Japan International Cooperation Agency
The Republic of Zimbabwe
Ministry of Transport & Energy

NO. 2

STUDY ON THE PROMOTION OF PHOTOVOLTAIC RURAL ELECTRIFICATION IN THE REPUBLIC OF ZIMBABWE

Final Report

Summary

MARCH 1999

The Institute of Energy Economics, Japan
Fuji Technosurvey Co., Ltd.

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PREFACE

In response to a request from the Government of the Republic of Zimbabwe, the Government of Japan decided to conduct the Study on the Promotion of Photovoltaic Rural Electrification in the Republic of Zimbabwe, and entrusted the study to Japan International Cooperation Agency (JICA).

JICA sent a Study team, led by Mr. Takayuki Tani of the Institute of Energy Economics, Japan and organized by the Institute of Energy Economics, Japan and Fuji Technosurvey Co., Ltd. to the Republic of Zimbabwe six times from January 1997 to December 1998

The team held discussions with the officials concerned of the Government of the Republic of Zimbabwe, and conducted related field surveys. After returning to Japan, the team conducted further studies and compiled the final results in this report.

I hope this report will contribute to rural electrification development in the Republic of Zimbabwe and to the enhancement of friendly relations between our two countries.

I wish to express my sincere appreciation to the officials concerned of the Government of the Republic of Zimbabwe for their close cooperation throughout the study.

March 1999

Kimio Fujita
President
Japan International Cooperation Agency

March 1999

Mr. Kimio Fujita
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Fujita:

Letter of Transmittal

We are pleased to submit to you the report of the Study on the Promotion of Photovoltaic Rural Electrification in the Republic of Zimbabwe. The report contains the formulation of the Rural Electrification master Plan, the results of the feasibility studies from the pilot monitoring project and recommendations. At the same time it reflects the advice and suggestions of the authorities concerned of the Government of Japan and your Agency. Also reflected are the comments of the officials of the Department of Energy (DOE) of the Ministry of Transport and Energy, the Zimbabwe Electricity Supply Authority (ZESA), the Project Management Unit (PMU) of the UNDP/GEF Project and the Solar Energy Industries Association of Zimbabwe (SEIAZ), through the discussions in the Advisory Committee and the meetings with the Counterpart Team for this Study held in Harare from time to time in the study period.

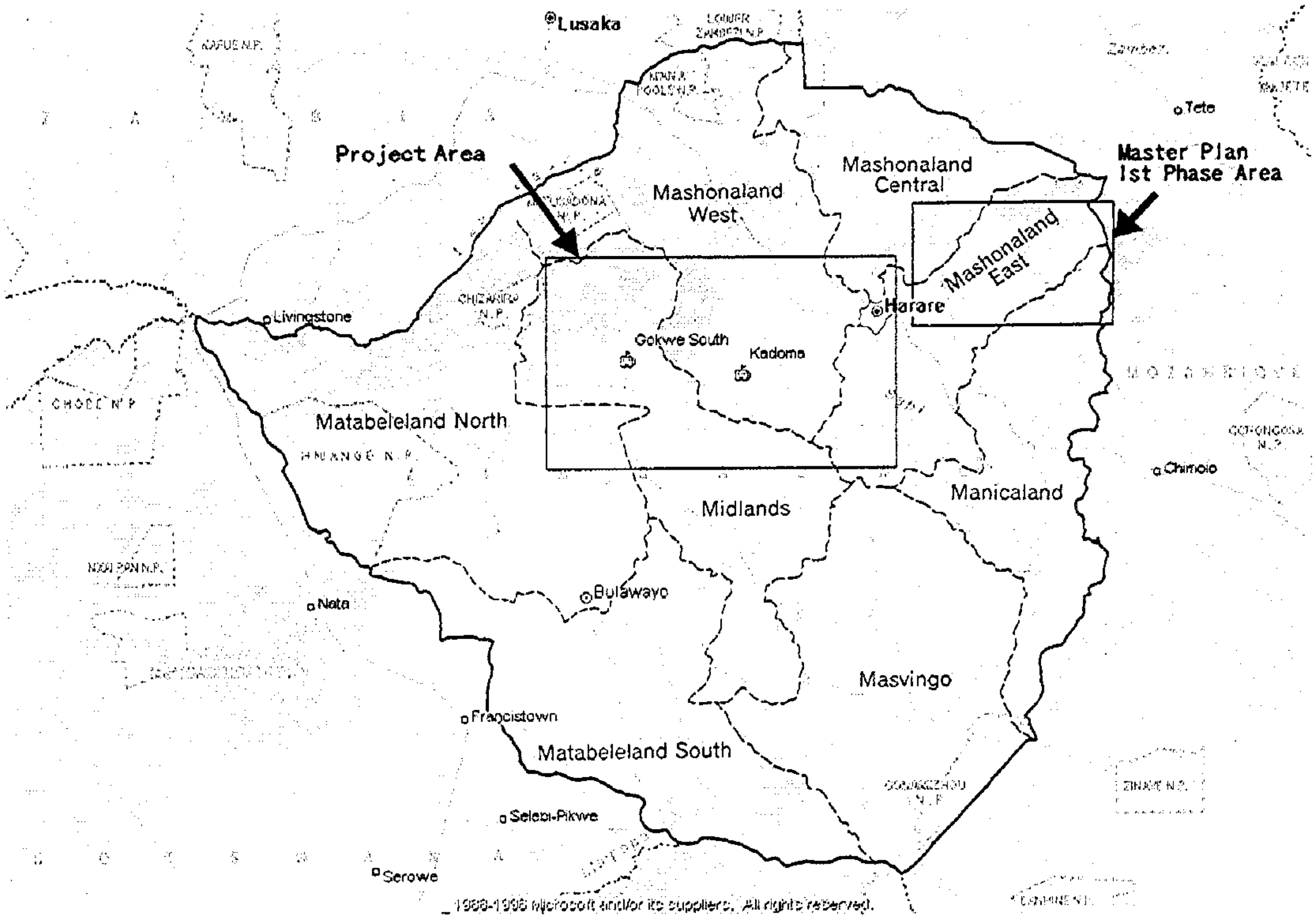
This report presents the rural electrification master plan of utilizing photovoltaics system.
The master plan suggests the electrification of 150 thousands households in 20 years, considering the number of un-electrified rural household and their economic situation. The total investment is expected as much as US$ 108 million and the Energy Supply Company (ESCO) method is recommended to implement this rural electrification
The prerequisites for this viability, however, are the positive participation of ZESA and improvement of the quality of system components supplied domestically.
The Government of Zimbabwe already recognized such necessity through discussions.

In view of importance of the electrification in rural areas of Zimbabwe and the expected improvement of the basic life condition of the rural people, we recommended that the rural electrification master plan should be introduced with top priority in the country.

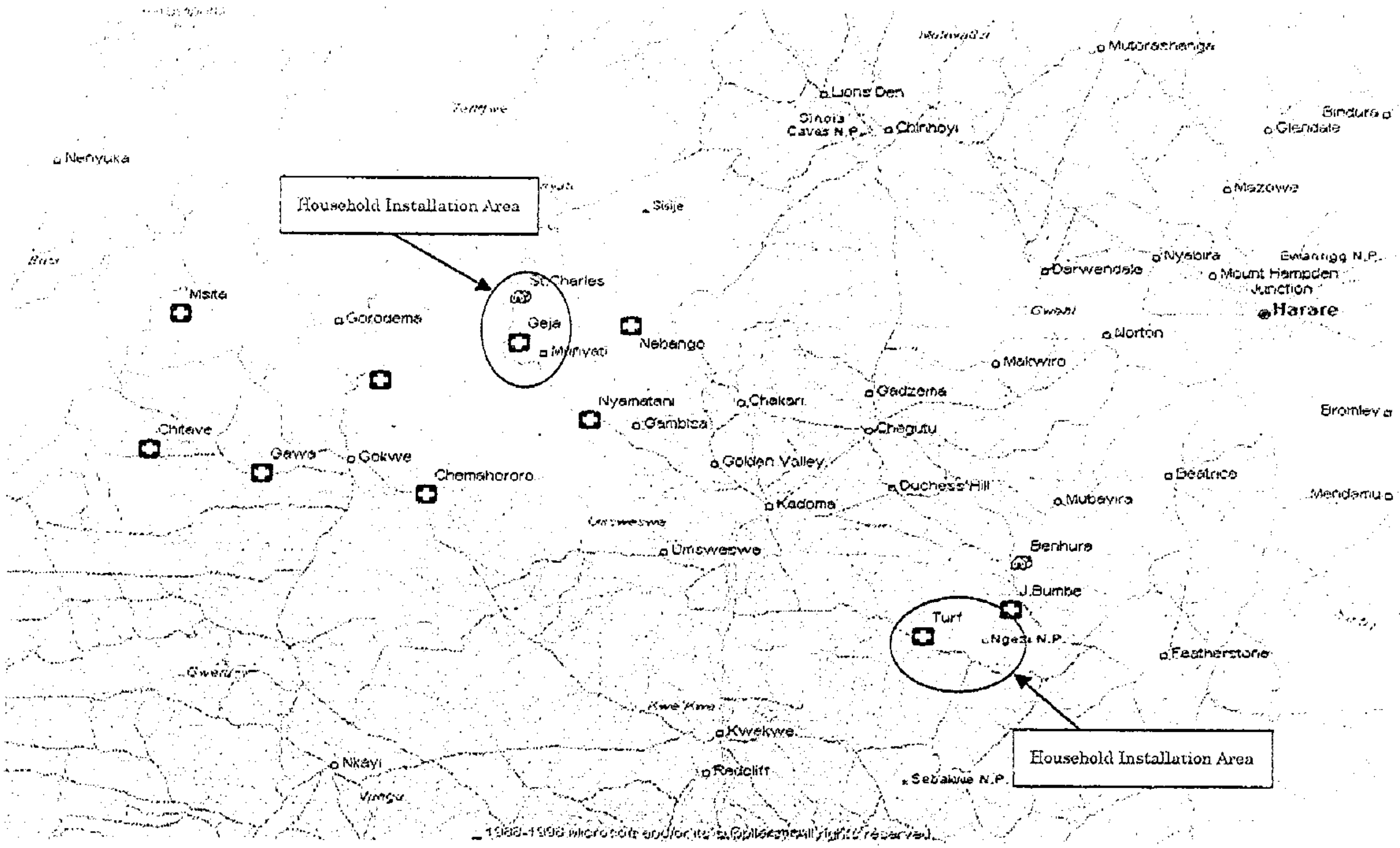
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and Ministry of International Trade and Industry. We also wish to express our deepest gratitude to DOE and the authoritative government agencies concerned of the Republic of Zimbabwe for the close cooperation and assistance extended to us during the period.

Very Truly yours,

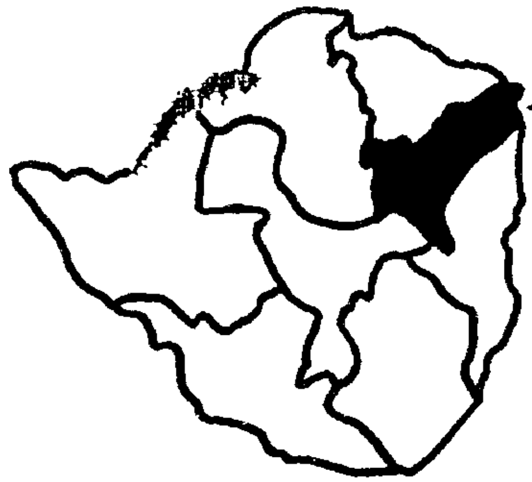
Takayuki Tani
Team Leader
The Study on the Promotion of
Photovoltaic Rural Electrification
In the Republic of Zimbabwe



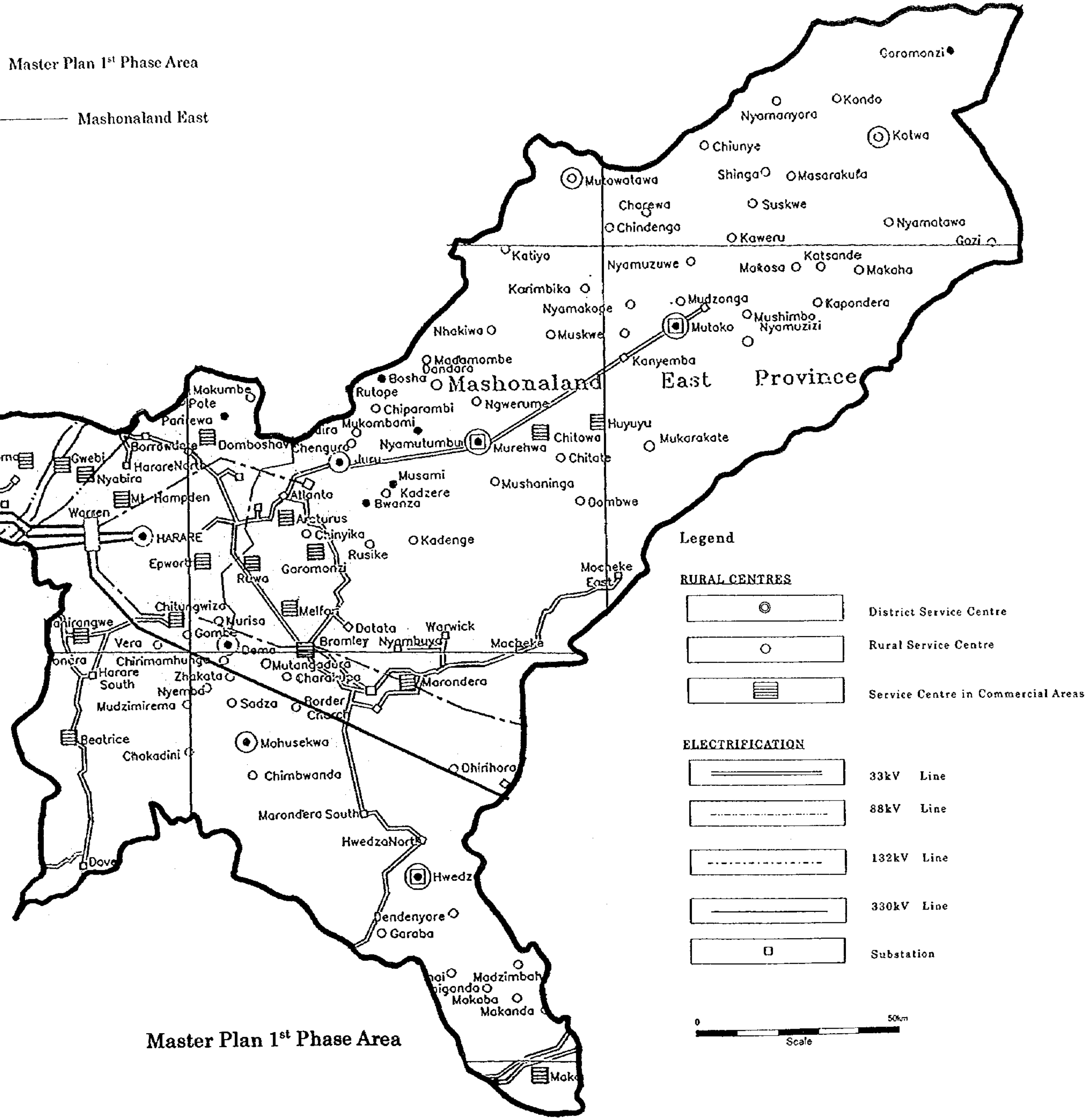
JICA PILOT PROJECT INSTALLATION AREA



JICA PILOT PROJECT INSTALLATION SITE



Zimbabwe Map



Master Plan 1st Phase Area

LIST OF ABBREVIATIONS

AFC	Agricultural Finance Corporation
ADB	African Development Bank
ARDA	Agriculture and Rural Development Authority
ARDC	Association and Rural Development Councils
BUN	Biomass Users' Network
CBO	Community-Based Organization
CLF	Communal Land Farm
CRF	Capital Recovery Factor
CSF	Credit Support Fund
DOE	Department of Energy
DSC	District Service Centre
GDP	Gross Domestic Product
GEF	Global Environment Facility
GOZ	Government of Zimbabwe
I/V	Current/Voltage
IPP	Independent Power Producer
JICA	Japan International Cooperation Agency
LED	Light Emitting Diode
LSCF	Large-Scale Commercial Farm
MOA	Memorandum of Agreement
NGO	Non-Governmental Organization
ORAP	Organization of Rural Associations for Progress
PCB	Print Board Circuit
PGF	Parastatal Government Farm
PMU	Project Management Unit
PV	Photovoltaic
RAF	Resettlement Area Farm
RDC	Rural Development Council
RC	Rural Centre
RE	Rural Electrification
REP	Rural Electrification Plan
RSC	Rural Service Centre
SAZ	Standards Association of Zimbabwe

SEDCO	Small Enterprises Development Corporation
SEIAZ	Solar Energy Industries Association of Zimbabwe
SADC	South African Development Commission
SAPP	South African Power Pool
SCN	State-Certified Nurse
SRN	State-Registered Nurse
SSCF	Small-Scale Commercial Farm
UNDP	United Nations Development Programme
WAPCOS	Water and Power Consultancy Services
ZESA	Zimbabwe Electircity Supply Authority
ZIC	Zimbabwe Investment Centre

Study on The Promotion of
Photovoltaic Rural Electrification
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1. Outline of the Study

1.1 Objective of the study

This study is designed to help prepare a photovoltaic (PV)-based rural electrification project in which even the low-income class can participate.

1.2 Background of the study

1.2.1 General situations of Zimbabwe

According to a survey conducted in 1992, Zimbabwe has a population of 10.4 million. Of a total of 2.16 million households, 70% live in local (rural) areas.

In 1994, gross domestic product (GDP) amounted to Z$76.2 billion, or Z$7,200 (approx. US$850) per capita.

Major domestic industries are manufacturing (mining), agriculture and tourism. Principal export items are mineral products, such as gold and nickel, and farm products like tobacco and cotton. Zimbabwe is almost self-supporting in food.

The latest survey (1997) conducted by JICA unveiled that an annual income of general households averaged Z$36,000(US$3,000) nationwide, and around Z$26,000(US$2,200) among the unelectrified households.

Agriculture involves the commercial plantations run by large-scale farms, the nationally-developed communal plantations, and the resettlement plantations. Compared with the commercial plantations, the common and resettlement plantations are lower in productivity, which results in lower incomes for the farming families there.

1.2.2 Electricity supply and rural electrification in Zimbabwe

In Zimbabwe electricity is supplied with coal-fired power generation (fueled by ample coal found in the country), hydro power generation primarily by the 1958-built Kariba dam, and purchased power through the international grid interconnected with neighboring countries. Generating capacity amounts to about 2,000MW. Of about 10,000GWh supplied in FY1995, roughly 30% was covered by purchased power from abroad.

On the demand side, the greater part goes to industry and commerce. General households account for about 20%. Per capita electricity consumption is 2.5kWh/day, which is about 1/15th of the world's average.

In Zimbabwe nationwide, about 30% of households are electrified. The household electrification rate exceeds 70% in urban areas, but remains below 5% in rural areas. By province, the electrification rate is 25% at its highest, and below 10% at its lowest.

In its effort to promote rural electrification, the government initiated in 1997 a ten-year program, under which local economic centers, including DSCs (District Service Centres) and RSCs (Rural Service Centres), are electrified by extending existing grids. No special electrification programs are planned for general households (Fig. 1).

1.2.3 PV introduction in Zimbabwe

Zimbabwe is rich of solar energy resources, and supplied with solar energy equivalent to about 2,000kWh/m² a year. In 1993, partially financed by UNDP, the GEF (Global Environmental Facility) project started, under which a total of 9,000 household-type PV systems of 45W-PV module type were to be installed in five years. Also, in 1996, Harare hosted the WSS (World Solar Summit 1996), where the "Harare declaration on sustainable development of solar energy" was adopted. Since then, Zimbabwe, which chaired the Summit, prepared a decade-long solar energy utilization program, or Zimbabwe Solar Program 1996-2005,and called for financial cooperation. On top of household-type PV systems, this program plans PV water pumping, public facility-use system, mini-grid PV system, etc.

Zimbabwe has some 50 firms specializing in the supply of PV-related equipment and system installation. They are engaged in such corporate activities as the manufacture, import and sale of PV-system component equipment and their installation. The majority of them are small and medium sized firms, each with less than 20 employees and annual sales of below US$10,000.

Along with the implementation of GEF project, these firms established SEIAZ (Solar Energy Industries Association of Zimbabwe), which is active in information exchanges and PR efforts.

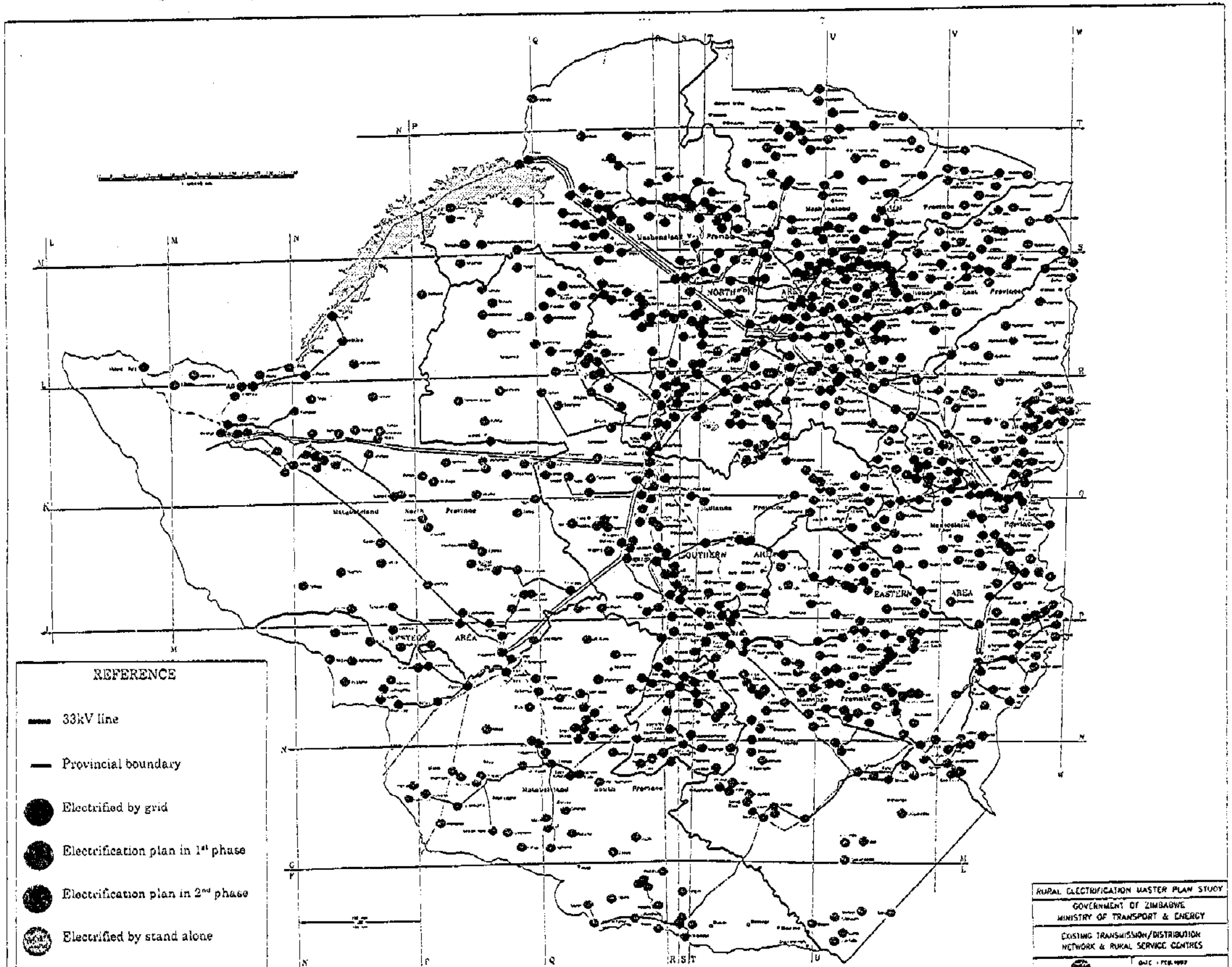


Fig-1 Electrified Area and Un-electrified Area

1.3 Survey schedule

	Year・month	Major works
Preparatory works at home	Jan. '97	To prepare and send an inception report (ICR).
1st field survey	Feb.-Mar. '97	Explanation of ICR, preliminary survey on monitoring system installation, reference materials & data gathering (electrification program, loan system, etc.)
1st domestic survey	May '97	To analyze collected reference materials, prepare a progress report.
2nd field survey	July-Aug. '97	To explain the progress report, install monitoring systems, initiate the operation, conduct (commission) a social survey.
3rd field survey	Oct.-Nov. '97	To elucidate the problems identified through monitoring, and instruct how to solve the problems.
2nd domestic survey	Jan. '98	To prepare and send an interim report.
4th field survey	Jan.-Feb. '98	Explanation of the interim report, and data gathering on monitoring conditions, GFP project, etc.
3rd domestic survey	June-July '98	To prepare for drafting a final report.
5th field survey	July-Aug. '98	To expand the capacity of monitoring systems, and gather data on monitoring conditions.
6th field survey	Dec. '98	To explain the drafted final report.

1.4 Counterpart and concerned organizations

Counterpart:

DOE (Department of Energy, Ministry of Transport and Energy)

Advisory committees:

DOE,

PMU (Project Management Unit of GEF),

ZESA (Zimbabwe Electricity Supply Authority),

SEIAZ (Solar Energy Industries Association of Zimbabwe),

BUN (Biomass Users Network)、

AFC(Agricultural Financing Corporation)

2. Policy and Contents of the Study

2.1 Policy and flow of the Study

2.1.1 Study policy

In reference to the implementation results of GEF project, it is hoped to prepare a rural electrification program which allows the participation of the households of the lower income class. To that end, through the installation and management of monitoring systems, problems are found in both management and technical processes. Then, how to solve such problems is considered and transferred to the rural electrification program to be prepared. At the same time, in order to estimate demand, select supporting measures and evaluate economics, specific surveys are conducted relative to the village socio-economic conditions, loan system and economic conditions.

2.1.2 Flow of the study

The flow of the study in preparing a rural electrification program is as illustrated in Fig. 2.

2.2 Major study contents by field

2.2.1 Study on management:

By identifying and analyzing what problems arose in the implementation of the GEF project from various materials gained from the preliminary study, a pilot project which can eliminate such problems is prepared.

Under the cooperation of our counterpart and local administrative organizations in Zimbabwe, the areas and households where the PV systems are installed for the pilot project are selected.

The fee for PV system use is set with reference to the results of a village socio-economic survey and the GEF project. An operator of the pilot project is selected among NGOs having experience with PV-system installation/management. The operator is requested to collect management-relevant data, like the rate of collection of fees. By analyzing its operation and management results, the results will be used in the preparation of a full-scale rural electrification project.

To determine whether a system sales or an electricity supply service is more practical for PV system-based rural electrification, the two approaches are compared in reference to the results of GEF and the pilot project. If the electricity service approach, an ESCO (Energy Service Company) approach, is to be introduced, the qualifications for an ESCO are considered in comparison with ESCO-candidate organizations in Zimbabwe.

2.2.2 The study in technical terms:

A 25Wp system is designed for the pilot project. Then, by measuring the characteristics of the locally available PV-system components, some are selected, or employed in the 25Wp system after design modification and trial manufacturing, as necessary. In the processes of product quality inspection and trial manufacturing, product quality problems are pointed out and methods to improve manufacturing technologies are proposed. Also, by checking the system installation work, how to improve that work is proposed.

The operation and maintenance conditions are analyzed from the data logger records, local technician's maintenance records, etc., so that the way users operate the systems can be learned and used in the preparation of designs for the full-scale rural electrification project.

2.2.3 Survey on farming village societies:

How much potential PV demand can be expected is estimated by surveying electricity needs and economic conditions in Zimbabwe's rural areas. Also, through a survey on the state of use among the currently PV system-equipped households, existing problems are learned.

The survey is consigned to a local consultant and made in a questionnaire style. The survey targets are unelectrified households and households already equipped with PV systems, 200 each, as well as unelectrified and already PV-equipped public facilities, 50 each. Because the ultimate PV-based electrification project is designed to be nationwide, the questionnaire must cover a number of provinces. Provincial characteristics, such as average income, population density, electricity needs, are examined as well.

2.2.4 Economic evaluation:

To determine the economics of the PV power generation system, its cost is compared with the cost of a grid extension from the electric utility's system in an effort to verify the appropriateness of PV power generation systems as an option to meet limited electricity needs in rural areas. At the same time, in order to learn economic effects of PV-system penetration, the extent an increase in the added value of PV system installation can contribute to GDP is analyzed.

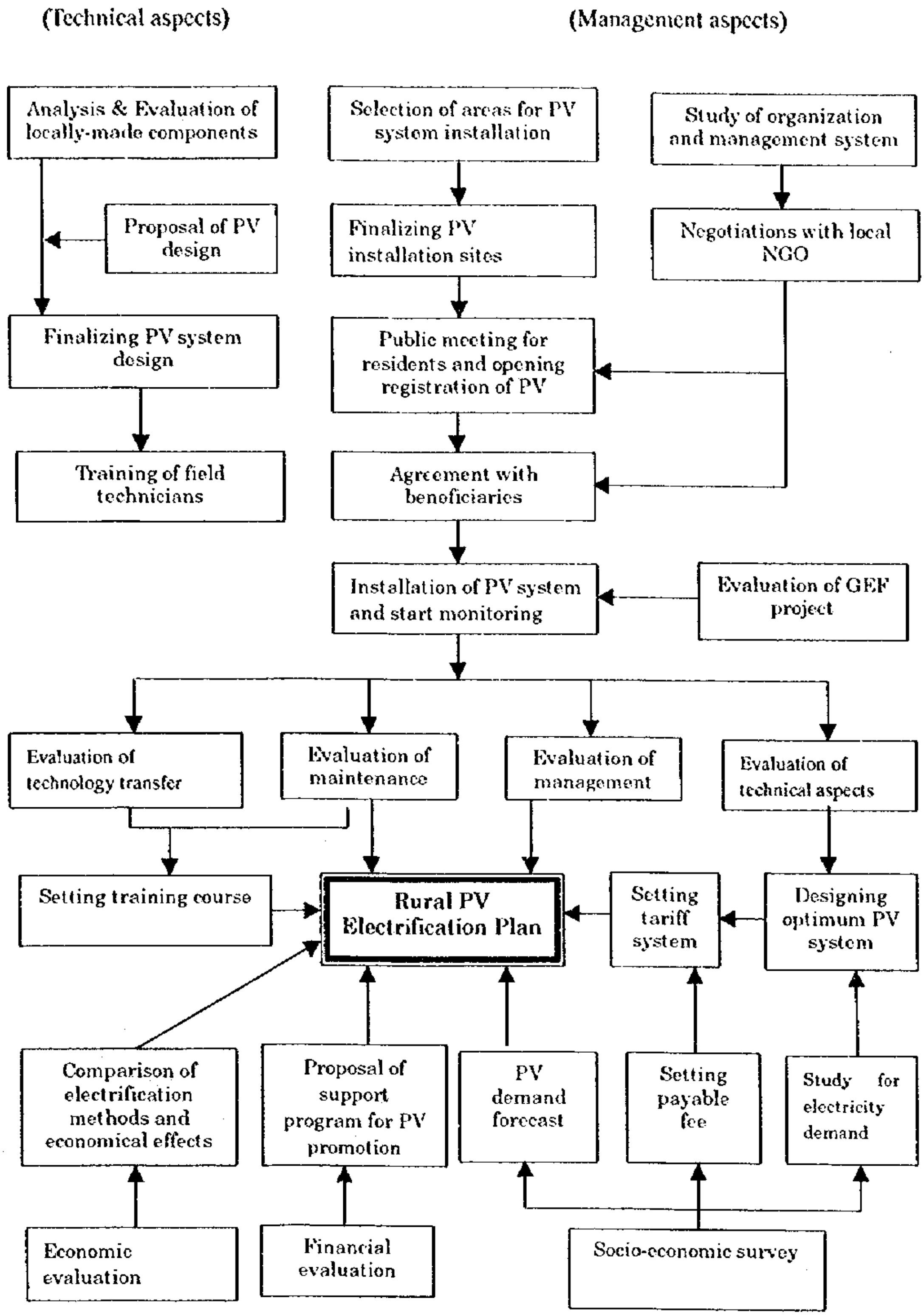


Figure 2 Diagram of JICA Study Scheme

2.2.5 Consideration of financing system:

The study of the financing system is conducted in order to propose an effective loan system for both the users and system providers (those responsible for PV system lease or installation), and covers the loan system involved in the existing GEF project. Finance systems employed by other developing countries in their rural electrification projects are checked as well. Also, a questionnaire is sent to PV-related firms in Zimbabwe to learn what problems are involved in the existing financing system. Then, how such problems can be solved is considered.

2.2.6 Preparation of a master plan for PV-based rural electrification

What should be done by individual organizations/agencies in promoting rural electrification programs is specified.

By estimating the number of households subject to PV-based rural electrification, specific targets for such electrification programs are set.

By varying assumptions, varied cases are prepared and studied, for which cash flows are calculated by estimating, or setting, the required funds, fund-raising methods, and the charges to be collected.

3. Overview of Study Results

3.1 Evaluation of GEF project

The GEF project is a scheme to allow potential users to buy PV systems easier thanks to a revolving fund which permits purchase on 2 – 3-year installments at 15% interest, compared with the high market rate of 35-40% in Zimbabwe. Also, as the managing organization of the project, PMU was created. PV-system parts imported by the PMU were exempted from import tariffs so that the system installation cost could be lowered. System installation was left to private firms, while maintenance was done either by the installation firms or the users by themselves. ZESA and NGOs partially participating in the project as sub-management organization and expected to install 500 and 160 systems respectively. The system installation cost was paid by AFC to the installation firms to be later reimbursed by the users in installments. The scheme of GEF project is illustrated in Fig. 3.

(1) In what points GEF contributed to the spread of PV systems

- With more than a few thousands PV systems installed in Zimbabwe in a short period, the GEF project demonstrated that PV system was an effective electricity supply system in unelectrified areas, and thus allowed those who live in unelectrified rural areas to have the hope that they could use electricity.
- As a result of their participation in the project, the PV system parts makers and installation firms could acquire relevant technologies.
- The project made ZESA more interested in the potential of PV-based rural electrification than ever.

(2) Problems identified through GEF project

- Because the term of loan repayment was as short as 2-3 years, and because a down payment equivalent to 15% of the system price was required, those who could buy a PV system were limited to a few classes, such as affluent farmers, teachers and other salaried workers.
- Locally-manufactured PV system components had quality problems. During the initial stage, the GEF project employed locally manufactured parts when available. But, some of them were poor in quality and caused problems with the systems. Despite their efforts to test many products and improve them, almost all major parts were imported by the time the project was over.
- The installation firms were poor in their level of technical capability. The GEF project left the system installation work to the installation firms under given technical standards.

But, post-installation inspections made by PMU staff showed that their work should be improved in many points.

- Because the whole area of Zimbabwe was applicable to the GEF project, and because PV systems were installed for all the applicants who satisfied loan qualifications, system-equipped households were scattered nationwide. As a result, the burden on a limited number of PMU inspection staff kept mounting along with progress in the project to the extent that the conditions of the systems installed nationwide could hardly be determined.
- In regard to the maintenance of PV systems, the PMU responsible for the management of the GEF project required the installation firms to offer post-installation service for a year after they installed the systems. Afterward, the users, often having scant knowledge of PV system maintenance, were required to take care of their systems. Accordingly, poor maintenance is expected.

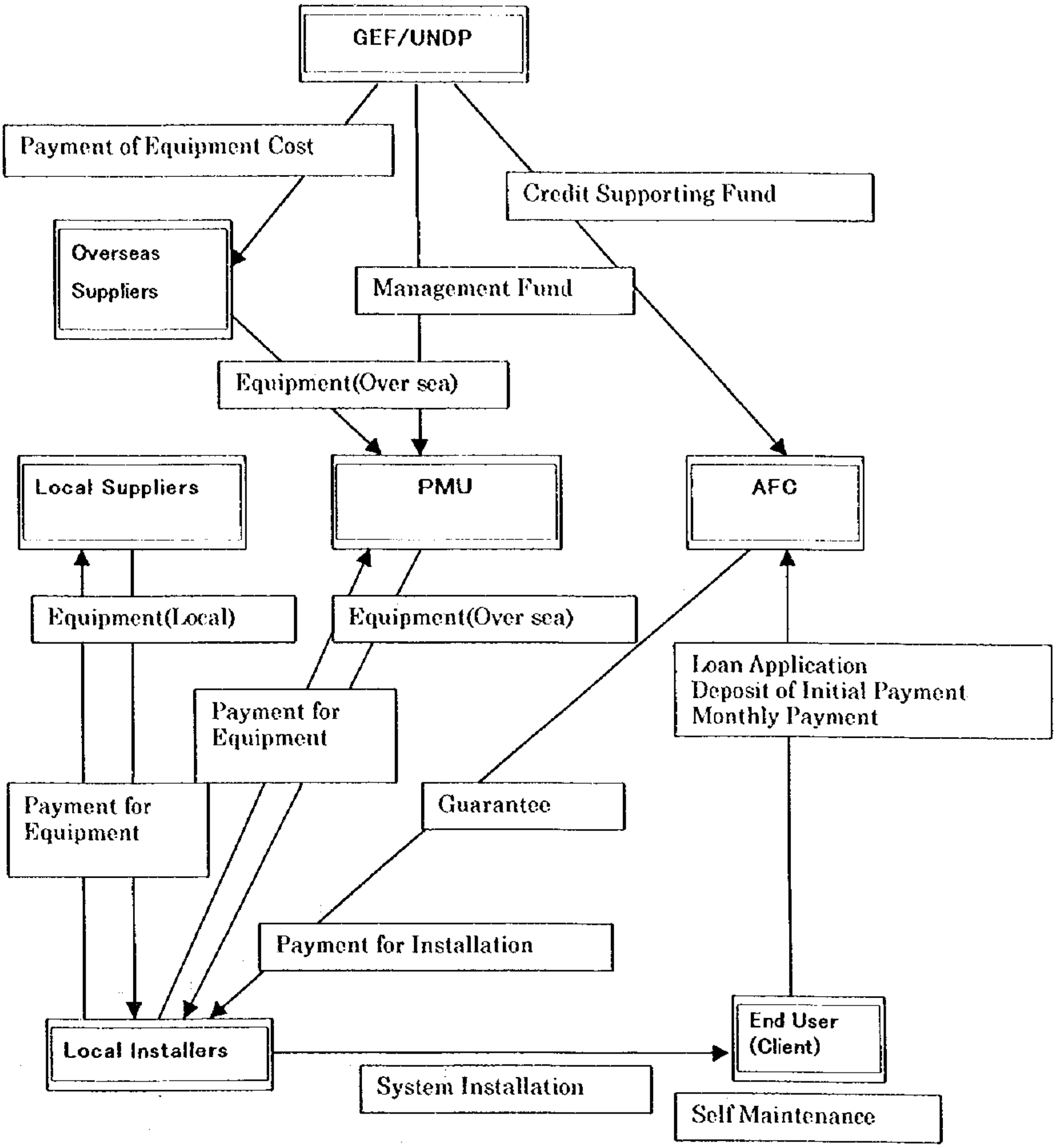


Figure.3 GEF Project Scheme

3.2 Scheme of JICA pilot project

The scheme of JICA project is designed in consideration of GEF project and situation of Zimbabwe, is shown in Fig. 4. The main emphasis points are follows:

(1) The JICA project is designed to develop a scheme which can be participated in by the lower income classes.

(2) With the JICA project, PV-system components are procured from domestically-manufactured ones as much as possible. To that end, a controller applicable to a very small-capacity PV system (25W class) was developed and employed in the PV system of the JICA project And technology transfer was made to enable local manufacture of the controller.

(3) With the JICA project, a managing organization which can ensure a continuity of service is established. The organization is responsible for the maintenance and management of the installed PV systems so as to guarantee the sustainable use of the systems in the long run.

(4) With the JICA project, local engineers are assigned under the managing organization. They are responsible for PV-system maintenance.

(5) A training facility for local engineers and system installation workers is established in hopes to upgrade their maintenance and installation technical levels .

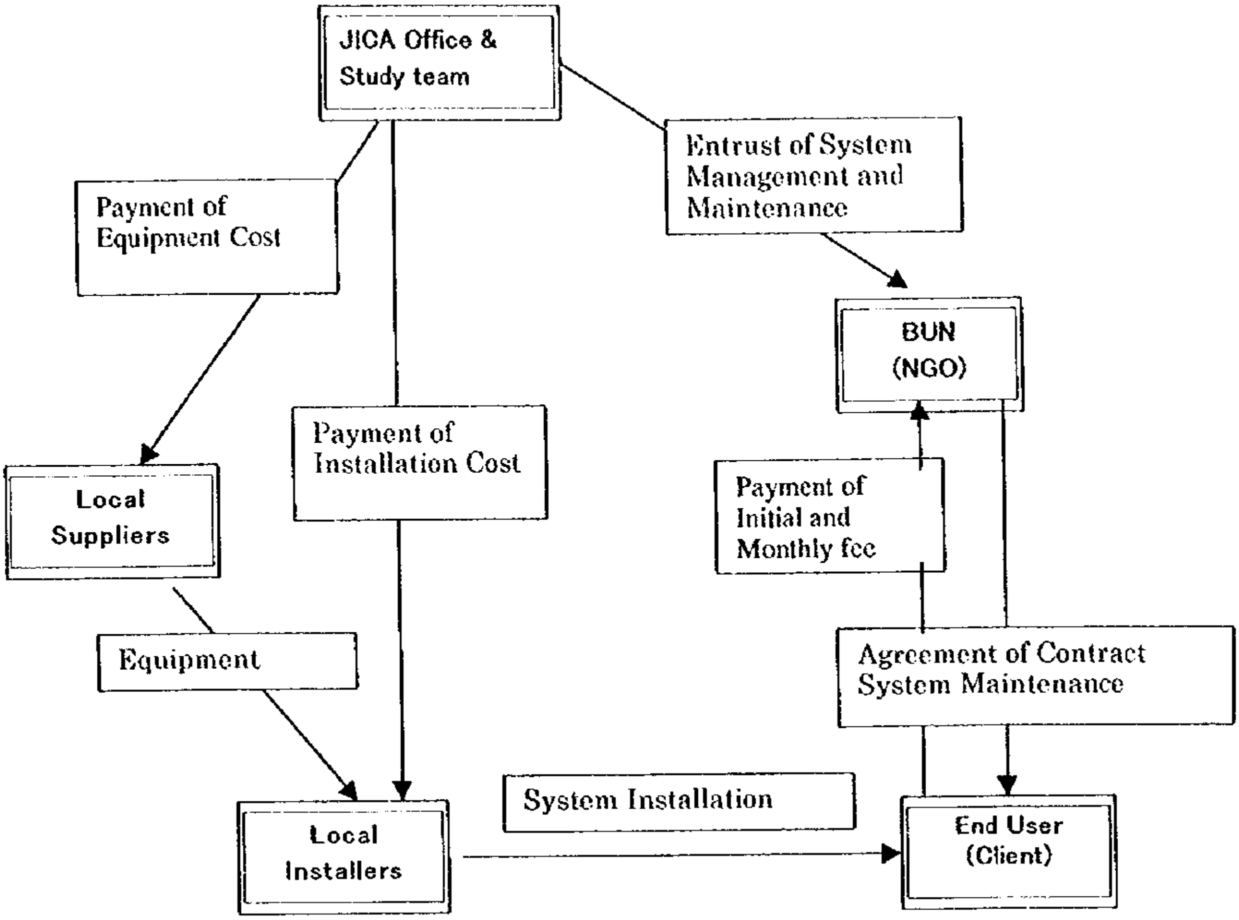


Figure 4 JICA Scheme

3.3 Implementation of the pilot project and its evaluation

3.3.1 Evaluation in management terms

(1) In order to allow easier participation by the low-income class, the JICA project employed the institutional approach of electricity supply service, which allowed the users to pay the charge for electricity use, instead of buying a PV system.

(2) Evaluation of PV-system components is detailed later in the section on "evaluation in technical terms." Overall, existing domestically manufactured components have quality problems.

(3) The JICA project contracted with a NGO as the managing organization and entrusted to it the management and maintenance of the pilot project, as well as the collection of charges. Because the users consumed more electricity than originally expected, suppliers were late in their deliveries and because poor-quality PV system components caused initial problems, it took more than the expected time before the management could be stabilized. The NGO was found weak in disciplining users for for illegal use and non payment of fees.

Among other factors, the distant location of the NGO office from the service areas had a negative effect on efficient management.

(4) Local technicians actually responsible for the maintenance work were selected among several local candidates in the service areas after receiving training at a JICA-sponsored training course. It was estimated that a local technician, once experienced, could cover more than 100 households per month.

(5) The salary earners can be charged every month, but it was confirmed that farming families would be better served if charged once a year during the harvest time.

3.3.2 Evaluation in technical terms

(1) PV-system components:

a. The same imported PV modules as in the GEF project were employed, and they produced no special problems.

b. Domestically-manufactured batteries were purchased and placed in use. Because of greater electricity consumption by the users than originally expected, and because of inappropriate settings of the charge controllers, many problems were caused, includingthe early failure of a number of batteries.

c. While domestically-manufactured controllers were used during the initial stage, the charge controllers were replaced with improved ones which consumed less electricity, which were again replaced with a further improved model. Not locally available, the parts for the improved model were procured and assembled in Japan.

d. Of the fluorescent lamps actually installed, about 1% failed and had to be replaced with new ones.

(2) System installation work:

a. The workers were rough in installing the system. Without having appropriate tools, they often damaged the wall and roof while installing the systems. They were instructed to use appropriate tools and work more carefully but in most cases no change in performance was seen..

b. Neither the azimuth and nor the tilt angle of PV modules were set correctly. The workers did not have necessary instruments and tools for accurate setting and some did not understand the concept of angle and azimuth. They were instructed how to use some simplified tools and how to make reliable installation.

c. Some wiring work was as poor as connecting the system to the battery simply by winding the wire around the terminal.

(3) Data logger-based evaluation of operating conditions

a. Sunshine data used in designing were those conventionally collected by the Harare meteorological observatory. It was confirmed that the data were little different from actually measured data in the pilot project districts.

b. As for operating characteristics of the charge controller, the locally-manufactured one first installed was found to have its HVR (high voltage reconnection) set at 12.5V despite the specification of 13.5V. This caused difficulties in recharging, and made the recovery of the battery slow. The improved model demonstrated operating characteristics exactly as expected.

c. Operating conditions of the systems installed at public facilities showed that medical clinics consumed less electricity than expected, thus leaving room for incremental electricity use. As for the systems installed at schools, the maintenance was left to the schools. Accordingly, there were big differences in battery conditions between those having rendered good maintenance work and others which did not.

d. Operating conditions of the systems installed in households showed that, due to greater electricity consumption than expected, the systems were running at full capacity. While the systems were designed with some allowances in the amount of sunshine, etc., electricity supply was sometimes interrupted when non-sunshine days continued so long that charging fell short. The greater electricity consumption is attributable to the fact that many households consumed electricity for not only lighting, but TVs as well.

e. Users' evaluation results showed that the number of the users who answered that they were satisfied increased from 44 in December 1997 to 84 in April 1998. The outcome suggested the system use entered the stable stage with a falling number of initial troubles. The greater part of the troubles were related to the charge controller and battery.
However, since August 1998 after only a year when the systems were installed, a lot of local made batteries with low terminal voltage had been observed. These conditions showedthat the lives of the batteries were running out. Therefore, JICA decided to replace these batteries to reliable imported batteries.

f. In the process of monitoring, it was found that the users consumed more electricity than expected and that many users hoped to increase the capacity of their systems. Accordingly, by designing a larger 50W system and confirming that the capacity expansion could be made with a minimum additional investment, capacity was expanded upon the users' request.

3.4. Social survey of farming village

3.4.1 General descriptions of agriculture in Zimbabwe

How the farmlands were categorized in Zimbabwe, what crops were raised by type of farmland, and what were characteristics by type of farming, among others, were surveyed. By type of farmland, Communal Land Farm (CLF) has the largest population. Accordingly, the most popular target of PV-based electrification will be farmers in the CLF.

Major farm products are maize, wheat and cotton.

3.4.2 Results of the rural socio-economic survey

Covering 200 unelectrified households, 200 PV-equipped households, and 50 each of unelectrified and PV-equipped public facilities, a survey was conducted to learn their economic conditions, electricity needs, expectations for PV system use, and other needs. The survey was conducted by a local consultant firm. The survey targets were distributed in six out of the eight provinces nationwide. They considered of 81% of CLF areas, 9% of resettlement areas, and 10% of others.

By occupation, the largest portion of the target interviews were farmers, followed by school teachers, the third largest were those in the service industry, typically shops.

Annual income averaged Z$36,000. But, the gap distinct between the unelectrified households (Z$26,000) and the already PV-equipped households (Z$42,000).

Looking at electricity-consuming appliances and fluorescent lights in use, 90% of the surveyed households possessed radios, and 45% had TVs. Even 22% of unelectrified households had TVs running on car batteries. Unelectrified households provided lighting with kerosene lamps and candles. The lighting expenses amounted to Z$60/month for unelectrified households, and Z$120/month for PV-equipped households.

3.4.3 Results of PV-user interview survey on system use

The average capacity of the PV system-equipped households is 40W. Since 1993, where the GEF project started, the number of PV-equipped households has been increasing. Of the PV-equipped households, 78% have black-white TVs. They consume electricity for 3-4 hours a day. About half of the PV-equipped households bought their PV systems for a lump-sum payment, and the remaining half in installments. A PV system was priced at Z$7,000 on average.

In regard to their introduction of PV systems, 90% of the households answered they were satisfied or almost satisfied. Questioned about what effects of the PV introduction, many cited that their entertainment hours increased, homework could be done easier, housekeeping could be done easier, and they became more interested in the outside world than ever.

Questioned about what new and additional electric appliances they hoped to have in the future, many cited refrigerators, TVs, fluorescent tubes, and radio/radio cassettes, among other things.

Direct interview survey conducted by the Study Team with JICA monitoring PV-system equipped households in Kadoma district (both 25 and 56 watt) by the JICA system showed most or 93% of them are satisfied very much with their system including households felt just about (nearly satisfied) due to still small capacity of the system than the families' needs.

3.4.4 Estimation of potential PV demand

Potential demand for PV power generation is gained by estimating how many households could afford PV-system introduction in economic terms.

If a 50W PV system is installed in use, the annual charge for use could be set in three ways, Z$1,400, Z$2,100, and Z$3,400, by varying the assumptions for the system cost and interest.

Given that the lighting expenses in annual income is less than 4%, the currently unelectrified households for which the charge for use stays within 4% of their annual income are taken as potential demand households for income reasons. Then, on the assumption that the distribution of annual income would be a logarithmic normal distribution, the calculation results showed that, as of 1997, those which could afford the charge of Z$1,400 (with an annual income of over Z$35,000) numbered some 300,000 households, and those able to pay Z$2,100 (over Z$52,500 income) about 160,000. Even those able to pay Z$3,400 (over Z$85,000 income) numbered as many as about 70,000 households.

3.5 Economic evaluation

3.5.1 Economics of PV-based electrification vs. grid extension

(1) Estimation of generating cost in Zimbabwe

How much coal-fired power generation cost in Zimbabwe was estimated from ZESA's data. The result was Z$0.23/kWh (Z$10.8/US$).

(2) Estimation of PV system cost in kWh terms

Taking the PV system installed under the JICA pilot project as an example, how much PV-based power generation cost was estimated by assuming the usable life of the PV module at 20 years. On the assumption that a battery and a charge controller would be usable for 2.5 years and 5 years, respectively, the cost could be put at about Z$35/kWh (with annual electricity supply of 22.8kWh).

(3) Cost estimation for grid extension case

The costs were estimated for the cases where a 11kV-grid would be extended to electrify the villages, each distant 5km or 10km from the grid. The grid extension cost was assumed as used by WAPCOS in their study on Zimbabwe rural electrification. The users in a village were assumed to number 50 households, and the transmission line to have a 20-year usable life. If electricity consumption remains the same as in the PV-based electrification case, the electricity supply cost would be some Z$93/kWh for the village 5km distant from the grid, and Z$164/kWh for the 10km-distant village.

(4) PV vs. Grid extension cost comparison in varying household electricity consumption

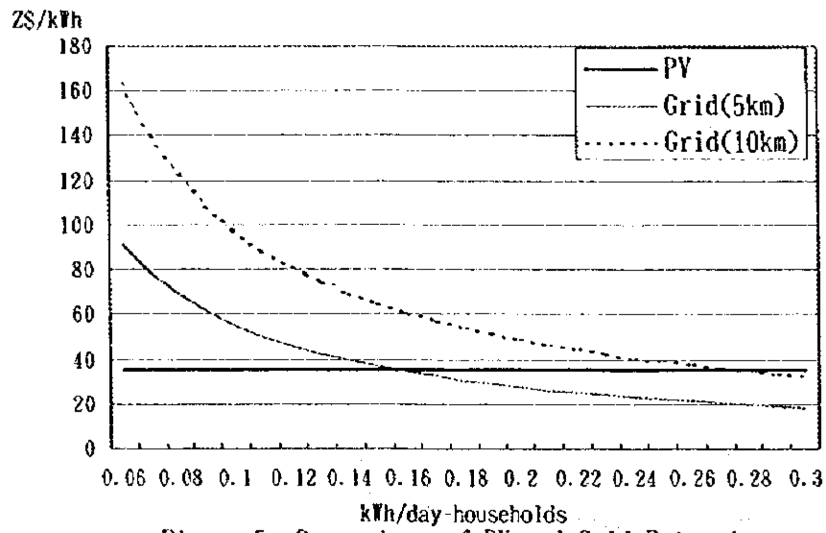


Figure 5 Comparison of PV and Grid Extension

3.5.2 Impact of spreading PV systems on the economy

Assuming that an effect of PV system installation on the economy (GDP change) could be measured as the sum total of an added value of PV system production + an added value of PV system installation works + the avoided grid extension cost by PV installation + the avoided electricity purchase cost by PV installation, and that 3,500 units of 45W PV system were installed in 1997, a 20-year effect (of avoided electricity purchase), calculated with a 10% discount rate, would be as listed below in present values.

Items	Value added (Z$)
Added value of PV system production(40% of sales amount)	14,000,000
Added value of PV system installation 80% of installation cost)	2,240,000
Avoided electricity purchase cost by PV system	135,817
Avoided transmission/distribution equipment cost	21,352,913
Total	37,728,730

Given that Zimbabwe's GDP in 1996 totaled Z$85 billion, the PV-related economic effect amounted to around 0.04% of 1996 GDP.

Also, taking the PV system import value as the cost, and the avoided grid-extension equipment import value and electricity purchase as the benefits, a cost-benefit analysis was made, which put the cost-benefit ratio at 0.66, and IRR at 4.5%. However, it should be noted that a little change in the assumption would change the analysis results sharply.

In the meantime, a PV project can produce a greater effect on the local economy than nationwide. It is expected to increase the employment opportunities in rural areas, raise the sales in shops by improving the atmosphere, and increase efficiency of production thanks to an easier access to information

3.6 Consideration of financing system

3.6.1 Analysis of the loan system under GEF project

The analysis results confirmed the funds flow of low-interest loans funded by the CSF (Credit Support Facility) organized by the AFC (Agricultural Finance Corporation). It also determined the routine for loan application and approval, the establishment of the facility, the down payment requirement and the flow of loan returns.

Usually, with a down payment set at 15%, and an annual interest rate at 15%, a three-year repayment plan is provided. A qualification for this repayment plan is a monthly income fivefold or more than the repayment amount. Those who used the loan system numbered some 4,200 at 1997 year end.

3.6.2 PV-promotion approach through non-AFC organizations

By getting ZESA and NGOs involved, efforts were made to spread the PV system use beyond sales through AFC. Initial funds required were provided by GEF to the organizations, which install PV systems for the users they develop, then collect the costs from the users in installments. These organizations are considered closer to the potential users in unelectrified rural villages than general PV system installation firms. ZESA plans to install 500 systems, and the NGOs an additional 160 systems.

3.6.3 Consideration of how to utilize subsidies

An objective of the GEF project is to control the cost of installments by establishing a Fund to provide low-interest loans. Yet, to allow a longer term of repayment can also be an option to lower the amount of installments. A three-year repayment at a 15% interest and a five-year repayment at the same 35% interest as the market rate prove to be almost identical in terms of the amount of monthly payment. The majority of Zimbabwe users seem to prefer a smaller amount of monthly payment, even if it involves a longer term of payment.

Also, subsidies, if granted directly to cover part of the system purchase, instead of paying a fixed rate of interest, could lower the monthly payment made by the users.

For example, a case is assumed that 9,000 units of 45W system, priced at US$1,000 each, would be purchased in the first year and repaid in three years. With the market rate assumed at 35%, and a grant to pay a fixed rate of interest at 15%, the differential in the grant-in-aid for paying interest is estimated. Then, the outcome is compared with a case where the same amount as the grant-in-aid for paying interest is offered to subsidize the system purchase. In case of the grant-in-aid for paying interest, the monthly payment amounts to $36. If the same amount of the grant-in-aid for paying interest is available for buying a PV system, the monthly payment would be lowered to $28 even when the market rate is applied.

Table 1 compares the grant-in-aid for paying interest and the case where the initial purchase cost is directly subsidized.

Table 1 Comparison of Replenishment to Interest and Subsidy to Initial Cost

(1,000US$)

Case		0	1	2	3	Total	Monthly payment (US$)
Bank rate	Loan	9,000					
	Principal		2,157	2,912	3,931		
	Interest	(35%)	3,150	2,395	1,376		
	Total		5,307	5,307	5,307	15,921	49
Replenishment to interest	Loan	9,000					
	Principal		2,592	2,981	3,428		
	Interest	(15%)	1,350	961	514		
	Total		3,942	3,942	3,942	11,825	36
	Balance					4,096	
Subsidy to initial cost	Loan	4,904					
	Principal		1,175	1,587	2,142		
	Interest	(35%)	1,717	1,305	750		
	Total		2,892	2,892	2,892	8,676	27

3.6.4 Improvement of credit access for PV-related firms

While low-interest loans for the users are provided by the CSF, PV-related firms, largely small and medium-sized, have difficulty getting loans from commercial banks. They need a fund-raising method which involves low interests, a longer term of loan repayment, and more generous collateral terms.

In order to make PV-related firms accessible to credits, it is required to establish a credit guarantee fund, to allow assets-based lending (including movable property), and to permit suppliers' credit grants, among others.

3.6.5 Fund-raising for PV-based rural electrification projects experienced by other developing countries

PV-based rural electrification projects in the Dominican Republic, Mexico, Sri Lanka, Indonesia, the Philippines, Tuvalu, Kiribati, Kenya and Zimbabwe were compared in various terms, including credit grants, financial conditions, taxation, and the factors behind their success and failure were analyzed.

The successful cases are characteristic in the point that subsidies were poured directly into the initial investments, with none spent in funding the management. Also, an ability to collect fees from users is a matter of crucial importance.

4. Basic policy of PV-based rural electrification programs

4.1 Selection of electrification approach

The approaches to prompt rural electrification include PV system sales and electricity supply service, the latter featuring that PV systems are owned by electricity suppliers and that the users consume electricity produced by the leased PV systems and simply pay the charge for use. The two approaches have both merits and demerits of their own. Yet, given following factors, among others,

(1) possibility to spread PV systems among the middle- and low-income classes,

(2) improvement of system reliability by maintenance & inspection rendered by local technicians, and

(3) involvement of public or semi-public organizations with solid management foundations, which allows the stable maintenance/management of the supply system for the long run,

the use of an electricity supply service format is recommended as the most desirable approach for PV-based rural electrification.

4.2 Managing organizations and their composition

4.2.1 Managing organizations

By examining the requirements for an electricity supply organization responsible for the management of PV-based rural electrification, existing candidates in Zimbabwe were compared. The results is that the formation of ZESA-Solar, a subsidiary of ZESA, is recommended.

Table 2 shows the requirements and candidate organizations compared.

Table 2 Characteristics of Candidate Organizations for ESCO

Functions	ZESA Solar	Rural District Councils	NGOs	Coopera tives	New private organiza tions	Existing governm ent organiza tions
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	○	△	△	×	○	△

(Note) ○ : Good, △ : Fair, × : Poor

4.2.2 Composition of the organization

Instead of inviting random geographic participation, this project accepts no less than 50-100 households as PV system users within the districts where a local engineer can visit once a month for maintenance service. With the 50-100 users as a unit, a local management office is formed in the area where 10-20 user units can be developed. The local management office is staffed with senior engineers, who supervise the local engineers, while being responsible for the collection and management of the charge for system use (including the. maintenance service charge) as well as inventory control of supplies. Furthermore, once a few local management offices are formed within a province, a district management center is established in an effort to increase efficiency through broad-area management.

A National Management Center (NMC) is formed as the central organization, responsible for coordination with ZESA, negotiations with the government, financial management, system design, specification and procurement of parts and training of staff, among others.

Table 3 shows the roles of individual elements which make up the electricity supply service system. Fig. 6 presents the relations among the elements.

Table 3 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 damages of the system.
User committee	Members of the committee are nominated from users.	To feed back an activity of field technicians to ESCO. To arbitrate some troubles such as cancellation of contract.
Field technicians	To reside in the same area as PV system users to be served.	To offer system maintenance. To instruct users how to properly use the system. To collect maintenance charges and replace parts, if necessary. To tap new users within the area in charge
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 conditions of system installation works
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, refilling of local technicians, provide 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 of claim handling, inventory management of supplies & 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 system 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.

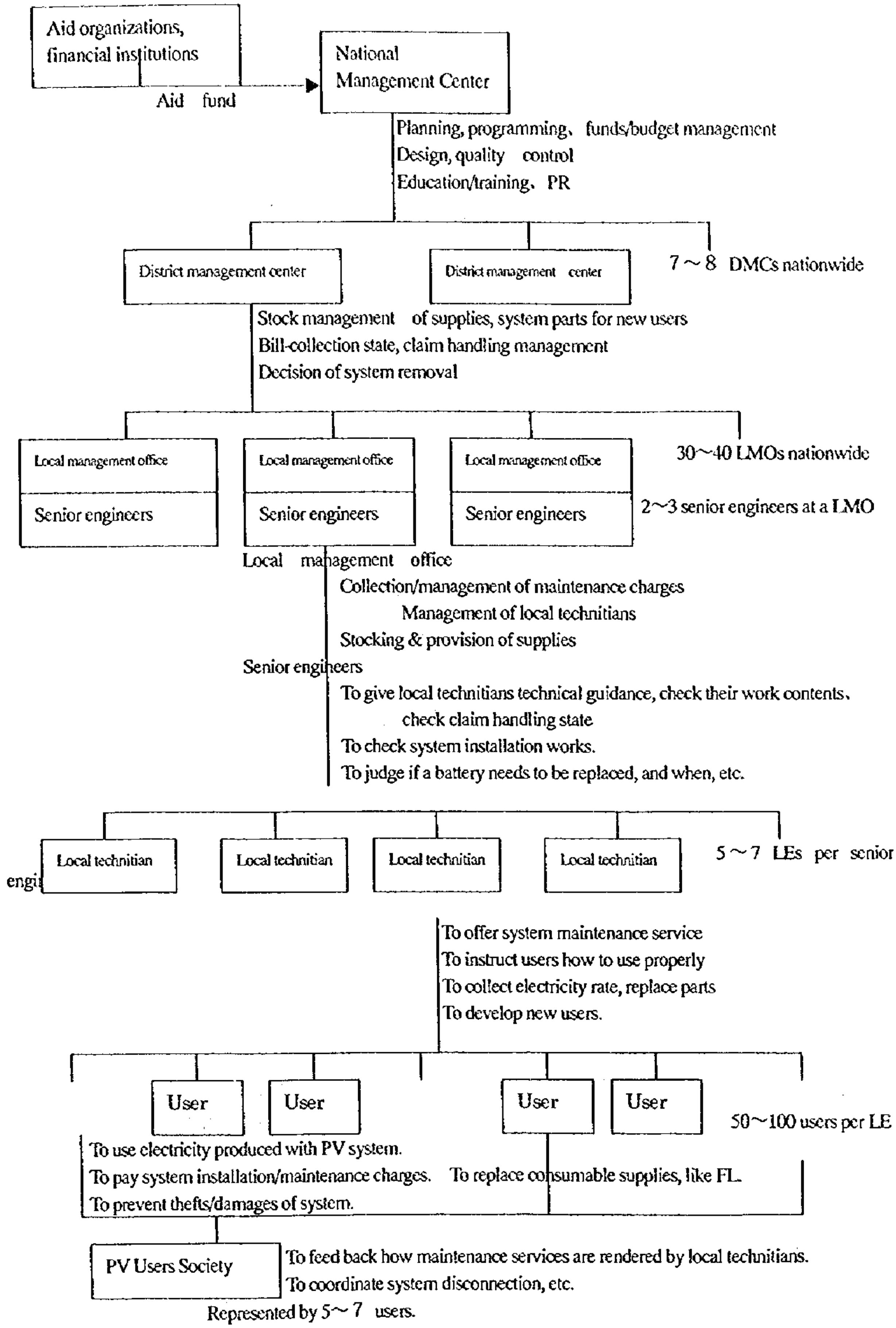


Fig. 6 A Simulated Organizational Chart of ZESA-Solar

4.3 System design

Based on the pilot project and village survey results, the PV system for households requires an average capacity of 50W. PV systems of around 25W and 75W are also prepared as the standard size of systems.

By publishing the specifications of the parts which make up the systems, local part suppliers can prepare for their participation in the project. Specifications of the standard systems are shown in Table 4.

Table 4 Standard PV Systems

Items	PV systems		
System size	25W-class	50W-class	75W-class
PV module	25W	50W	75W
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 illumination	5.41kWh/m^2/day	5.41kWh/m^2/day	5.41kWh/m^2/day
Design no-sunshine days	3 days	3 days	3 days
No. of days to recharge 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	

4.4 Targets of PV-based electrification and electrification goals

In Zimbabwe, the number of unelectrified households currently reaches 1.5 million in rural areas. From now on, the extension of transmission & distribution lines is expected to make electricity available for some 10,000 households in ten years. Yet, as the rural population is projected to grow more than 3%/year, the number of unelectrified households is sure to increase further.

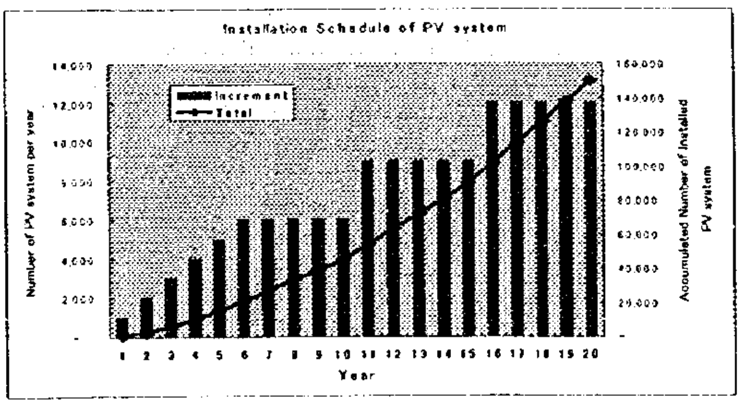
Of the unelectrified households, how many could buy an electricity supply service was estimated from the rural village survey results. If an annual payment remains at around Z$1,500, some 200,000 households can buy the service right now. Even for an annual payment of around Z$3,000, there are 50,000 households which can be subject to PV-based electrification.

By setting the annual charge for use below Z$1,500, this project was prepared to get a total of 150,000 households electrified, including 15,000 in the first phase and an additional 135,000 in the second phase. Depending on actual progress in the first phase, the goal in the second phase can be revised.

Table 5 PV System Installation Plans

Phase 1	Year	1	2	3	4	5
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	6 to 10	11 to 15	16 to 20	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



Procedure of establishment of required offices for PV electrification will be expected as Figure 7. Required number of staff as shown in Table 6, ZESA-Solar, responsible for the project management, will need to be staffed with an estimated 1,000 staff who cover the 150,000 households.

Table 6 Expected Staffing Requirements (Last fiscal year of every 5 years)

Fiscal year	1st～5th	6th～10th	11th～15th	16th～20th
Managers	2	4	6	8
Senior engineers	25	46	71	89
Office clerks	15	30	45	54
Drivers	14	28	42	51
Workers	12	24	36	43
Field technicians	150	375	600	750
Total	218	507	800	995

Figure-7 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.	同左 + Karoi, Mhangura, Gokwe, Mkwasine, Chiredzi, Rutenga, Beitbridge, Gwanda, Filabusi, Esigodini, Plumtree, Turk mine, Victoria falls, etc.

5. Master plan for the implementation of PV-based rural electrification

5.1 Action program for implementation

To implement PV-based rural electrification programs efficiently requires, not only PV system installation and control/management by ZESA-Solar, but positive cooperation among various organizations and agencies involved in PV power generation. In specific terms, such cooperation can be organized for the aid programs listed below. Namely, they include quality improvement of PV system parts, the establishment of a technical center, the acquisition of measuring instruments to check PV-system functions, acquirement of measuring technologies, the introduction of standards and a certificate system, and the establishment of technical training centers for maintenance staff.

The actions to be taken by individual agencies and organizations are listed in Table 7, "A List of Actions for PV-based Rural Electrification." The actions are also outlined in Figure 8. Figure 9 shows the work schedule for rural electrification plan.

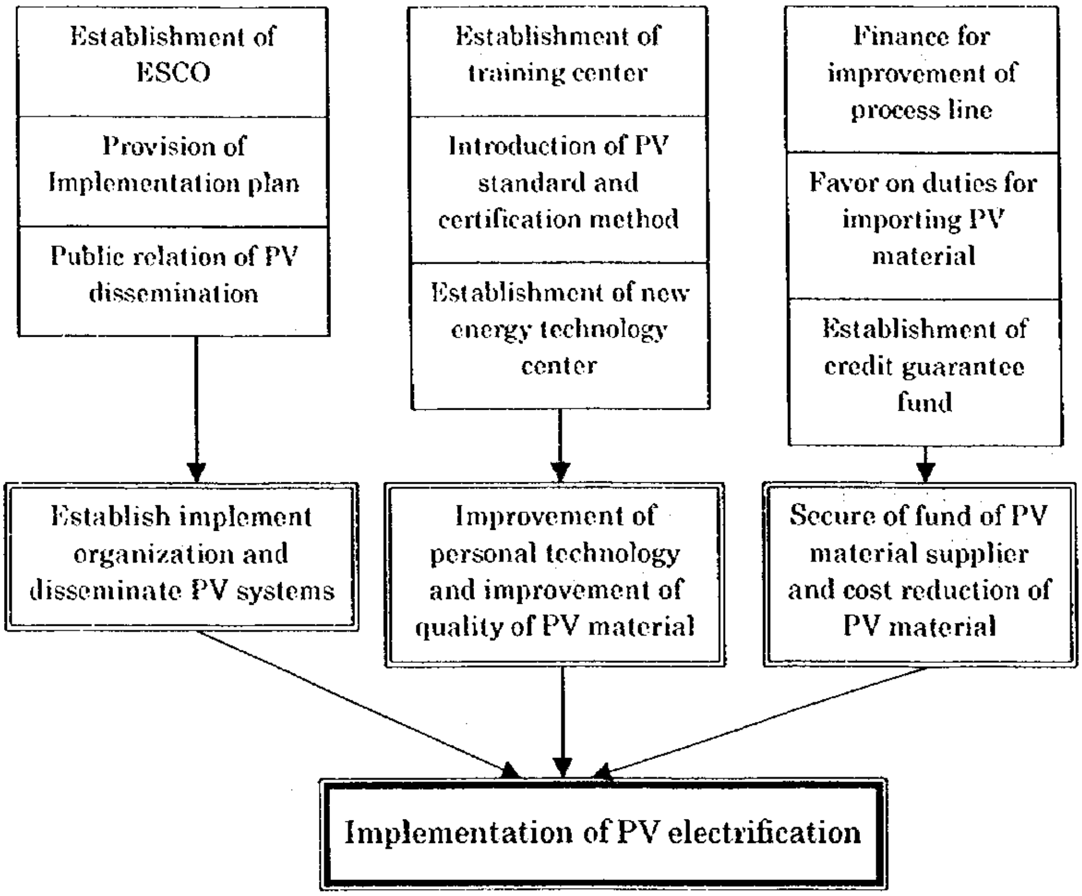


Figure 8 Supporting Program for PV Electrification

Table 7 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 Company (ESCO). (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 US$10.8 million Phase 2 US$97.2 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 parts 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 of Rural District Councils

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

Section	Items	Executive Organization	Work schedule							Investment costs(1,000US$)							Note
		Fiscal Year	1	2	3	4	5	6	7	1	2	3	4	5	6	7	
Government	Policy making Setting number of PV system installation Examination of ESCO system Establishment of ZESA-SOLAR	DOE, ZESA	■														
	Making implementation plan in 1st phase by ZESA-SOLAR Study of PV demand Site selection of 1st phase Making detaild plan and financing	DOE, ZESA, ZESA-SOLAR	■	■													
	PV installation(1st phase)	ZESA-SOLAR			■	■	■	■	■			720	1,440	2,160	2,880	3,600	US$720／system No. of System First year 1,000 2 2,000 3 3,000 4 4,000 5 5,000
Private	Establishment of PV installation and supply systems To supply PV components PV module Introduction of imported PV module in 1st phase	SEIAZ MEMBER			■	■	■	■	■								
	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 Encouragement of training course in KwekwePolytech Training of field technicians and installers Number of training Field technician 50 persons/year Senior engineer 7 persons/year installer 10 persons/year	ZESA, SEIAZ, MOE(Education)	■	■	■	■	■	■	■	50	50	50	50	50	50	50	Model house, Actinometer
	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 Making poster for PV system Advatising PV system using TV and radio	DOE, ZESA, SEIAZ, ARDC		■	■	■	■	■	■								
PV Business Organizatios	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.	SAZ, SEIAZ	■	■	■	■	■	■	■								
	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	■	■	■	■	■	■	■								

5.2 Funding plan and cash flow

5.2.1 Sketch of PV system

As illustrated below, the PV system to be installed consists of a PV module, a charge controller, a battery a fluorescent lamp, and a outlet (for radio or TV).

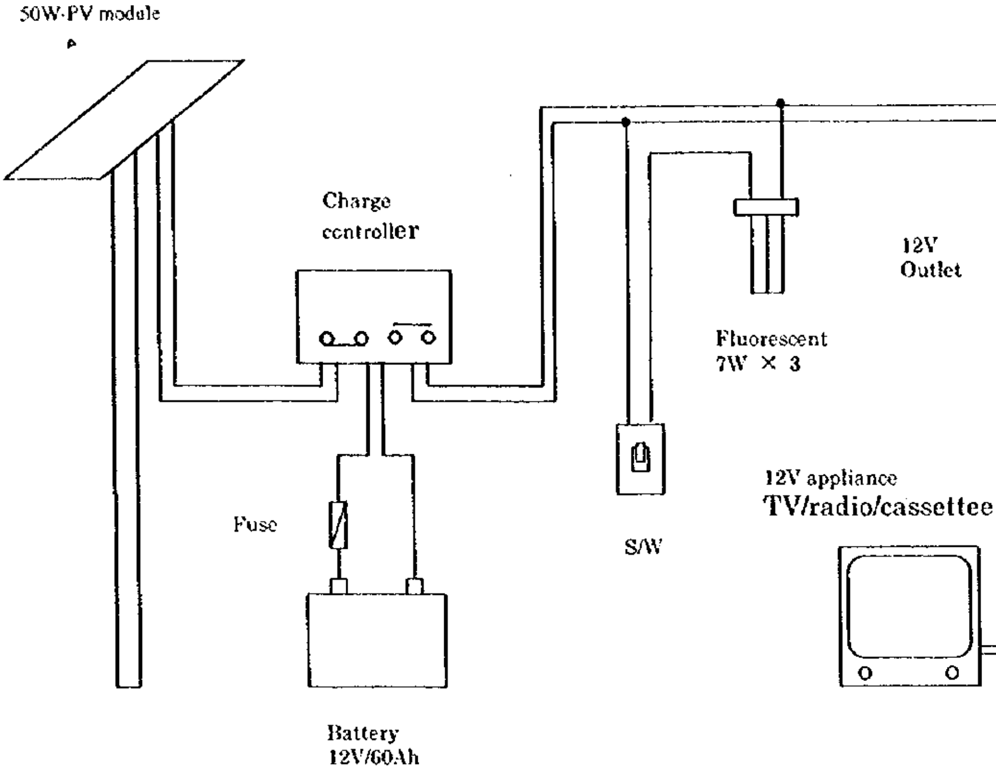


Figure 10 General Household User PV System

5.2.2 Unit costs of PV-system parts and personnel expenses

In order to determine how much investment would be required, the unit costs of individual parts of the PV system were set at the prices procurable in Zimbabwe. (Though in 1997 prices, they are expressed in the US dollars in order to minimize the impact of exchange rates.) Of the personnel expenses, those for local engineers are based on actual records, and the others in terms of estimated unit cost.

Table 8 Unit Costs and Usable Lives of System Components

Parts	Cost per system (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	Tubes are 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		

Table 9 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 non-labor expenses (administrative overhead) incurred in local management offices, etc. are appropriated as follows: local management offices - an equivalent amount to the total sum of the personnel expenses; district management center – 1.5 times of the total sum of the personnel expenses; National management center – twofold of the total sum of the personnel expenses.

5.2.3 Case setting and charges for use

The fees which must be borne by the users are calculated by setting different cases with different fund-raising methods and different project scales (in terms of the number of PV-equipped households).

Table 10 shows different fund-raising methods and alternative cases for Phases 1 and 2. Why the alternative cases were prepared are depicted as well.

Table 11 shows the types of funds raised in the different cases, the amounts to be raised, and the terms of calculation. Their calculation results are also shown.

The calculation results show that, if funded wholly with internal funds , the fee to be paid by the users amounts to some US$150/year in Phase 1 (15,000 households) alone, and about US$120/year if entering Phase 2 (150,000 households). Thus, if advantageous fund-raising, typically grant funds and low-interest loans, are available, the users' financial burdens could be lowered further. Namely, if 82% of the initial investment of 6,000 systems in Phase 1 is covered with grant funds, the charge for use could be lowered to about US$125. Moreover, if the project advances to Phase 2, and 80% of its investment is covered with special loans, the charge for use could further be reduced to a low US$87 so that even the low-income class can participate in the electrification project.

Table 10 Objectives of Case Setting

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. (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 11 Breakdowns of Required Funds, Terms for Cash Flow Calculations and Calculation Results

	Case A	Case B	Case C	Case D
Owned funds (US$ Mil.)	10.80	7.26	108.00	35.34
Grant aid	0	3.54	0	3.54
Low-interest loans	0	0	0	69.12
Required funds total	10.80	10.80	108.00	108.00
Term of calculation(years)	24	24	39	39
Initial installation cost US$	150	150	150	150
Annual payment US$	154	125	124	87

Low-interest loans: The terms of loans are a 1% interest rate, 10-year grace period, and 20-year term of repayment.

5.2.4 Considerations

(1) Cases A～D (Figures 11～14) are attached as the examples of cash flow. It is designed that an internal return rate of 10% against the owned funds can be gained throughout the term of calculation. But, as illustrated in the graph, spending outruns revenues during the initial stage of the project, which means operating funds need to be raised from outside. Given that massive equipment investment funds are required during the initial stage, to get grant aid and use long-unredeemed special loans is almost required.

(2) Sensitivity analyses were made on Case (Table 12, Figure 16). Taking the initial investment cost, personnel expenses and the ratio of grant funds as the variables, to what extent the annual user fee would have to deviate from the base case is analyzed.

Table 12 Sensitivity Analysis (Case B)

annual user fee(US$/year)

Rate of change ( ) is the ratio of grant funds.	20%UP (70%)	10%UP (80%)	Base case (90%)	10%down (100%)	20% down	Sensitivity
PV system cost	141.0	135.5	126.0	118.5	111.0	0.75
Personnel expenses	140.0	133.0	126.0	119.0	112.0	0.70
Ratio of grant funds	133.0	129.5	126.0	123.0		0.33

Sensitivity (US$/%) represents to what extent the amount of annual payment (US$) should change as a result of a 1% change in relevant variables.

In Case B, the system cost produces the greatest effect, and a 1% change in the system cost causes the annual charge to fluctuate by about US$0.75.

(3) Lifetime cost

Taking the case assuming the implementation of Phase 1 alone (Case A) and another case assuming the implementation of Phase 2 as well (Case D) as examples, the costs incurring throughout the term of the project were aggregated as present values with a 10% discount rate, then compared (Table 13).

Case A with 15,000 systems installed during Phase 1 and Case D where 150,000 systems are installed through Phase 2 result in different shares held by the system-related and personnel expenses-related costs in the lifelong cost. When the number of installed systems is limited, the personnel expenses and administrative cost occupy a larger share. Thus, it is desirable to install as many systems as possible.

Table 13 Comparison of Lifelong Costs

	Case A (15,000 systems installed)			Case D (150,000 systems installed)	
	Money amount (US$1,000)	Share (%)		Money amount (US$1,000)	Share (%)
Initial investment	8,437	45.3	Initial investment	38,664	50.8
Equipment replacement cost	2,618	14.0	Equipment replacement cost	11,998	15.7
Personnel expenses	3,540	19.0	Personnel expenses	9,405	12.3
Expenses, administrative cost	4,040	21.7	Expenses, administrative cost	10,474	13.7
Loan repayment			Loan repayment	5,752	7.5
Total	18,635		Total	76,293	

The figures for loan repayment include interests

5.3 Recommendations

(1) Examined given feasibility, Case B is most recommended. Namely, it is recommended to initiate Phase 1 of the rural electrification program by getting US$3.54 million as a grant to cover 82% of the equipment cost of 6,000 systems (=6,000x720x0.82).

(2) The charge for use can be set on the assumption that the remaining 9,000 systems would be installed with internal funds, while the introduction of low cost loan funds must be taken into account as well.

(3) Preparation for Phase 2 should be advanced during the implementation of Phase 1 by developing as many users as possible, so that independent management of ZESA-Solar can be allowed.

5.4 Conclusion

In order to successfully promote rural electrification using solar PV systems, the Zimbabwe Government needs to do the following as soon as possible.

(1) The government needs to establish the target number of households for PV based rural electrification and to nominates ZESA as the implementation organization.

(2) ZESA needs to determine the specific installation area for PV based rural electrification within the areas proposed by this report and to prepare a year by year implementation plan which includes the annual finance requirements for the project. Using this plan, the Government will need to begin arranging for the necessary finance as soon as possible.

(3) The Government needs to aggressively work with local PV industry and support organizations in order to bring them to the level of capability needed to support the PV rural electrification project.

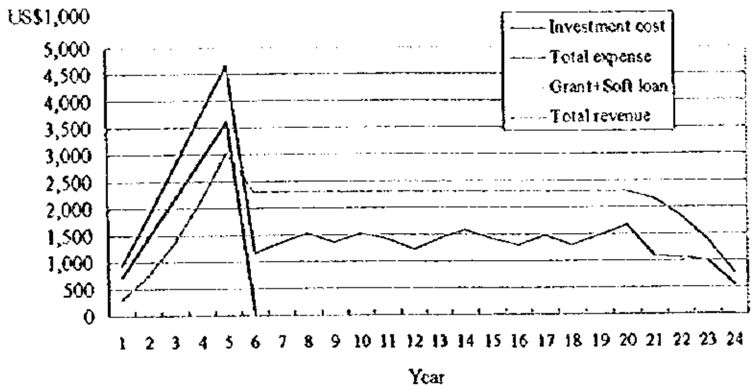


Figure 11 Cash Flow of Case A

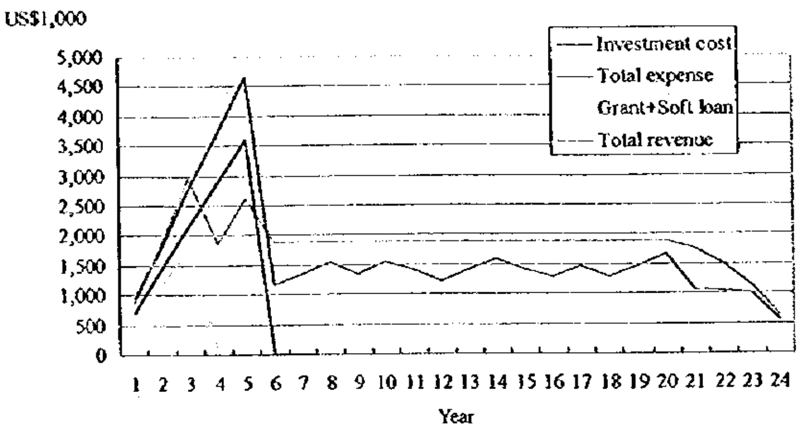


Figure 12 Cash Flow of Case B

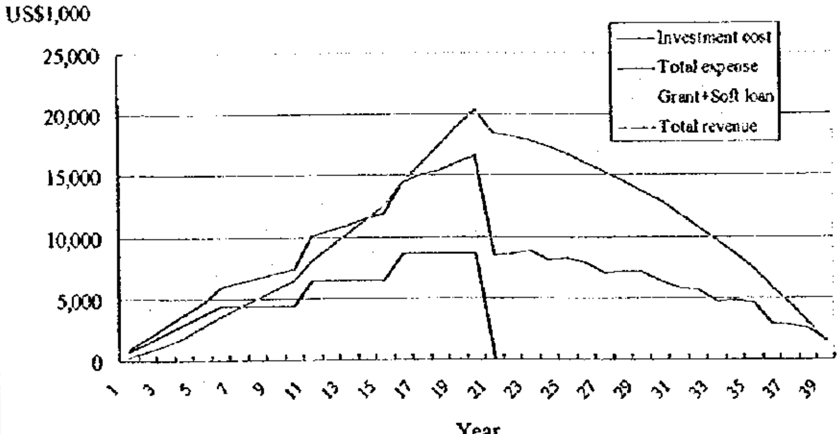


Figure 13 Cash Flow of Case C

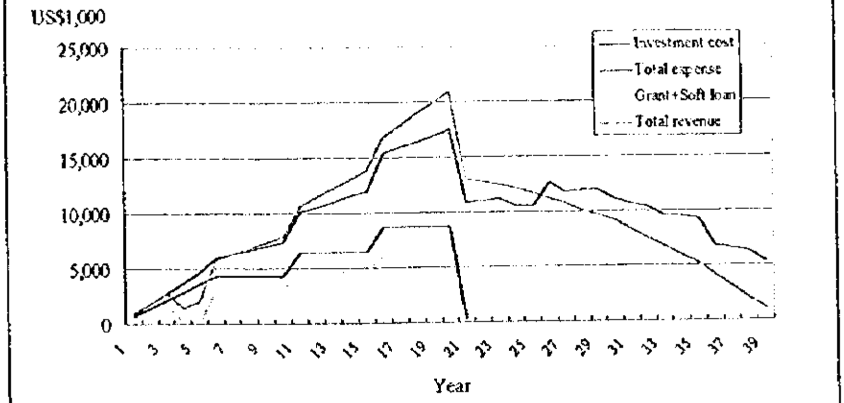


Figure 14 Cash Flow of Case D

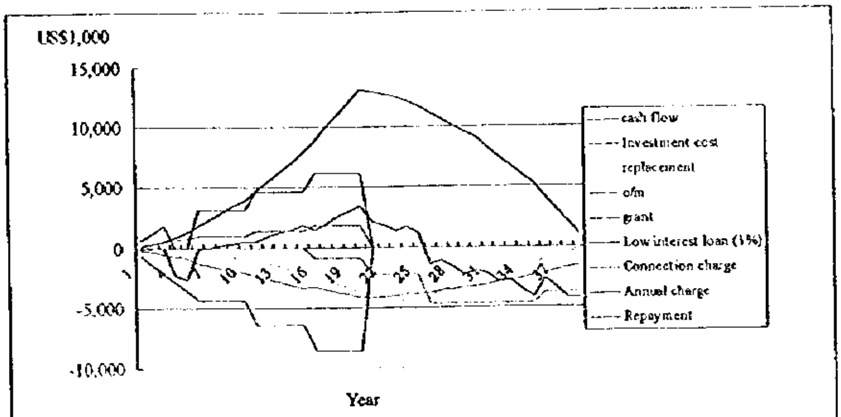


Figure 15 Income and Expenditure (Case D)

UNIT:US$

	Factor	20%up(70%)	10% up(80%	Base(90%)	10%down(100%	20%down(110%	Sensitive
Case B	PV&Batte	100.1	98.0	92.0	88.5	85.0	0.38
	Wage	106.0	99.0	92.0	85.5	79.0	0.68
	Grant	106.0	99.0	92.0	85.5	79.0	0.68

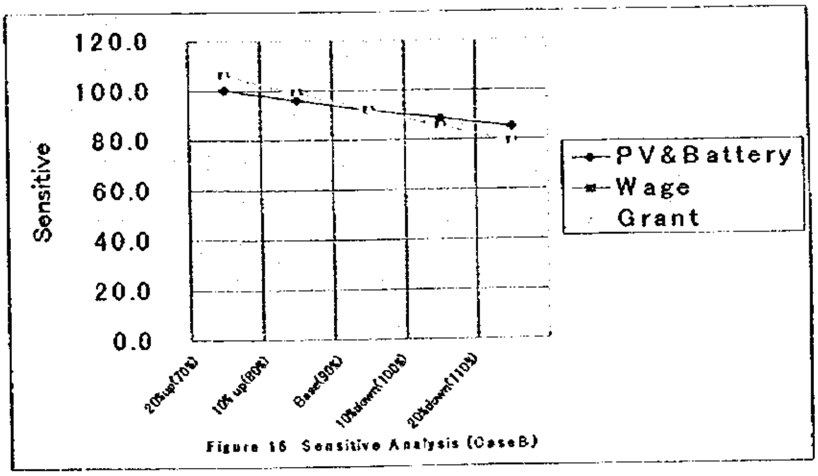


Figure 16 Sensitive Analysis (CaseB)

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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