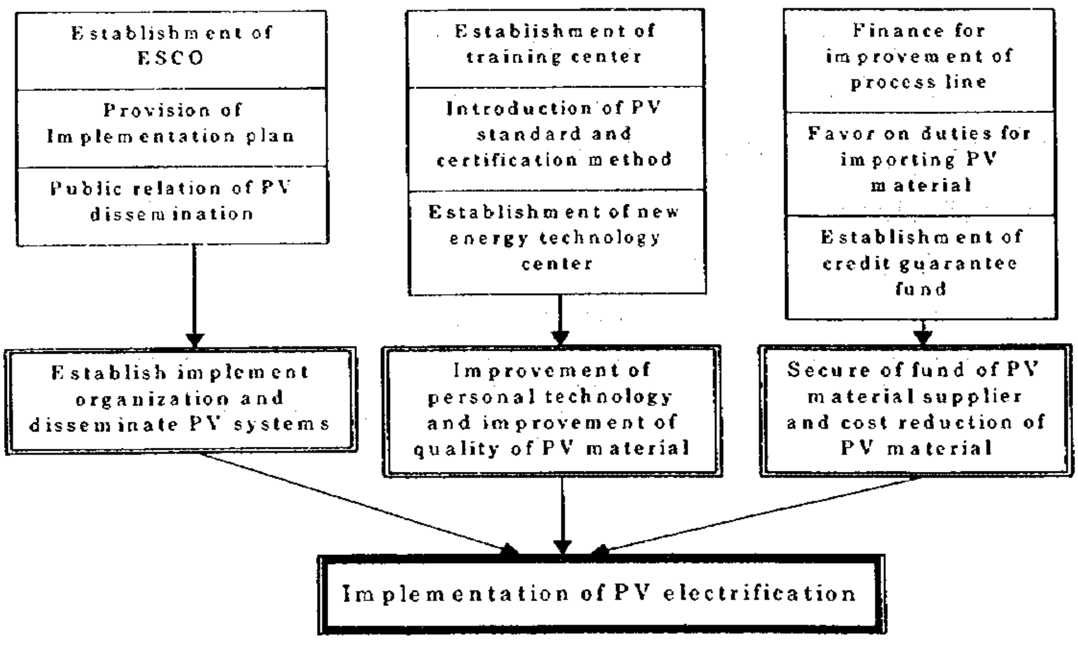

Fig 9-2 Supporting Program for PV Electrification

9.5.1 Quality Improvement of PV-system Equipment and Establishment of Technical Centers

As clearly determined by this study project, locally-manufactured PV-system components are uneven in quality. As for batteries, their usable life varied greatly, with some becoming no longer usable after only a half year in use. Also, some of the charge controllers had voltage settings which were incorrect or not constant, a cause of shortened battery life. Around 1% of the fluorescent lighting apparatus was not satisfactory. These suggest there are some problems in the manufacturing processes.

Quality control (QC) is an activity designed to allow the offering of products or service which can consistently meet customers' exact needs. Namely, QC requires the knowledge of customers' needs first. In Zimbabwe, QC has been already in practice by some firms associated with Western companies or having introduced technologies from abroad. But, few small and medium-sized companies have sufficient QC commitments yet. Specific QC methods can vary depending on different situations in different firms. Yet, it is essential that the top executive of individual firms makes the decision for proper QC introduction, then, by inviting experts from outside or fostering in-house specialists, sets forth clear-cut objectives and policies, while pouring necessary time and money into such efforts. Also, at national and industry levels, it is appropriate to establish technical centers and other structures to assist companies in improving their QC for PV components.

9.5.2 Standards-setting and Introduction of a Certificate System

Product standards improve user confidence in PV systems and provide the installation-service companies and parts manufacturers with yardsticks for their QC activity. Thus, product standards should be prepared from the perspectives of not merely system providers but system users and component manufacturers as well. For example, while system design used to focus on the capacity of PV modules (ex. 50Wp, 75Wp, etc.), PV systems can best be designed from the perspective of how users will use electricity (e.g. to design a system for 2 lamps + a radio, or for 2 lamps + a TV). However, standards must be realistic. If standards are set higher than is necessary to meet the system requirements, it can raise the product cost beyond that which is affordable by most rural households.

Once product standards are set, manufacturers must commit to QC in an attempt to meet the standards, and successful manufacturers naturally expect to have the quality of their products certified. Because QC activity is relatively expensive, the products which reach the set standards should be certified on the market. The common method is to provide market certification through the government, or the industry, which issues a certificate of conformance to a company when its quality of product or service is confirmed as meeting the standards.

The presence of the certificate enables the users to confirm the quality of products or service. The standards certificate system, if put to effective use, can be expected to spur QC activity among the system and parts manufacturers. For standards and certification to work in the market place, the government and private sectors are required to make concerted efforts to inform the users of the presence and viability of product standards and the meaning of certification.

For small and medium sized firms, each hardly able to introduce QC by themselves, to respond to such a standards system, the government and PV industry organizations need to offer supporting measures so that they can develop their ability to carry out QC and pass the standards under the certificate system. Also, the firms planning QC activity or introduction of QC-related machines and equipment should be provided with preferential loans to help finance that important activity.

In Zimbabwe, SAZ (Standards Association of Zimbabwe) is responsible for the preparation of a wide range of standards. The standardization of PV-system components is in progress under leadership taken by SAZ in collaboration with SIRDC (Scientific and Industrial Research and Development Centre). If SIRDC provides certificate tests, product improvement by private firms can be expected. However, the greatest present problem in setting and putting to use standards for PV system components is the absence of adequate measuring instruments in Zimbabwe. Under the present conditions, no one can judge whether product standards, even if set, are satisfied or not. Without measuring instruments for PV systems, even SIRDC is unable to evaluate such components. SIRDC is in need of some Z$3 million for buying necessary testing instruments.Although the study project provided some test equipment a number of required test systems remain to be obtained. Of them, particularly expensive testing instruments include a battery evaluation unit to measure a battery life, and an I-V curve tracer with solar simulator to evaluate module characteristics..

Internationally, the PVGAP (PV Global Approval Program) is already operating and many countries are participating this program. Specifications and methods of testing are provided and labels for qualified materials are available for certification. The secretariat of PVGAP is in Geneva, Switzerland

9.5.3 Establishment of Technical Training Centers

To keep a PV system well requires local technician's visit at least once a month. Once the users' experience of system operation exceeds five years, the cycle of visits can be widened to every other month. Yet, at least during "Phase 1," every-month visits by a local technician should be in practice for the security of systems.

The proposed project requires assigning a local technician to every 50 systems during the initial years, and to an average of every 100 systems a few years later as experience and capability for maintenance improves. Accordingly, a district consisting of about 1,000 systems requires some 10-20 local technicians. The target of 15,000 households to be equipped with PV systems during "Phase 1" means that at least 200 local technicians must be secured and trained during the five years of "Phase 1." In addition, assuming dropouts for some reason, including lack of required talent, an additional 30 technicians need to be trained during the five-year Phase 1. Effectively, "Phase 1" requires a training center where at least 50 local technicians can be trained every year. Though a growing number of systems are installed, the number of local technicians to be trained each year during "Phase 2" remains the same as in Phase 1.

For training local technicians, the instruction methodology already put into practice by the JICA study team at Kwekwe Technical College is appropriate. Also, for successful rural electrification, local technicians and senior engineers need to be reeducated or retrained periodically, so that they can check and keep their capabilities at certain levels.

9.5.4 Financial System for PV Industry

Financial situation of PV industry in Zimbabwe was already described in Chapter 7. It is very difficult to prepare an investment cost for middle and small companies in PV industry at present. In order to solve this issue, it is necessary to establish trust fund and to prepare soft loan to PV companies. Also, this soft loan should be applied for research and development.

9.5.5 Improvement of Stock Control and Distribution Functions

Spare parts and parts for the assembly of new systems are needed at the user locations since it is slow and expensive to move materials directly from Harare to remote sites. Particularly, it will be hard to inexpensively move batteries directly from Harare to the remote user households. Therefore, for the project, system components are specified and purchased at the main company site then delivered to a district management center, where they are inspected, then forwarded to local management offices to serve individual users. Under such a components supply system, every district is required to keep stocks of supplies so as not to cause delays in repairs. District offices will need a mains or solar PV system in order to periodically charge or float charge batteries in storage.

Users on their part are required to purchase their appliances including fluorescent lamps by themselves. Thus, such apparatus must be available near to the users. It is possible to send fluorescent lights and other supplies to the local technicians to sell them to the users. But, this option can put an extra burden on the local technicians in terms of both product transport and bill collection. Additionally the local technicians will visit their users only once a month or so, inconvenience due to delays in replacement, can be caused to the users. Therefore, a more viable option is to consign the sale of fluorescent lights and bulbs to the shops already found in individual districts.

Efficient stock control requires a good grasp of product sales patterns and market trends, as well as the production capacities of PV parts manufacturers and their delivery periods. While it is true that for the present, Zimbabwe's PV-related market is too small to allow truly efficient stock control yet implementing the structures for effective stock control is vital from the beginning of the project.

9.6 Expected Benefits of the Project

9.6.1 Benefits of PV-based Rural Electrification

Economic benefits of PV system-based rural electrification are considered here. Benefits of a given project can be best highlighted if compared with a case where such a project is not implemented.

(1) Users' benefits

Users are able to use clean and safe illumination by PV electricity, making it possible for them to better study or work at night. In particular, education can be improved through extending study hours through good quality light and by distance education through the TV.

Besides English taken as an official language, Zimbabwe has several local languages such as Shona and Ndebere. Rural people usually speak in their local languages and rarely use English. If rural electrification is widely carried out by PV systems, TVs will become popular among rural people, through which they can improve in English which is the common language which allows easier communications among different ethnic groups and foreigners.

Agricultural yields can be expected to improve if TV information about agricultural methodology improvements, farm product market trends and climates is available. Particularly, weather information is important for rural areas relying primarily on farming.

(2) ZESA's benefits

If ZESA extended its grids to electrify rural areas where electricity demand is too small, it could not recover its investment with the electricity rates at present levels. In the case of PV-based electrification, necessary systems could be installed in all of the households, scattered and situated away from existing distribution lines, with only about one fourth of the investments involved in grid extension. Also, investments could be recovered if PV-based electricity rates are set independent of existing grid-based electricity tariffs.

(3) Government's benefits

At present, Zimbabwe's power source mix consists of coal-fired thermal, hydro and imported electricity. If PV electrification could meet part of electricity demand, which is likely to surge in the years to come, the government would be able to save hard currency by reducing the purchased electricity. Also, PV-based electrification of remote areas involves less investment than grids-based projects, thus alleviating government's financial burden in its capitalization.

(4) SEIAZ's benefits

This PV electrification project, proposed based on the findings of the preliminary pilot project, features well-planned installation of PV systems over a long period of time which permits the stabilization of demand which in the past has been unpredictable. As a result, PV-related industries can expect constant revenues and confidently increase their equipment investment for the future. Also, the formation of a new energy center as part of supporting programs can help domestic PV component manufacturers improve their product quality to be both price and quality competitive with imported materials.

(5) Environmental benefits

PV electrification is environmentally friendly. While producing electricity, it releases no carbon dioxide, currently a serious problem causing global warming, nor does it have toxic fumes or noise associated with its use..

9.6.2 Benefits of ESCO Approach

As already discussed in this report, PV-based electrification can be advanced in two ways. One is the sales oriented approach, and the other is the ESCO approach which is strongly recommended here based on the findings of the study project. The benefits which can be expected from the ESCO approach are:.

(1) Users' benefits

With the ESCO approach, the users of PV systems can be free from PV system maintenance. Users of the sales oriented approach have the problem of maintaining the PV system.

The ESCO approach can reach to the lower-income classes as it can provide a lower monthly payment for the provision of electrical service.

Those who are benefited most by the sales oriented approach are primarily the dealers of PV systems instead of the system users which are the principal target of any rural electrification project.

(2) Users' tax-free benefits

With the ESCO approach, it is ZESA-Solar, a government organization, that owns the PV systems to be installed. With this approach, PV systems will not be subject to the sales tax and thus allows a lower installation cost though of course the government's sales tax revenues would not be as great.

(3) Chance of low cost finance

With the ESCO approach, it is ZESA-Solar that would be responsible for raising the necessary funds. This eliminates the need for the fragmented loans to users, or to installation-service companies. If it is ZESA-Solar, or its parent company ZESA, or the Zimbabwe government, that is subject to the loans, it becomes possible to gain more favorable financial conditions or even grants from overseas donors..

(4) Benefits on delivery of materials

With the conventional sales-oriented approach, sales companies have to procure PV systems in small quantities based on their own product specifications, then transport and install the systems independent of competitors. They also have to keep stocks of parts if they are to be certain of meeting acceptable delivery schedules.. In comparison, the ESCO system allows procurement in large quantities, perhaps for discount prices. Because the district management centers keep optimal stocks of these standardized parts and can ship quickly upon request, an earlier delivery to the use site is ensured. This approach also permits well-planned distribution, which leads to lower transportation cost which can be a major cost when user sites are rural and remote.

(5) Benefits on product quality improvement

With conventional sales-oriented approach, product quality is not necessarily a priority, first cost tends to be emphasized strongly.. Because the ESCO approach must consider a system's lifelong optimal cost, rather than just first investment cost, full consideration will be given to the relationship between quality and cost of the systems and parts. In addition, because a large amount of products are purchased at one time, the ESCO is able to instruct suppliers to meet product standards and can be effectively penalized if they do not.

(6) Benefits on human resources development

In-house human resource development by sales companies usually takes the form of on-the-job training, and few of them can afford well-organized, systematic training. An ESCO approach involves well-planned training of technicians and technical training needs to be incorporated into an ESCO's action program on a fiscal year basis. Training should be given not merely at the beginning but repeatedly at periodical intervals.

9.7 Action Programs for Project Implementation

Action programs for the implementation of PV-based rural electrification project are described below by each organization involved in the project.

9.7.1 Action Program for the Government

The government is required to decide following policies.

(1) To decide a specific target for PV-based electrification.

The proposed project is designed to electrify 150,000 households, or 10% of currently unelectrified households, in two decades.

(2) To decide the employment of ESCO approach.

As detailed in Chapter 8, it is strongly recommended to employ ESCO approach in implementing this project.

(3) To decide the incorporation of ZESA-Solar.

As detailed in Chapter 8, it is recommended to incorporate ZESA-Solar to act as the principal organization of this project.

9.7.2 Action Program for ZESA-Solar, the Principal Organization

ZESA-Solar, or the principal organization, is required to advance following items.

(1) To survey potential demand in the candidate districts for Phase 1

Of 1.5 million households in currently unelectrified areas, those which can afford Z$1,500 of annual bills will be the customer base where PV systems will be introduced under this project. The candidate province is proposed to be either Mashonaland East, Mashonaland Central or Manicaland.

(2) To select the districts subject to Phase 1.

The districts to be selected for this project are those accessible by ZESA-Solar, and are located 5km or more away from existing grids. In more specific terms, the districts situated within 20-30km from ZESA's rural offices, or those within 20-30km from ZESA's rural service centers, can be the candidates for the project.

(3) To prepare the implementation and investment plans for Phase 1.

This project calls for the introduction of PV systems into 15,000 households during Phase 1. The installation costs total an estimated US$10.8 million (= US$720/household x 15,000 households). Cash flow for several cases will be calculated and a plan made to provide the necessary funds.

9.7.3 Action Program under Government- and Private-sector Collaboration

While leading the private sector, the government is required to advance following items.

(1) Establishment of training centers

Under this project, it is recommended to bolster the training course established at existing Kwekwe Technical College, and require training of local technicians and installation service workers there.

	Numbers of trainees
Local technicians	50 persons/year
Senior engineers	7 persons/year
Installation service workers	10 persons/year

(2) Establishment of new energy technical center

It is recommended to establish a new energy research center, primarily for PV electrification. The research center would be expected to conduct R&D on utilization technologies and how to improve system efficiency, and also be responsible for the quality tests necessary for the certificate system.

(3) Public Relations and demand development for PV electrification

Consumer education as to the benefits of PV electrification need to be prepared and distributed. Such materials as to explain PV-based electrification schemes which can be posted at RDCs, medical clinics, etc. where people are gathering or information through radio and TV programs on how to obtain and properly use PV electrification would be appropriate.

9.7.4 Action Program for PV Business Organizations

PV business organizations need to carry out the following items.

(1) To set standards/criteria, and introduce a certificate system

By setting standards for PV systems and components. Those which meet the standards are certified and labeled so that users can be sure they meet the standards.

(2) To propose improvements of the financing system and taxation.

Proposed improvements may include the establishment of a Credit Guaranty Fund, provision of loans under preferential terms applicable to expansion and capacity upgrading, and preferential customs tariff arrangements applicable to imported PV-system components.

(3) To introduce QC and consistently carry it out.

Quality control activities include thorough quality checks, improvement of manufacturing environment and processes and improvement of designs.

(4) To carry out stock control.

Efficient stock control should include determination of optimal stocks the introduction of an inventory management system, centralized and distributed parts stocks and centrally controlled delivery service.

9.7.5 Actions to be Originally Taken by Private Firms

Private firms are required to advance following items.

(1) To establish a reliable PV-system supply system.

Smooth PV-system installation requires a reliable system to supply components (PV modules, controllers, batteries, lamps etc.)

(2) To ensure reliable PV-system installation service.

Those who are engaged in the installation service must be given training and the appropriate tools in order to perform their tasks properly and reliably.

(3) To market PV systems as independent firms (a continuation of the GEF concept).

While the ESCO concept can fulfill the needs of the majority of middle and low income households, upper income families may desire larger or specialized PV systems for their use. Individual firms should be encouraged to sell PV systems to those users within the project area who want to have a special design not available under the rural electrification scheme.

9.7.6 Project Schedules

Figure 9-3 entitled "PV-Based Rural Electrification Project (Short- & Medium-Term Prospects) contains the proposed schedules for project implementation, prepared for individual organizations. Figure 9-4 shows PV rural electrification estimated schedule.

9.8 Fund-raising Plan and Case Study

9.8.1 Preconditions

The table below shows an estimate of the cost to equip 150,000 households with PV systems under a rural electrification project. The estimation was made based on the findings of the JICA study.

Table 9-4 Unit Costs and Usable Lives of System Components(based on 1997 price)

Parts	Unit cost (US$)	Life	Remarks
PV panel(50W)	300	20 years	
Charge controller	60	5 years	
Battery	60	3 years	
FL lamps (2 units)	50	5 years	To be replaced by users.
Battery box	20	20 years	
PV-panel pole	70	20 years	
Cable and accessories	80	20 years	
Total	640		
System installation cost	80		

Standard PV system : 50W

Table 9-5 Unit Costs of Personnel Expenses

Class	US$/month	Class	US$/month
Manager	800	Driver	200
Senior engineer	400	Worker	200
Administrative	300	Technician	100

The overhead (non-labor) costs incurred in the local management offices, are assumed to be equal to its total personnel expenses. For a district management center, the overhead cost is assumed to be 1.5 times its total personnel expenses, and for the National Management Center, the overhead is estimated to be 2 times its personnel expenses.

Figure 9-3 Work schedule for rural electrification plan by PV system (Prospects for short and medium term)

Section	Items	Organizations / Fiscal Year	Work schedule 1	2	3	4	5	6	7	Investment costs (1,000US$) 1	2	3	4	5	6	7	Note
Government	**Policy making**	DOE, ZESA	■														
	Setting number of PV system installation																
	Examination of ESCO system																
	Establishment of ZESA-SOLAR																
	Making implementation plan in 1st phase by ZESA-SOLAR	DOE, ZESA, ZESA-SOLAR	■	■													
	Study of PV demand		■														
	Site selection of 1st phase		■	■													
	Making detaild plan and financing			■													
	PV installation (1st phase)	ZESA-SOLAR			■	■	■	■	■			720	1,410	2,160	2,880	3,600	US$720／system; No. of System: First year 1,000; 2 2,000; 3 3,000; 4 1,000; 5 5,000
Private	**Establishment of PV installation and supply systems**	SEIAZ MEMBER			■	■	■	■	■								
	To supply PV conponents																
	PV module																
	Introduction of imported PV module in 1st phase																
	Charge controller																
	Introduction of JICA manufactured controller		■	■						500							US$60/controller First stage:15,000sets
	Battery																
	Improvement of local battery quality		■	■						1,000							US$60/Battery First satge:20,000sets
	Fluorescent light																
	Using local products																
	PV system installation																
	Training for skilled labour			■													
	Activity of PV promotion by each private companies		■	■	■	■	■	■	■								
Government & Private	**Establishment of training centre**	ZESA, SEIAZ, MOE(Education)								50	50	50	50	50	50	50	
	Encouragement of training course in KwekwePolytech		■														
	Training of field technicians and installers			■	■	■	■	■	■								Model house, Actinometer
	Number of training																
	Field technician 50 persons/year																
	Senior engineer 7 persons/year																
	installer 10 persons/year																
	Establishment of new energy centre The centr conducts R & D on utilization technologies and how to improve system efficiency, and also responsible for quality tests necessary for the certificate system	DOE, SIRDC, UOZ		■	■						200						Meteorological equipment, Battery test system PV test system, IV curve measurement system PV design system
	Advatisement of PV system and developing PV demand	DOE, ZESA, SEIAZ, ARDC		■	■	■	■	■	■								
	Making poster for PV system																
	Advatising PV system using TV and radio																
PV Business Organizatios	**To set standards/criteria, and introduce a certificate system**	SAZ, SEIAZ	■	■													
	By setting standards for PV systems and components. Those which meet the standards are certified and labeled so that users can be sure they meet the standards.			■	■	■	■	■	■								
	To propose improvements of the financing system and taxation. Proposed improvements may include the establishment of a Credit Guaranty Fund, provision of loans under preferential terms applicable to expansion and capacity upgrading, and preferential customs tariff arrangements	SEIAZ	■	■													
	To introduce QC and consistently carry it out. Quality control activities include thorough quality checks, improvement of manufacturing environment and processes and improvement of designs.	SEIAZ, SAZ	■	■	■	■	■	■	■								
	To carry out stock control. Efficient stock control should include determination of optimal stocks the introduction of an inventory management system, centralized and distributed parts stocks and centrally controlled delivery service.	SEIAZ	■	■	■	■	■	■	■								

Figure-9-4 PV Rural Electrification Estimated Schedule

Year	1st	5th	10th	20th
Installation	1,000	15,000	45,000	150,000
National Management Center (Harare)				
District Management Center (DMC)				
Local Management Office (LMO)				
Senior engineer	4	21	38	75
Local technician	20	150	375	750
User group	20	150	375	750
Users in group	50	100	120	200
Objective Province(s)	Mashonaland East	Mashonaland East Mashonaland Central	Mashonaland East, Manicaland, Mashonaland Central	Mashonaland East, Manicaland, Mashonaland Central, Mashonaland West, Masvingo, Midlands, Matabeleland North, Matabeleland South
Location of DMC		Bindura	Marondera, Bindura, Mutare	Marondera, Bindura, Mutare, Chinoyi, Masvingo, Bulawayo, Hwange
Location of Local Management Office	Mutoko, Murewa	Mutoko, Murewa, Marondera, Bromley, Centenary, Mount Darwin, Mvurui, Concession, Katwa, Mutawatawa, etc.	Mutoko, Murewa, Bromley, Centenary, Mount Darwin, Mvurui, Concession, Nyanga, Rusape, Chimanimani, Chipinge, Middle Sabi, Katwa, Mutawatawa, Ruwange, Bingaguru, Bazely Bridge Muzaraani, Dotit, Guruve, etc.	同 左 + Karoi, Mhangura, Gokwe, Mkwasine, Chiredzi, Rutenga, Beitbridge, Gwanda, Filabusi, Esigodini, Plumtree, Turk mine, Victoria falls, etc.

9.8.2 Case-setting

This project is designed to electrify 150,000 households in currently un-electrified rural areas by having each household equipped with a PV system under an ESCO arrangement. During the first phase of this project, PV systems will be installed at 15,000 households at a much slower rate than in Phase 2. Phase 1 allows testing of institutional systems before entering into the full scale project so that problems that arise can be solved before entering Phase 2. Four cases were prepared, each assuming a components of internal funds, grant aid, and low-interest (1%) loan.

Table 9-6 Fund raising and objectives of each set cases

Case	Phase 1 (15,000)	Phase 2 (135,000)	Objectives of cases
A	All internal funding	No implementation	Base case to calculate the monthly charge when all investment cost is owned by the ESCO
B	Initial 6,000 systems cost except FL lamps, cable and accessories is a grant, rest is from internal funds	No implementation	To determine the effect on user fees of having system cost of initial 6,000 systems is provided by a grant. (Finally, lamps, cable, and accessories are owned by user, therefore, these components can not be approved by a grant)
C	All internal funds	Internal funds	How much the monthly charge will decrease from base case with increasing customers
D	Same as Case B	80% of system cost is from low interest loans, rest and installation cost is from internal funds	Determination of user fees under the ideal case with phase-1 supported by grant and phase-2 supported by low interest loans.

Table 9-7 Itemized necessary fund, term of calculation (million US$)

	Case-A	Case-B	Case-C	Case-D
Internal funds	10.80	7.26	108.00	35.34
Grant aid	0	3.54	0	3.54
Low interest loans	0	0	0	69.12
Total	10.80	10.80	108.00	108.00
Term of calculation (y)	24	24	39	39

9.8.3 Initial Investment Cost and Annual Payment of Customers

When Phase 1 (15,000 systems installed) alone is implemented:

If ESCO covers the whole of the required investment in the project with its own funds as assumed in Case A, the users are required to pay US$150 for the initial installation cost, and US$154 as their annual payment.

In Case B, which assumes the equipment investment (excluding florescent lamps, cable, and accessories) of an initial 6,000 systems is funded with grants, the users are required to pay US$150 for the initial installation cost, and US$125 as their annual payment.

When the project is implemented through Phase 2 and a total of 150,000 systems are installed:

In Case C, which assumes that the whole of required investments is financed with internal funds, the users are required to pay US$150 for the initial installation cost, and US$124 as their annual payment.

In Case D, the assumption is same as Case B in Phase 1. 80% of the equipment investment which would be made from the 6th to 20th years be funded with preferential loans, like OECF's special environmental loans, the initial installation cost and annual payment due to the users could be set at US$150 and US$87, respectively, thus allowing even very low-income households to participate in the project.

Regardless of the cases, the fees are set at a level where the internal discount rate is effectively 10%. Accordingly, even when the project organization has no internal funds and has to borrow the required funds from financial institutions, this economic analysis shows that the project can successfully be organized as long as the effective interest rate stays below 10%.

However, as obviously noted from the cash flow simulation results, (see Table 9-8 to 9-11, and Figures 9-4 to 9-7) the project is expected to yield earnings only from the 6th year onward in Cases A, and as late as the 15th year and 8th onward in Cases C and D. In those cases, until the project has a positive cash flow, its management cost must be covered with short-term loans. No real project can operate by obtaining short-term loans for 14 consecutive years. There are two options to overcome this difficulty. One is to make up the short fall with government subsidies over the negative cash flow 14 years, then, from the 15 th year on, ZESA-Solar pays the subsidies back to the government. The other is to obtain loans with favorable terms as assumed in Case D from the beginning of the project.e a 10-year grace period.

Table 9-12 Initial installation cost and annual payment by each case (US$)

	Case-A	Case-B	Case-C	Case-D
Installation cost (US$)	150	150	150	150
Annual payment (US$)	154	125	124	87

9.8.4 Sensitivity Analysis

A sensitivity analysis was performed to determine the relative influence of system cost, labor cost and percentage of grant aid in the initial investment cost. The calculation was done by fixing the installation cost at US$150, changing the items above and calculating the annual payment to give an IRR (Internal Rate of Return) of 10% against internal funds.

The results of the sensitivity analysis is shown in Table 9-13 and Figure 9-9

Table 9-13 Example of sensitivity analysis (Case-B)

Annual payment (US$/year)

(Percent of grant)	20% up (70%)	10% up (80%)	Base case (90%)	10% down (100%)	20% down	Sensitivity US$/%
System cost	141.0	135.5	126.0	118.5	11.0	0.75
Labor cost	140.0	133.0	126.0	119.0	112.0	0.70
Percent of grant	133.0	129.5	126.0	123.0		0.33

Sensitivity: change of annual payment(US$)/change of items(%)

. In Case-C, system cost effects more than labor cost and a 1% change of system cost causes a 0.75US$ change of annual payment.

9.8.5 Lifetime Cost

Total lifetime cost is computed with a discount rate of 10% to calculate the present value of each item in Case-A and Case-D, shown in Table 9-14.

Table 9-14 Lifetime cost (discount rate 10%)

(1,000US$)

Case-A(15,000 systems)			Case-D(150,000 systems)		
Items	Amount	Ratio(%)	Items	Amount	Ratio(%)
Initial investment	8,437	45.3	Initial investment	38,664	50.8
Parts renewal cost	2,618	14.0	Parts renewal cost	11,998	15.7
Labor cost	3,540	19.0	Labor cost	9,405	12.3
Administration cost	4,040	21.7	Administration cost	10,474	13.7
Repayment			Repayment	5,752	7.5
Total	18,635	100.0	Total	76,293	100.0

In case-A, 15,000 systems, about 40% of total cost is labor cost and administration cost but in Case-D, 150,000 systems are installed then the labor and administration cost reduces to about 26% of total cost. The system cost is almost same in the case of 15,000 and 150,000 system installations showing that it the annual payment is reduced as customer numbers increase.

9.9 Priorities in Project Implementation

Items to be implemented by each action group are described in Table 9-15, including the main action items, responsible organization, outlines of actions required, expected benefits, funds needed and tasks to be carried out.

9.9.1 Coordination between PV-based and Grids-based Electrification Projects

Full coordination must be secured between the program for PV-system introduction to the rural areas and the grid extension plan. It would beinappropriate to install PV systems in those rural areas to be connected to the grid in the near future. Such areas should be excluded from those to be equipped with PV systems under this project. For this reason, before selecting the target areas, ZESA and ZESA-Solar, the principal implementing organizations, need to have in-depth consultations in association with the approprate government agencies.

9.9.2 Supporting Program Requirements

Major supporting programs are those for quality improvement of PV-system components, the establishment of technical centers, the introduction of standards for PV-system components, a component certificate system, the establishment of technical training centers and the improvement of stock management and distribution functions. These subjects cannot be solved within ZESA alone, and have to be tackled through collaboration with other organizations, such as SIRDC (Scientific and Industrial Research and Development Centre). The creation of technical centers and technical training centers is expected to contribute not only to human resource development, but also PV-system quality improvements and cost reduction, it is recommended that they be established at the earliest possible opportunity through consultations with relevant international organizations.

9.9.3 Management Cost of the Project during Red-ridden Period

Of the four cases assumed in Section 9.8.2, the A, C, and D cases are expected to return not only earnings but also the project management cost during the first 5-14 years however the cash flow analysis indicates that this will not happen. It would not be practical for the principal organization to keep the project afloat by repeatedly borrowing short-term (one-year) loans if the interest rate is high.

In the absence of such preferential low-interest loans with a decade-long grace period as assumed in Case D, the project organization will have to finance the project over the short term with its internal funds. Yet, it will take years before the cash flow becomes positive even in Cases A, C, and D. In the case that the project shall fully be financed with internal funds, the government will need to take some measures to help bolster the project in the early years. For instance, the government may offer subsidies to make up the short fall during the negative cash flow period or buy bonds issued by the project implementer to finance its management cost during the short fall period.

Table 9-8 PV Promotion Project for 24 years (Case A) in US$

Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
Cash Out																										
Condition of the project																										
No.PV			1,000	2,000	3,000	4,000	5,000																-1,000	-2,000	-3,000	-4,000
Accumulated			1,000	3,000	6,000	10,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000	14,000	12,000	9,000	5,000
Households/technician			50	60	75	83	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
No. of Technician			20	50	80	121	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	140	120	90	50
Technicians/engineer			5	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of engineer			4	9	14	18	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	20	18	13	8
No. of rural office			2	4	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
No. of provincial office			0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
No. of National office			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment cost																										
Cost of PV	640	US$/set	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640
Installation cost	80	US$/set	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Total investment cost			720,000	1,440,000	2,160,000	2,880,000	3,600,000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
Replacement cost																										
Battery	US$/piece	60				60,000	120,000	180,000	300,000	420,000	180,000	300,000	420,000	180,000	300,000	420,000	180,000	300,000	420,000	180,000	300,000	420,000	180,000	240,000	300,000	0
Charge controller	US$/piece	60						60,000	120,000	180,000	240,000	300,000	60,000	120,000	180,000	240,000	300,000	60,000	120,000	180,000	240,000	300,000	0	0	0	0
Office expenses																										
Rural office																										
Manager	0																									
Administrative	1		2	4	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Driver	1		2	4	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Worker	1		2	4	6	8	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Engineers	2 to 3		4	9	14	18	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	22	20	18	13	8
Technicians	10 to 25		20	50	80	121	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	150	140	120	90	50
Provincial office																										
Manager	1		0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative	2		0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Driver	2		0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Worker	1		0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2		0	0	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
National office																										
Manager	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative	3 to 5		3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Driver	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Worker	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2 to 4		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Rural office		US$/Y/person																								
Administrative	1	3,600	7,200	14,400	21,600	28,800	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Driver	1	2,400	4,800	9,600	14,400	19,200	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Worker	1	2,400	4,800	9,600	14,400	19,200	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Engineers	2 to 3	4,800	19,200	43,200	67,200	86,400	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600	96,000	86,400	62,400	38,400
Technicians	10 to 25	1,200	24,000	60,000	96,000	145,200	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000	168,000	144,000	108,000	60,000
			60,000	136,800	213,600	298,800	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600	348,000	314,400	254,400	182,400
Provincial office																										
Manager	1	9,600	0	0	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	2	3,600	0	0	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Driver	2	2,400	0	0	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	0	0	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	1 to 2	4,800	0	0	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
			0	0	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
National office																										
Manager	1	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	3 to 5	3,600	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800
Driver	2	2,400	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	2 to 4	4,800	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
			37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200
Rural office	Labor cost x 2		120,000	273,600	427,200	597,600	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200	696,000	628,800	508,800	364,800
Provincial office	Labor cost x 2.5		0	0	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
National office	Labor cost x 3		111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600
Total O/M			231,600	385,200	622,800	793,200	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800	891,600	824,400	704,400	560,400
Total cash out			951,600	1,825,200	2,782,800	3,733,200	4,654,800	1,174,800	1,354,800	1,534,800	1,354,800	1,534,800	1,414,800	1,234,800	1,414,800	1,594,800	1,414,800	1,294,800	1,474,800	1,294,800	1,474,800	1,654,800	1,071,600	1,064,400	1,004,400	560,400
Cash In																										
Connection charge(US$/system)		150	150,000	300,000	450,000	600,000	750,000																			
Annual charge(US$/year)		151	153,780	461,340	922,680	1,537,800	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,152,920	1,845,360	1,384,020	768,900
Total cash In			303,780	761,340	1,372,680	2,137,800	3,056,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,306,700	2,152,920	1,845,360	1,384,020	768,900
Cash Flow			-647,820	-1,063,860	-1,410,120	-1,595,400	-1,598,100	1,131,900	951,900	771,900	951,900	771,900	891,900	1,071,900	891,900	711,900	891,900	1,011,900	831,900	1,011,900	831,900	651,900	1,081,320	780,960	379,620	208,500
Accumulation			-647,820	-1,711,680	-3,121,800	-4,717,200	-6,315,300	-5,183,401	-4,231,501	-3,459,601	-2,507,701	-1,735,801	-843,902	227,998	1,119,898	1,831,798	2,723,698	3,735,597	4,567,497	5,579,397	6,411,297	7,063,197	8,144,516	8,925,476	9,305,096	9,513,596
IRR		IRR	10%																							

Table 9-9 PV Promotion Project for 24 years (Case B) in US$

Year			1	2	3	4	5	6	7	8
Cash Out										
Condition of the project										
No.PV			1,000	2,000	3,000	4,000	5,000			
Accumulated			1,000	3,000	6,000	10,000	15,000	15,000	15,000	15,000
Households/technician			50	60	75	83	100	100	100	100
No. of Technician			20	50	80	121	150	150	150	150
Technicians/engineer			5	6	6	7	7	7	7	7
No. of engineer			4	9	14	18	22	22	22	22
No. of rural office			2	4	6	8	10	10	10	10
No. of provincial office			0	0	1	1	1	1	1	1
No. of National office			1	1	1	1	1	1	1	1
Investment cost										
Cost of PV	640	US$/set	640	640	640	640	640	640	640	640
Installation cost	80	US$/set	80	80	80	80	80	80	80	80
Total investment cost			720,000	1,440,000	2,160,000	2,880,000	3,600,000	0	0	0
Replacement cost										
Battery	US$/piece	60				60,000	120,000	180,000	300,000	420,000
Charge controller	US$/piece	60						60,000	120,000	180,000
Office expenses										
Rural office										
Manager	0									
Administrative	1		2	4	6	8	10	10	10	10
Driver	1		2	4	6	8	10	10	10	10
Worker	1		2	4	6	8	10	10	10	10
Engineers	2 to 3		4	9	14	18	22	22	22	22
Technicians	10 to 25		20	50	80	121	150	150	150	150
Provincial office										
Manager	1		0	0	1	1	1	1	1	1
Administrative	2		0	0	2	2	2	2	2	2
Driver	2		0	0	2	2	2	2	2	2
Worker	1		0	0	1	1	1	1	1	1
Engineers	2		0	0	2	2	2	2	2	2
National office										
Manager	1		1	1	1	1	1	1	1	1
Administrative	3 to 5		3	3	3	3	3	3	3	3
Driver	2		2	2	2	2	2	2	2	2
Worker	1		1	1	1	1	1	1	1	1
Engineers	2 to 4		2	2	2	2	2	2	2	2
Rural office		US$/Y/person								
Administrative	1	3,600	7,200	14,400	21,600	28,800	36,000	36,000	36,000	36,000
Driver	1	2,400	4,800	9,600	14,400	19,200	24,000	24,000	24,000	24,000
Worker	1	2,400	4,800	9,600	14,400	19,200	24,000	24,000	24,000	24,000
Engineers	2 to 3	4,800	19,200	43,200	67,200	86,400	105,600	105,600	105,600	105,600
Technicians	10 to 25	1,200	24,000	60,000	96,000	145,200	180,000	180,000	180,000	180,000
			60,000	136,800	213,600	298,800	369,600	369,600	369,600	369,600
Provincial office										
Manager	1	9,600	0	0	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	2	3,600	0	0	7,200	7,200	7,200	7,200	7,200	7,200
Driver	2	2,400	0	0	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	0	0	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	1 to 2	4,800	0	0	9,600	9,600	9,600	9,600	9,600	9,600
			0	0	33,600	33,600	33,600	33,600	33,600	33,600
National office										
Manager	1	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	3 to 5	3,600	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800
Driver	2	2,400	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	2 to 4	4,800	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
			37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200
Rural office	Labor cost x 2		120,000	273,600	427,200	597,600	739,200	739,200	739,200	739,200
Provincial office	Labor cost x 2.5		0	0	84,000	84,000	84,000	84,000	84,000	84,000
National office	Labor cost x 3		111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600
Total O/M			231,600	385,200	622,800	793,200	934,800	934,800	934,800	934,800
Total cash out			951,600	1,825,200	2,782,800	3,733,200	4,654,800	1,174,800	1,354,800	1,534,800
Cash In										
Connection charge(US$/system)		150	150,000	300,000	450,000	600,000	750,000	0	0	0
Annual charge(US$/year)		125	125,317	375,951	751,903	1,253,171	1,879,756	1,879,756	1,879,756	1,879,756
Grant			590,000	1,180,000	1,770,000					
Total cash in			865,317	1,855,951	2,971,903	1,853,171	2,629,756	1,879,756	1,879,756	1,879,756
Cash Flow			-86,283	30,751	189,103	-1,880,029	-2,025,044	704,956	524,956	344,956
Accumulation			-86,283	-55,532	133,571	-1,746,458	-3,771,502	-3,066,546	-2,541,590	-2,196,633
IRR		IRR	10%							

Year	9	10	11	12	13	14	15	16
Cash Out								
Condition of the project								
No.PV								
Accumulated	15,000	15,000	15,000	15,000	15,000	15,000	15,000	15,000
Households/technician	100	100	100	100	100	100	100	100
No. of Technician	150	150	150	150	150	150	150	150
Technicians/engineer	7	7	7	7	7	7	7	7
No. of engineer	22	22	22	22	22	22	22	22
No. of rural office	10	10	10	10	10	10	10	10
No. of provincial office	1	1	1	1	1	1	1	1
No. of National office	1	1	1	1	1	1	1	1
Investment cost								
Cost of PV	640	640	640	640	640	640	640	640
Installation cost	80	80	80	80	80	80	80	80
Total investment cost	0	0	0	0	0	0	0	0
Replacement cost								
Battery	180,000	300,000	420,000	180,000	300,000	420,000	180,000	300,000
Charge controller	240,000	300,000	60,000	120,000	180,000	240,000	300,000	60,000
Office expenses								
Rural office								
Manager								
Administrative	10	10	10	10	10	10	10	10
Driver	10	10	10	10	10	10	10	10
Worker	10	10	10	10	10	10	10	10
Engineers	22	22	22	22	22	22	22	22
Technicians	150	150	150	150	150	150	150	150
Provincial office								
Manager	1	1	1	1	1	1	1	1
Administrative	2	2	2	2	2	2	2	2
Driver	2	2	2	2	2	2	2	2
Worker	1	1	1	1	1	1	1	1
Engineers	2	2	2	2	2	2	2	2
National office								
Manager	1	1	1	1	1	1	1	1
Administrative	3	3	3	3	3	3	3	3
Driver	2	2	2	2	2	2	2	2
Worker	1	1	1	1	1	1	1	1
Engineers	2	2	2	2	2	2	2	2
Rural office								
Administrative	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Driver	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Worker	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Engineers	105,600	105,600	105,600	105,600	105,600	105,600	105,600	105,600
Technicians	180,000	180,000	180,000	180,000	180,000	180,000	180,000	180,000
	369,600	369,600	369,600	369,600	369,600	369,600	369,600	369,600
Provincial office								
Manager	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Driver	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
National office								
Manager	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800
Driver	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200
Rural office	739,200	739,200	739,200	739,200	739,200	739,200	739,200	739,200
Provincial office	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
National office	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600
Total O/M	934,800	934,800	934,800	934,800	934,800	934,800	934,800	934,800
Total cash out	1,354,800	1,534,800	1,414,800	1,234,800	1,414,800	1,594,800	1,414,800	1,294,800
Cash In								
Connection charge(US$/system)	0	0	0	0	0	0	0	0
Annual charge(US$/year)	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756
Grant								
Total cash in	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756	1,879,756
Cash Flow	524,956	344,956	464,956	644,956	464,956	284,956	464,956	584,956
Accumulation	-1,671,677	-1,326,720	-861,764	-216,808	248,149	533,105	998,061	1,583,017
IRR								

Year	17	18	19	20	21	22	23	24
Cash Out								
Condition of the project								
No.PV					-1,000	-2,000	-3,000	-4,000
Accumulated	15,000	15,000	15,000	15,000	14,000	12,000	9,000	5,000
Households/technician	100	100	100	100	100	100	100	100
No. of Technician	150	150	150	150	140	120	90	60
Technicians/engineer	7	7	7	7	7	7	7	7
No. of engineer	22	22	22	22	20	18	14	8
No. of rural office	10	10	10	10	10	10	10	10
No. of provincial office	1	1	1	1	1	1	1	1
No. of National office	1	1	1	1	1	1	1	1
Investment cost								
Cost of PV	640	640	640	640	640	640	640	640
Installation cost	80	80	80	80	80	80	80	80
Total investment cost	0	0	0	0				
Replacement cost								
Battery	420,000	180,000	300,000	420,000	180,000	240,000	300,000	0
Charge controller	120,000	180,000	240,000	300,000	0	0	0	0
Office expenses								
Rural office								
Manager								
Administrative	10	10	10	10	10	10	10	10
Driver	10	10	10	10	10	10	10	10
Worker	10	10	10	10	10	10	10	10
Engineers	22	22	22	22	20	18	13	8
Technicians	150	150	150	150	140	120	90	60
Provincial office								
Manager	1	1	1	1	1	1	1	1
Administrative	2	2	2	2	2	2	2	2
Driver	2	2	2	2	2	2	2	2
Worker	1	1	1	1	1	1	1	1
Engineers	2	2	2	2	2	2	2	2
National office								
Manager	1	1	1	1	1	1	1	1
Administrative	3	3	3	3	3	3	3	4
Driver	2	2	2	2	2	2	2	2
Worker	1	1	1	1	1	1	1	1
Engineers	2	2	2	2	2	2	2	2
Rural office								
Administrative	36,000	36,000	36,000	36,000	36,000	36,000	36,000	36,000
Driver	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Worker	24,000	24,000	24,000	24,000	24,000	24,000	24,000	24,000
Engineers	105,600	105,600	105,600	105,600	96,000	86,400	62,400	38,400
Technicians	180,000	180,000	180,000	180,000	168,000	144,000	108,000	60,000
	369,600	369,600	369,600	369,600	348,000	314,400	254,400	182,400
Provincial office								
Manager	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	7,200	7,200	7,200	7,200	7,200	7,200	7,200	7,200
Driver	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
National office								
Manager	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	10,800	10,800	10,800	10,800	10,800	10,800	10,800	10,800
Driver	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
	37,200	37,200	37,200	37,200	37,200	37,200	37,200	37,200
Rural office	739,200	739,200	739,200	739,200	696,000	628,800	508,800	364,800
Provincial office	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
National office	111,600	111,600	111,600	111,600	111,600	111,600	111,600	111,600
Total O/M	934,800	934,800	934,800	934,800	891,600	824,400	704,400	560,400
Total cash out	1,474,800	1,294,800	1,474,800	1,654,800	1,071,600	1,064,400	1,004,400	560,400
Cash In								
Connection charge(US$/system)	0	0	0	0				
Annual charge(US$/year)	1,879,756	1,879,756	1,879,756	1,879,756	1,754,439	1,503,805	1,127,854	626,585
Grant								
Total cash in	1,879,756	1,879,756	1,879,756	1,879,756	1,754,439	1,503,805	1,127,854	626,585
Cash Flow	404,956	584,956	404,956	224,956	682,839	439,405	123,454	66,185
Accumulation	1,987,974	2,572,930	2,977,886	3,202,843	3,885,682	4,325,087	4,448,541	4,514,726
IRR								

Table 9-10 PV Promotion Project for 39 years (Case C) in US$ (1/2)

Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cash Out																						
Condition of the project																						
No. PV			1,000	2,000	3,000	4,000	5,000	6,000	6,000	6,000	6,000	6,000	9,000	9,000	9,000	9,000	9,000	12,000	12,000	12,000	12,000	12,000
Accumulated			1,000	3,000	6,000	10,000	15,000	21,000	27,000	33,000	39,000	45,000	54,000	63,000	72,000	81,000	90,000	102,000	114,000	126,000	138,000	150,000
Households/technician			50	60	75	83	100	120	120	120	120	120	150	150	150	150	150	200	200	200	200	200
No. of Technician			20	50	80	121	150	175	225	275	325	375	360	420	480	540	600	510	570	630	690	750
Technicians/engineer			5	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of engineers			4	9	14	18	22	25	33	40	47	54	52	60	69	78	86	73	82	90	99	108
No. of rural office			2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
No. of provincial office			0	0	1	1	1	3	3	3	3	3	5	5	5	5	5	7	7	7	7	7
No. of National office			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment cost																						
Cost of PV	640	US$/set	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640
Installation cost	80	US$/set	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Total investment cost			720,000	1,440,000	2,160,000	2,880,000	3,600,000	4,320,000	4,320,000	4,320,000	4,320,000	4,320,000	6,480,000	6,480,000	6,480,000	6,480,000	6,480,000	8,640,000	8,640,000	8,640,000	8,640,000	8,640,000
Replacement cost																						
Battery	US$/piece	60				60,000	120,000	180,000	300,000	420,000	540,000	660,000	780,000	900,000	1,020,000	1,320,000	1,440,000	1,560,000	1,860,000	1,980,000	2,280,000	2,580,000
Charge controller	US$/piece	60						60,000	120,000	180,000	240,000	300,000	420,000	480,000	540,000	600,000	660,000	960,000	1,020,000	1,080,000	1,140,000	1,200,000
Office expenses																						
Rural office																						
Manager	0																					
Administrative	1		2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
Driver	1		2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
Worker	1		2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
Engineers	2 to 3		4	9	14	18	22	25	33	40	47	54	52	60	69	78	86	73	82	90	99	108
Technicians	10 to 25		20	50	80	121	150	175	225	275	325	375	360	420	480	540	600	510	570	630	690	750
Provincial office																						
Manager	1		0	0	1	1	1	3	3	3	3	3	5	5	5	5	5	7	7	7	7	7
Administrative	2		0	0	2	2	2	6	6	6	6	6	10	10	10	10	10	14	14	14	14	14
Driver	2		0	0	2	2	2	6	6	6	6	6	10	10	10	10	10	14	14	14	14	14
Worker	1		0	0	1	1	1	3	3	3	3	3	5	5	5	5	5	7	7	7	7	7
Engineers	2		0	0	2	2	2	6	6	6	6	6	10	10	10	10	10	14	14	14	14	14
National office																						
Manager	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative	5 to 6		3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	5	5	5	5	5
Driver	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Worker	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2 to 4		2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
Rural office		US$/Y/person																				
Administrative	1	3,600	7,200	14,400	21,600	28,800	36,000	72,000	72,000	72,000	72,000	72,000	108,000	108,000	108,000	108,000	108,000	126,000	126,000	126,000	126,000	126,000
Driver	1	2,400	4,800	9,600	14,400	19,200	24,000	48,000	48,000	48,000	48,000	48,000	72,000	72,000	72,000	72,000	72,000	84,000	84,000	84,000	84,000	84,000
Worker	1	2,400	4,800	9,600	14,400	19,200	24,000	48,000	48,000	48,000	48,000	48,000	72,000	72,000	72,000	72,000	72,000	84,000	84,000	84,000	84,000	84,000
Engineers	2 to 3	4,800	19,200	43,200	67,200	86,400	105,600	120,000	158,400	192,000	225,600	259,200	249,600	288,000	331,200	374,400	412,800	350,400	393,600	432,000	475,200	518,400
Technicians	10 to 25	1,200	24,000	60,000	96,000	145,200	180,000	210,000	270,000	330,000	390,000	450,000	432,000	504,000	576,000	648,000	720,000	612,000	684,000	756,000	828,000	900,000
			60,000	136,800	213,600	298,800	369,600	498,000	596,400	690,000	783,600	877,200	933,600	1,044,000	1,159,200	1,274,400	1,384,800	1,256,400	1,371,600	1,482,000	1,597,200	1,712,400
Provincial office																						
Manager	1	9,600	0	0	9,600	9,600	9,600	28,800	28,800	28,800	28,800	28,800	48,000	48,000	48,000	48,000	48,000	67,200	67,200	67,200	67,200	67,200
Administrative	2	3,600	0	0	7,200	7,200	7,200	21,600	21,600	21,600	21,600	21,600	36,000	36,000	36,000	36,000	36,000	50,400	50,400	50,400	50,400	50,400
Driver	2	2,400	0	0	4,800	4,800	4,800	14,400	14,400	14,400	14,400	14,400	24,000	24,000	24,000	24,000	24,000	33,600	33,600	33,600	33,600	33,600
Worker	1	2,400	0	0	2,400	2,400	2,400	7,200	7,200	7,200	7,200	7,200	12,000	12,000	12,000	12,000	12,000	16,800	16,800	16,800	16,800	16,800
Engineers	1 to 2	4,800	0	0	9,600	9,600	9,600	28,800	28,800	28,800	28,800	28,800	48,000	48,000	48,000	48,000	48,000	67,200	67,200	67,200	67,200	67,200
			0	0	33,600	33,600	33,600	100,800	100,800	100,800	100,800	100,800	168,000	168,000	168,000	168,000	168,000	235,200	235,200	235,200	235,200	235,200
National office																						
Manager	1	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	5 to 6	3,600	10,800	10,800	10,800	10,800	10,800	14,400	14,400	14,400	14,400	14,400	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Driver	2	2,400	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	2 to 4	4,800	9,600	9,600	9,600	9,600	9,600	14,400	14,400	14,400	14,400	14,400	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200
			37,200	37,200	37,200	37,200	37,200	45,600	45,600	45,600	45,600	45,600	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000
Rural office	Labor cost x 2		120,000	273,600	427,200	597,600	739,200	996,000	1,192,800	1,380,000	1,567,200	1,754,400	1,867,200	2,088,000	2,318,400	2,548,800	2,769,600	2,512,800	2,743,200	2,964,000	3,194,400	3,424,800
Provincial office	Labor cost x 2.5		0	0	84,000	84,000	84,000	252,000	252,000	252,000	252,000	252,000	420,000	420,000	420,000	420,000	420,000	588,000	588,000	588,000	588,000	588,000
National office	Labor cost x 3		111,600	111,600	111,600	111,600	111,600	136,800	136,800	136,800	136,800	136,800	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000
Total O/M			231,600	385,200	622,800	793,200	934,800	1,384,800	1,581,600	1,768,800	1,956,000	2,143,200	2,449,200	2,670,000	2,900,400	3,130,800	3,351,600	3,262,800	3,493,200	3,714,000	3,944,400	4,174,800
Total cash out			951,600	1,825,200	2,782,800	3,733,200	4,654,800	5,944,800	6,321,600	6,688,800	7,056,000	7,423,200	10,129,200	10,830,000	10,940,400	11,530,800	11,931,600	14,422,800	15,013,200	15,414,000	16,004,400	16,594,800
Cash In																						
Connection charge (US$/system)		150	150,000	300,000	450,000	600,000	750,000	900,000	900,000	900,000	900,000	900,000	1,350,000	1,350,000	1,350,000	1,350,000	1,350,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Annual charge (US$/year)		124	124,043	372,150	744,299	1,240,432	1,860,648	2,604,907	3,349,166	4,093,425	4,837,685	5,581,944	6,698,333	7,814,721	8,931,110	10,047,499	11,163,888	12,652,406	14,140,925	15,629,443	17,117,961	18,606,480
Total cash In			274,043	672,150	1,194,299	1,840,432	2,610,648	3,504,907	4,249,166	4,993,425	5,737,685	6,481,944	8,048,333	9,164,721	10,281,110	11,397,499	12,513,888	14,452,406	15,940,925	17,429,443	18,917,961	20,406,480
Cash Flow			-677,557	-1,153,050	-1,588,501	-1,892,768	-2,044,152	-2,439,893	-2,072,434	-1,695,374	-1,318,315	-941,256	-2,080,867	-1,665,279	-659,290	-133,301	582,288	29,606	927,725	2,015,443	2,913,561	3,811,680
Accumulation			-677,557	-1,830,607	-3,419,108	-5,311,876	-7,356,028	-9,795,921	-11,868,355	-13,563,729	-14,882,044	-15,823,300	-17,904,168	-19,269,506	-19,928,796	-20,062,097	-19,479,809	-19,450,203	-18,522,478	-16,507,035	-13,593,474	-9,781,794
IRR		IRR	10%																			
Discount rate		0.1000																				
NPV		1,007,640	-677,557	-1,053,244	-1,320,780	-1,442,565	-1,425,063	-1,551,445	-1,203,709	-896,451	-636,888	-418,645	-841,548	-604,227	-222,410	-41,074	163,894	7,812	217,668	433,329	570,875	682,181
		1,000																				

Table 9-10 PV Promotion Project for 39 years (Case C) in US$ (2/2)

Year			21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Cash Out																					
Cumulation of the project																					
No.PV			-1,000	-2,000	-3,000	-4,000	-5,000	-6,000	-6,000	-6,000	-6,000	-6,000	-9,000	-9,000	-9,000	-9,000	-9,000	-12,000	-12,000	-12,000	-12,000
Accumulated			149,000	147,000	144,000	140,000	135,000	129,000	123,000	117,000	111,000	105,000	96,000	87,000	78,000	69,000	60,000	48,000	36,000	24,000	12,000
Households/technician			200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
No. of Technician			745	735	720	700	675	645	615	585	555	525	480	435	390	345	300	240	180	120	60
Technicians/engineer			7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of engineer			107	105	103	100	97	93	88	84	80	75	69	63	56	50	43	35	26	18	9
No. of rural office			35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
No. of provincial office			7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of National office			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment cost																					
Cost of PV	640	US$/set	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640
Installation cost	80	US$/set	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Total investment cost																					
Replacement cost																					
Battery	US$/unit	90	2,700,000	2,910,000	3,180,000	2,520,000	2,700,000	2,880,000	2,400,000	2,340,000	2,520,000	1,800,000	1,980,000	1,080,000	1,260,000	1,440,000	1,440,000	720,000	720,000	720,000	0
Charge controller	US$/unit	90	1,620,000	1,620,000	1,620,000	1,620,000	1,620,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	720,000	720,000	720,000	720,000	720,000		0	0	0
Office expenses																					
Rural office																					
Manager	0																				
Administrative	1		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Driver	1		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Worker	1		35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Engineers	2 to 3		107	105	103	100	97	93	88	84	80	75	69	63	56	50	43	35	26	18	9
Technicians	10 to 25		745	735	720	700	675	645	615	585	555	525	480	435	390	345	300	240	180	120	60
Provincial office																					
Manager	1		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Administrative	2		14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Driver	2		14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Worker	1		7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Engineers	2		14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
National office																					
Manager	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative	3 to 6		6	6	6	6	6	6	5	6	6	6	6	6	6	5	5	6	6	6	6
Driver	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Worker	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2 to 4		4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Rural office		US$/Y/person																			
Administrative	1	3,600	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000
Driver	1	2,400	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
Worker	1	2,400	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
Engineers	2 to 3	4,800	513,600	504,000	494,400	480,000	465,600	446,400	422,400	403,200	384,000	360,000	331,200	302,400	268,800	240,000	206,400	168,000	124,800	86,400	43,200
Technicians	10 to 25	1,200	894,000	882,000	864,000	840,000	810,000	774,000	738,000	702,000	666,000	630,000	576,000	522,000	468,000	414,000	360,000	288,000	216,000	144,000	72,000
			1,701,600	1,680,000	1,652,400	1,614,000	1,569,600	1,514,400	1,454,400	1,399,200	1,344,000	1,284,000	1,201,200	1,118,400	1,030,800	948,000	860,400	750,000	634,800	524,400	409,200
Provincial office																					
Manager	1	9,600	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200
Administrative	2	3,600	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400
Driver	2	2,400	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
Worker	1	2,400	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800
Engineers	1 to 2	4,800	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200
			235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200
National office																					
Manager	1	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	3 to 6	3,600	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Driver	2	2,400	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	2 to 4	4,800	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200
			54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000
Rural office	Labor cost x 2		3,403,200	3,360,000	3,304,800	3,228,000	3,139,200	3,028,800	2,908,800	2,798,400	2,688,000	2,568,000	2,402,400	2,236,800	2,061,600	1,896,000	1,720,800	1,500,000	1,269,600	1,048,800	818,400
Provincial office	Labor cost x 2.5		588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000
National office	Labor cost x 3		162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000
Total O/M			4,153,200	4,110,000	4,054,800	3,978,000	3,889,200	3,778,800	3,658,800	3,548,400	3,438,000	3,318,000	3,152,400	2,986,800	2,811,600	2,646,000	2,470,800	2,250,000	2,019,600	1,798,800	1,568,400
Total cash out			8,473,200	8,670,000	8,854,800	8,118,000	8,209,200	7,918,800	7,078,800	7,148,400	7,218,000	6,378,000	5,852,400	5,086,800	4,791,600	4,806,000	4,630,800	2,970,000	2,739,600	2,518,800	1,568,400
Cash In																					
Connection charge(US$/system)		100																			
Annual charge(US$/year)		124	18,482,437	18,234,360	17,862,221	17,366,048	16,745,832	16,001,673	15,257,313	14,513,064	13,768,795	13,024,536	11,908,147	10,701,768	9,675,380	8,558,981	7,442,592	5,954,074	4,466,556	2,977,037	1,488,518
Total cash In			18,482,437	18,234,360	17,862,221	17,366,048	16,745,832	16,001,673	15,257,313	14,513,064	13,768,795	13,024,536	11,908,147	10,701,768	9,675,380	8,558,981	7,442,592	5,954,074	4,466,556	2,977,037	1,488,518
Cash Flow			10,009,237	9,564,360	9,007,421	9,248,048	8,536,632	8,082,873	8,178,513	7,364,664	6,550,795	6,646,536	6,055,747	5,614,968	4,883,780	3,752,981	2,811,792	2,984,074	1,726,956	458,237	-79,882
Accumulation			237,113	9,701,472	18,709,213	28,047,261	36,583,892	44,666,666	52,845,178	60,209,872	66,760,627	73,407,163	79,462,910	84,987,868	89,461,638	93,204,018	96,016,410	99,000,484	100,726,440	101,184,676	101,104,794
IRR		IRR																			

Table 9-11 PV Promotion Project for 39 years (Case D) in US$ (1/2)

Year			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cash Out																						
Condition of the project																						
No. PV			1,000	2,000	3,000	4,000	5,000	6,000	6,000	6,000	6,000	6,000	9,000	9,000	9,000	9,000	9,000	12,000	12,000	12,000	12,000	12,000
Accumulated			1,000	3,000	6,000	10,000	15,000	21,000	27,000	33,000	39,000	45,000	54,000	63,000	72,000	81,000	90,000	102,000	114,000	126,000	138,000	150,000
Households/technician			50	60	75	83	100	120	120	120	120	120	150	150	150	150	150	200	200	200	200	200
No. of Technician			20	50	80	121	150	175	225	275	325	375	360	420	480	540	600	510	570	630	690	750
Technicians/engineer			5	6	6	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of engineer			4	9	14	18	22	25	33	40	47	54	52	60	69	78	86	73	82	90	99	108
No. of rural office			2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
No. of provincial office			0	0	1	1	1	3	3	3	3	3	5	5	5	5	5	7	7	7	7	7
No. of National office			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment cost																						
Cost of PV	640	US$/set	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640
Installation cost	80	US$/set	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Total investment cost			720,000	1,440,000	2,160,000	2,880,000	3,600,000	4,320,000	4,320,000	4,320,000	4,320,000	4,320,000	6,480,000	6,480,000	6,480,000	6,480,000	6,480,000	8,640,000	8,640,000	8,640,000	8,640,000	8,640,000
Replacement cost																						
Battery	US$/piece	60				60,000	120,000	180,000	300,000	420,000	540,000	660,000	780,000	900,000	1,020,000	1,320,000	1,440,000	1,560,000	1,800,000	1,980,000	2,280,000	2,540,000
Charge controller	US$/piece	60						60,000	120,000	180,000	240,000	300,000	420,000	480,000	540,000	600,000	660,000	960,000	1,080,000	1,080,000	1,140,000	1,200,000
Office expenses																						
Rural office																						
Manager	0																					
Administrative	1		2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
Driver	1		2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
Worker	1		2	4	6	8	10	20	20	20	20	20	30	30	30	30	30	35	35	35	35	35
Engineers	2 to 3		4	9	14	18	22	25	33	40	47	54	52	60	69	78	86	73	82	90	99	108
Technicians	10 to 25		20	50	80	121	150	175	225	275	325	375	360	420	480	540	600	510	570	630	690	750
Provincial office																						
Manager	1		0	0	1	1	1	3	3	3	3	3	5	5	5	5	5	7	7	7	7	7
Administrative	2		0	0	2	2	2	6	6	6	6	6	10	10	10	10	10	14	14	14	14	14
Driver	2		0	0	2	2	2	6	6	6	6	6	10	10	10	10	10	14	14	14	14	14
Worker	1		0	0	1	1	1	3	3	3	3	3	5	5	5	5	5	7	7	7	7	7
Engineers	2		0	0	2	2	2	6	6	6	6	6	10	10	10	10	10	14	14	14	14	14
National office																						
Manager	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative	3 to 6		3	3	3	3	3	4	4	4	4	4	5	5	5	5	5	6	6	6	6	6
Driver	2		2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Worker	1		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2 to 4		2	2	2	2	2	3	3	3	3	3	4	4	4	4	4	4	4	4	4	4
Rural office		US$/Y/person																				
Administrative	1	3,600	7,200	14,400	21,600	28,800	36,000	72,000	72,000	72,000	72,000	72,000	108,000	108,000	108,000	108,000	108,000	126,000	126,000	126,000	126,000	126,000
Driver	1	2,400	4,800	9,600	14,400	19,200	24,000	48,000	48,000	48,000	48,000	48,000	72,000	72,000	72,000	72,000	72,000	84,000	84,000	84,000	84,000	84,000
Worker	1	2,400	4,800	9,600	14,400	19,200	24,000	48,000	48,000	48,000	48,000	48,000	72,000	72,000	72,000	72,000	72,000	84,000	84,000	84,000	84,000	84,000
Engineers	2 to 3	4,800	19,200	43,200	67,200	86,400	105,600	120,000	158,400	192,000	225,600	259,200	249,600	288,000	331,200	374,400	412,800	350,400	393,600	432,000	475,200	518,400
Technicians	10 to 25	1,200	24,000	60,000	96,000	145,200	180,000	210,000	270,000	330,000	390,000	450,000	432,000	504,000	576,000	648,000	720,000	612,000	684,000	756,000	828,000	900,000
			60,000	136,800	213,600	298,800	369,600	498,000	596,400	690,000	783,600	877,200	933,600	1,044,000	1,159,200	1,274,400	1,384,800	1,256,400	1,371,600	1,482,000	1,597,200	1,712,400
Provincial office																						
Manager	1	9,600	0	0	9,600	9,600	9,600	28,800	28,800	28,800	28,800	28,800	48,000	48,000	48,000	48,000	48,000	67,200	67,200	67,200	67,200	67,200
Administrative	2	3,600	0	0	7,200	7,200	7,200	21,600	21,600	21,600	21,600	21,600	36,000	36,000	36,000	36,000	36,000	50,400	50,400	50,400	50,400	50,400
Driver	2	2,400	0	0	4,800	4,800	4,800	14,400	14,400	14,400	14,400	14,400	24,000	24,000	24,000	24,000	24,000	33,600	33,600	33,600	33,600	33,600
Worker	1	2,400	0	0	2,400	2,400	2,400	7,200	7,200	7,200	7,200	7,200	12,000	12,000	12,000	12,000	12,000	16,800	16,800	16,800	16,800	16,800
Engineers	1 to 2	4,800	0	0	9,600	9,600	9,600	28,800	28,800	28,800	28,800	28,800	48,000	48,000	48,000	48,000	48,000	67,200	67,200	67,200	67,200	67,200
			0	0	33,600	33,600	33,600	100,800	100,800	100,800	100,800	100,800	168,000	168,000	168,000	168,000	168,000	235,200	235,200	235,200	235,200	235,200
National office																						
Manager	1	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	3 to 6	3,600	10,800	10,800	10,800	10,800	10,800	14,400	14,400	14,400	14,400	14,400	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Driver	2	2,400	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	2 to 4	4,800	9,600	9,600	9,600	9,600	9,600	14,400	14,400	14,400	14,400	14,400	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200
			37,200	37,200	37,200	37,200	37,200	45,600	45,600	45,600	45,600	45,600	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000
Rural office	Labor cost x 2		120,000	273,600	427,200	607,200	739,200	996,000	1,192,800	1,380,000	1,607,200	1,754,400	1,867,200	2,088,000	2,318,400	2,548,800	2,709,600	2,512,800	2,745,600	2,964,000	3,194,400	3,424,800
Provincial office	Labor cost x 2.5		0	0	84,000	84,000	84,000	252,000	252,000	252,000	252,000	252,000	420,000	420,000	420,000	420,000	420,000	588,000	588,000	588,000	588,000	588,000
National office	Labor cost x 3		111,600	111,600	111,600	111,600	111,600	136,800	136,800	136,800	136,800	136,800	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000
Total O/M			231,600	385,200	622,800	802,800	934,800	1,384,800	1,581,600	1,768,800	1,996,000	2,143,200	2,449,200	2,670,000	2,900,400	3,130,800	3,291,600	3,262,800	3,495,600	3,714,000	3,944,400	4,174,800
Repayment																	921,796	921,796	921,796	921,796	921,796
Total cash out			951,600	1,825,200	2,782,800	3,733,200	4,664,800	6,014,800	5,371,000	6,668,800	7,063,000	7,423,200	10,199,200	10,630,000	10,960,400	11,830,800	11,951,600	15,344,596	15,934,396	16,336,796	16,926,196	17,419,596
Cash In																						
Connection charge(US$/system)		150	150,000	300,000	450,000	600,000	750,000	900,000	900,000	900,000	900,000	900,000	1,350,000	1,350,000	1,350,000	1,350,000	1,350,000	1,800,000	1,800,000	1,800,000	1,800,000	1,800,000
Annual charge(US$/year)		87	86,765	260,200	520,090	867,650	1,301,475	1,822,064	2,342,654	2,863,244	3,383,834	3,904,424	4,685,308	5,466,193	6,247,078	7,027,962	7,808,847	8,850,027	9,891,207	10,932,386	11,973,566	13,014,746
Grant			600,000	1,180,000	1,770,000																	
Low interest loan (1%)		80%						3,072,000	3,072,000	3,072,000	3,072,000	3,072,000	4,608,000	4,608,000	4,608,000	4,608,000	4,608,000	6,144,000	6,144,000	6,144,000	6,144,000	6,144,000
Total cash In			826,765	1,740,210	2,740,590	1,467,650	2,051,475	5,794,064	6,314,654	6,835,244	7,355,834	7,876,424	10,643,308	11,424,193	12,205,078	12,985,962	13,766,847	16,794,027	17,835,207	18,876,386	19,917,566	20,958,746
Cash Flow			-124,836	-84,105	-42,210	-2,266,550	-2,603,325	-150,736	-6,946	146,444	-289,834	453,224	514,108	864,190	1,264,678	1,455,162	1,835,247	1,449,431	1,900,810	2,540,590	2,991,370	3,442,149
Accumulation			-124,836	-208,740	-251,050	-2,517,601	-5,120,926	-5,271,662	-5,278,607	-5,132,063	-5,422,230	-4,970,000	-4,464,897	-3,870,704	-2,706,026	-1,250,864	1,584,384	3,033,814	4,934,024	7,474,614	10,466,984	13,908,133
IRR		IRR	10%																			

Table 9-11 PV Promotion Project for 39 years (Case D) in US$ (2/2)

Year				21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39
Cash Out																						
Condition of the project																						
No.PV				-1,000	-2,000	-3,000	-4,000	-5,000	-6,000	-6,000	-6,000	-6,000	-6,000	-9,000	-9,000	-9,000	-9,000	-9,000	-12,000	-12,000	-12,000	-12,000
Accumulated				149,000	147,000	144,000	140,000	135,000	129,000	123,000	117,000	111,000	105,000	96,000	87,000	78,000	69,000	60,000	48,000	36,000	24,000	12,000
Households/technician				200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200	200
No. of Technician				745	735	720	700	675	645	615	585	555	525	480	435	390	345	300	240	180	120	60
Technicians/engineer				7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of engineer				107	105	103	100	97	93	88	84	80	75	69	63	56	50	43	35	26	18	9
No. of rural office				35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
No. of provincial office				7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
No. of National office				1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Investment cost																						
Cost of PV	640	US$/set		640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640	640
Installation cost	80	US$/set		80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80	80
Total investment cost																						
Replacement cost																						
Battery	US$/piece		60	2,700,000	2,940,000	3,180,000	2,520,000	2,700,000	2,880,000	2,160,000	2,340,000	2,520,000	1,800,000	1,980,000	1,980,000	1,260,000	1,440,000	1,440,000	720,000	720,000	720,000	0
Charge controller	US$/piece		90	1,620,000	1,620,000	1,620,000	1,080,000	1,620,000	1,260,000	1,260,000	1,260,000	1,260,000	1,260,000	720,000	720,000	720,000	720,000	720,000	0	0	0	0
Office expenses																						
Rural office																						
Manager	0																					
Administrative	1			35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Driver	1			35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Worker	1			35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35	35
Engineers	2 to 3			107	105	103	100	97	93	88	84	80	75	69	63	56	50	43	35	26	18	9
Technicians	10 to 25			745	735	720	700	675	645	615	585	555	525	480	435	390	345	300	240	180	120	60
Provincial office																						
Manager	1			7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Administrative	2			14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Driver	2			14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
Worker	1			7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
Engineers	2			14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14
National office																						
Manager	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Administrative	5 to 8			5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
Driver	2			2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
Worker	1			1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Engineers	2 to 4			4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
Rural office		US$/person																				
Administrative	1		3,600	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000	126,000
Driver	1		2,400	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
Worker	1		2,400	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000	84,000
Engineers	2 to 3		4,800	513,600	504,000	494,400	480,000	465,600	446,400	422,400	403,200	384,000	360,000	331,200	302,400	268,800	240,000	206,400	168,000	124,800	86,400	43,200
Technicians	10 to 25		1,200	894,000	882,000	864,000	840,000	810,000	774,000	738,000	702,000	666,000	630,000	576,000	522,000	468,000	414,000	360,000	288,000	216,000	144,000	72,000
				1,701,600	1,680,000	1,652,400	1,614,000	1,569,600	1,514,400	1,454,400	1,399,200	1,344,000	1,284,000	1,201,200	1,118,400	1,030,800	948,000	860,400	750,000	634,800	524,400	409,200
Provincial office																						
Manager	1		9,600	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200
Administrative	2		3,600	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400	50,400
Driver	2		2,400	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600	33,600
Worker	1		2,400	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800	16,800
Engineers	1 to 2		4,800	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200	67,200
				235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200	235,200
National office																						
Manager	1		9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600	9,600
Administrative	5 to 8		3,600	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000	18,000
Driver	2		2,400	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800	4,800
Worker	1		2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400	2,400
Engineers	2 to 4		4,800	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200	19,200
				54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000	54,000
Rural office	Labor cost x 2			3,403,200	3,360,000	3,304,800	3,228,000	3,139,200	3,028,800	2,908,800	2,798,400	2,688,000	2,568,000	2,402,400	2,236,800	2,061,600	1,896,000	1,720,800	1,500,000	1,269,600	1,048,800	818,400
Provincial office	Labor cost x 2.5			588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000	588,000
National office	Labor cost x 3			162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000	162,000
Total O/M				4,153,200	4,110,000	4,054,800	3,978,000	3,889,200	3,778,800	3,658,800	3,548,400	3,438,000	3,318,000	3,152,400	2,986,800	2,811,600	2,646,000	2,470,800	2,250,000	2,019,600	1,798,800	1,568,400
Repayment				2,304,491	2,304,491	2,304,491	2,304,491	2,304,491	4,703,952	4,703,952	4,703,952	4,703,952	4,703,952	4,703,952	4,703,952	4,703,952	4,703,952	4,703,952	5,782,156	5,782,156	5,782,156	5,782,156
Total cash out				10,777,091	10,974,491	11,159,291	10,432,491	10,513,691	12,622,752	11,782,752	11,892,352	11,921,952	11,081,952	10,852,352	10,390,752	9,495,552	9,509,952	9,334,752	8,752,156	8,521,756	8,300,956	7,350,556
Cash In																						
Connection charge(US$/system)			150																			
Annual charge(US$/year)			87	12,927,981	12,754,451	12,494,156	12,147,096	11,713,271	11,192,681	10,672,091	10,151,502	9,630,912	9,110,322	8,329,437	7,548,552	6,767,668	5,986,783	5,205,898	4,164,719	3,123,539	2,082,360	1,041,180
Grant																						
Low interest loan (1%)			80%																			
Total cash In				12,927,981	12,754,451	12,494,156	12,147,096	11,713,271	11,192,681	10,672,091	10,151,502	9,630,912	9,110,322	8,329,437	7,548,552	6,767,668	5,986,783	5,205,898	4,164,719	3,123,539	2,082,360	1,041,180
Cash Flow				2,150,890	1,779,960	1,334,865	1,714,605	1,199,580	-1,430,071	-1,110,661	-1,740,850	-2,291,040	-1,971,630	-2,522,915	-2,842,200	-2,727,884	-3,523,169	-4,128,854	-4,587,437	-5,398,217	-6,218,596	-6,309,376
Accumulation				16,058,425	17,838,385	19,173,247	20,887,852	22,087,432	20,657,362	19,546,701	17,805,851	15,514,811	13,543,181	11,020,266	8,178,066	5,450,182	1,927,013	-2,201,840	-6,789,277	-12,187,494	-18,406,090	-24,715,466
IRR		IRR																				
Discount rate			0.1000																			
NPV			16,817	310,097	240,527	161,963	192,081	121,780	-151,660	-99,190	-156,727	-186,888	-124,290	-127,621	-118,070	-129,156	-151,690	-161,671	-92,072	-109,930	-124,082	-116,211

Table 9-15 A List of Actions for PV-based Rural Electrification

Actions	Agencies responsible for the actions	Contents	Expected benefits	Required funds	Subjects
To incorporate an Energy Service Corporation. (Incorporation of ZESA – Solar)	DOE ZESA	ESCO with a solid foundation for management needs to be formed as the electricity supply machine. ESCO acts as the central organization in the introduction and management of PV systems.	Instead of selling PV systems directly to the users, the systems are provided by ESCO through which the users receive electricity. This approach ensures better maintenance of PV system in the long run than the other option.	Phase 1 Z$108 million Phase 2 Z$972 million	An ESCO with solid foundation for management must be formed.
To prepare an action program.	ESCO(ZESA-Solar) ZESA DOE	Including the selection of the districts to be electrified by installing PV systems, demand estimation, determination of the solvency of potential users, and fund-raising plans, everything related to the introduction and management of PV systems are made.	This project, the first step toward rural electrification in Zimbabwe, can bring about incalculable benefits.		The project must be prepared in a compatible manner to grid extension and other electrification programs.
To establish training centers.	ZESA SEIAZ MOE	For Phase 1 designed to electrify 15,000 households, about 200 ~ 250 local engineers need to be newly secured and trained in five years.	This allows training of large numbers of high-level PV engineers, who can furnish the 15,000 households in Phase 1 with fair maintenance service.	The center can be established within Kwekwe Technical School. Teaching materials & testing sets cost some US$50,000/year	The center must be located in an easily accessible place, and keep close contact with relevant universities and international organizations.
To establish a New Energy Technology Center.	DOE SIRDC UOZ	Locally-manufactured PV parts vary widely in product quality, which can be attributable to some problems in the manufacturing process. To help solve this, a New Energy Technology Center needs to be established.	New Energy Technology Center, if formed, can greatly contribute to PV promotion through quality improvement of Zimbabwe-made PV component equipment.	The building and staff of the newly-formed center can be borrowed from existing SIRDC. Initial investments in testing sets involve about US$200,000.	The center must be located in an easily accessible place, and keep close contact with relevant universities and international organizations.
To introduce a PV standards certificate system.	SAZ SIRDC SEIAZ	To help local PV parts manufacturers improve their product quality, the crucial problem for the present, this system must be introduced and operated by SIRDC.	This system, if established, can help local firms improve quality of their PV component equipment.		Concurrently with the introduction of standards, measuring instruments which are in short right now must be secured. (They can be procured for about Z$1 million.)
To establish a Credit Guarantee Fund.	Central government SEIAZ	This fund must be established in order to help local firms receive loans from financial institutions easier when they sell PV systems to the users and/or ESCO.	This fund, if formed, allows local firms to sell PV systems without worrying the collection of funds.		The fund must be given some mechanism to allow expansion of its scale depending on the spread of PV systems.
To establish a favored system for PV system improvement loans.	Central government SEIAZ	This preferential system must be established in order to help local firms receive loans from financial institutions easier when they plan to improve their PV system development and manufacturing processes.	This system, if established, can encourage local PV system manufacturers to develop and improve their PV systems.		The review standards should be made strict. Yet, successful output, typically patents, must unconditionally be approved as the asset of a given firm.
To establish a favored tariff system for PV imports.	Central government SEIAZ	When local firms and ESCO import PV systems or parts from overseas, they should be given favored tariff treatment.	This, if given, permits easier imports of good-quality PV systems from all over the world.		The favored tariff system must be designed in a form not to discriminate the local firms.
To unfold PR activity of PV systems.	DOE ZESA SEIAZ ARDC	By broadcasting how to use PV systems, maintenance of the systems, and advantages of the systems through radio and TV programs, unelectrified households can be stimulated their will to introduce PV systems.	The spread of PV-related knowledge can help broaden the use of PV systems, which in turn leads to PV system cost reductions as well as a falling rate of mechanical troubles.		PR efforts must be made from all angles, including the system introduction, operation, payment of the charge, and protection of the system, so that good understandings can be gained both from existing and potential users.

DOE: Department of Energy, ZESA: Zimbabwe Electricity Supply Authority, ESCO: Energy Service Company, SEIAZ: Solar Energy Industries Association of Zimbabwe, MOE: Ministry of Education,
SIRDC: Scientific and Industrial Research and Development Center, SAZ: Standards Association of Zimbabwe, UOZ: University of Zimbabwe, ARDC: Association and Rural Development Councils

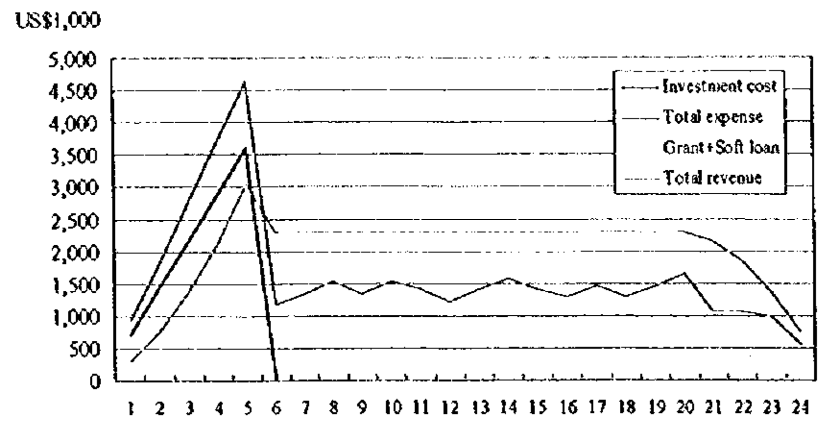

Figure 9-5 Cash Flow of Case A

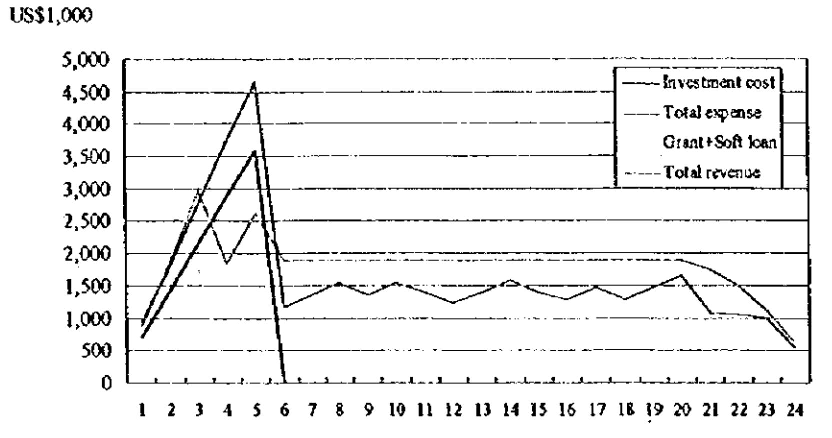

Figure 9-6 Cash Flow of Case B

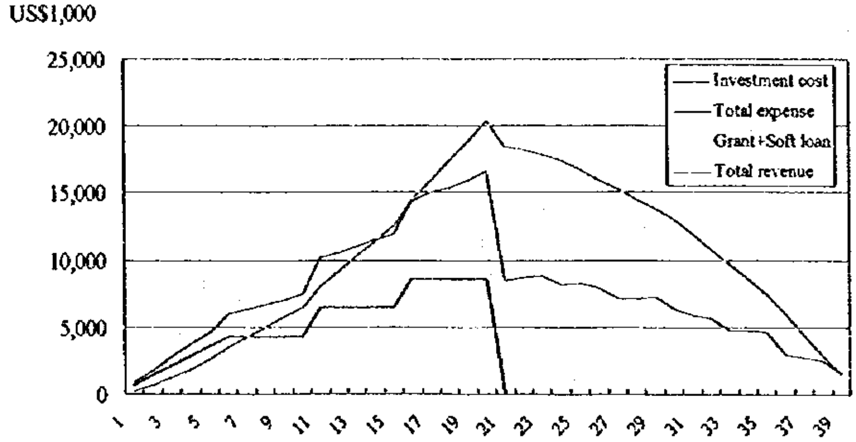

Figure 9-7 Cash Flow of Case C

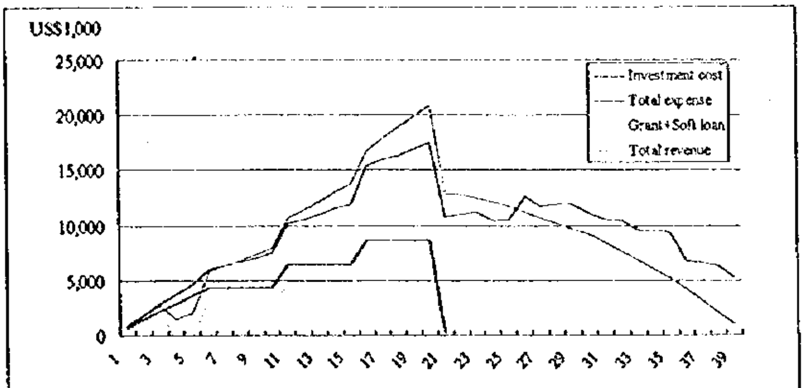

Figure 9-8 Cash Flow of Case D

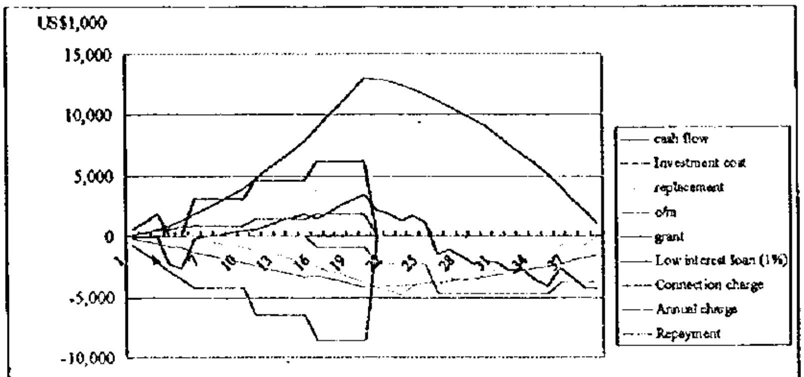

Figure 9-9 Income and Expenditure (Case C)

UNIT:US$

	Factor	20%up(70%)	10% up(80%	Base(90%)	10%down(100%	20%down(110%)	Sensitive
Case B	PV&Batte	100.1	96.0	92.0	88.5	85.0	0.38
	Wage	106.0	99.0	92.0	85.5	79.0	0.58
	Grant	106.0	99.0	92.0	85.5	79.0	0.58

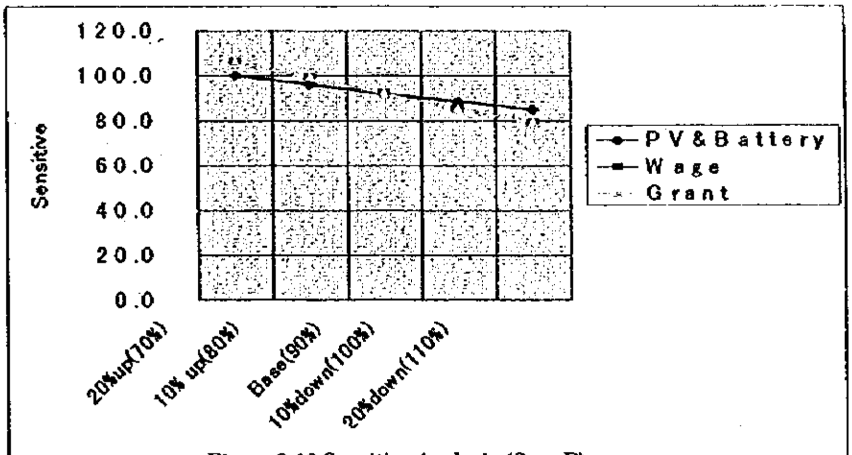

Figure 9-10 Sensitive Analysis (Case B)

1) The sensitive analysis is applied for Case B.
2) PV & Battery includes PV cost, Battery cost, Installation cost, Charge controller cost.
3) Wage includes all kinds of manpower fee.
4) Percentage of Grant is the share to the total investment amount.

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