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

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

Final Report

Main Report

MARCH 1999

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

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

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

Final Report

Main Report

MARCH 1999

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

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.

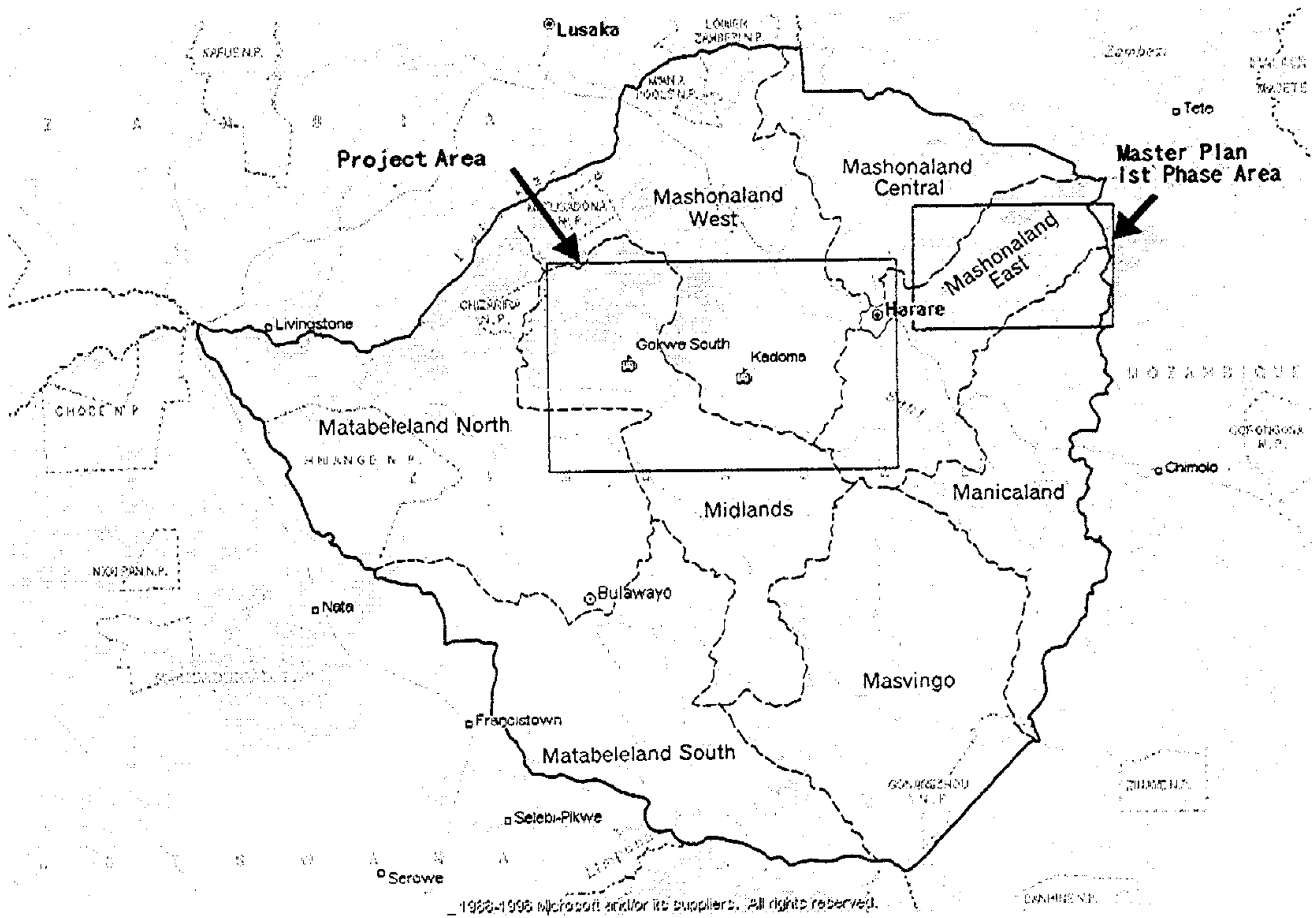
This report presents the rural electrification master plan of utilizing photovoltaics system.
The master plan suggests the electrification of 150 thousands households in 20 years, considering the number of un-electrified rural household and their economic situation. The total investment is expected as 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.

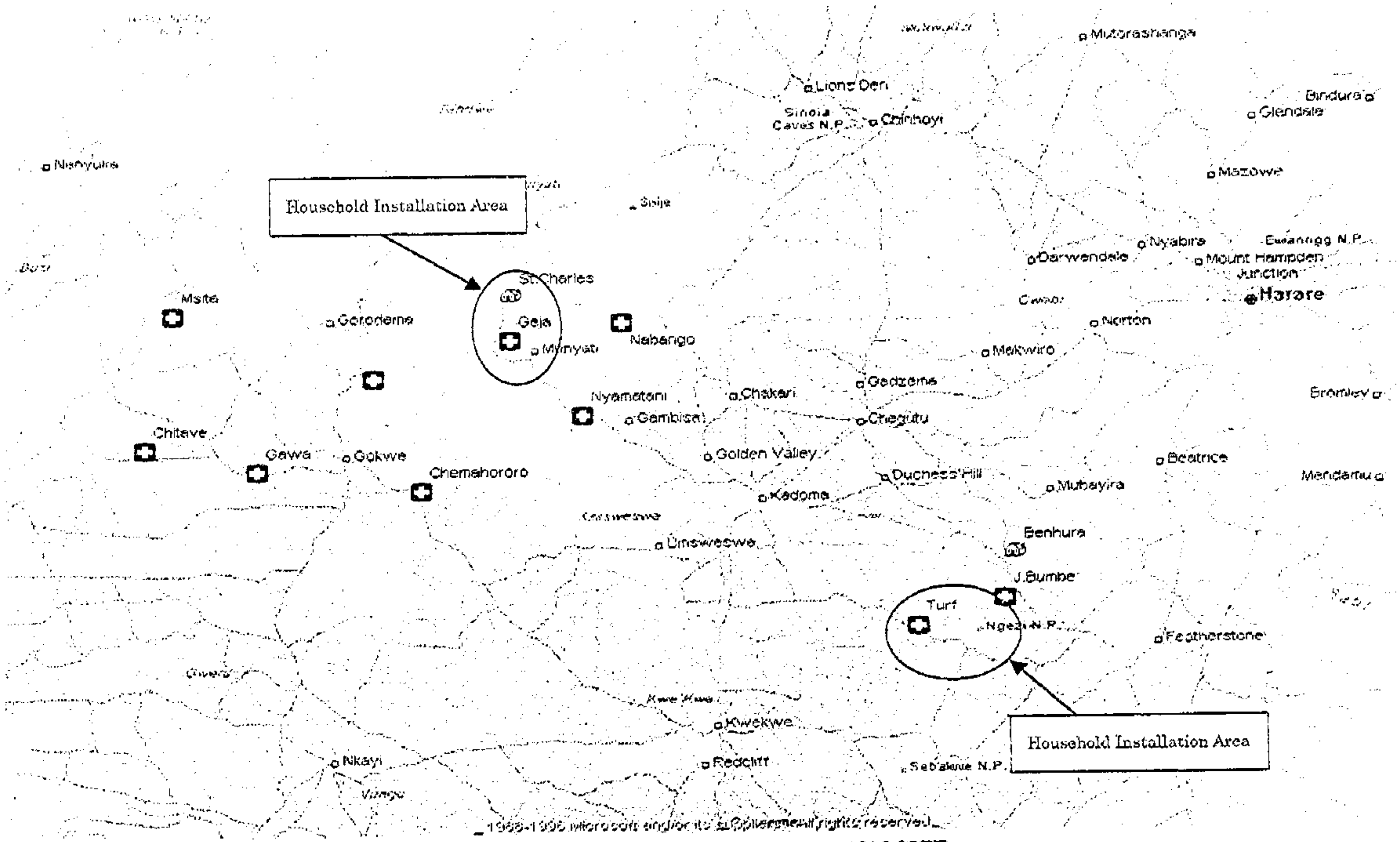
We wish to take this opportunity to express our sincere gratitude to your Agency, the Ministry of Foreign Affairs and Ministry of International Trade and Industry. We also wish to express our deepest gratitude to DOE and the authoritative government agencies concerned of the Republic of Zimbabwe for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

Very Truly yours,

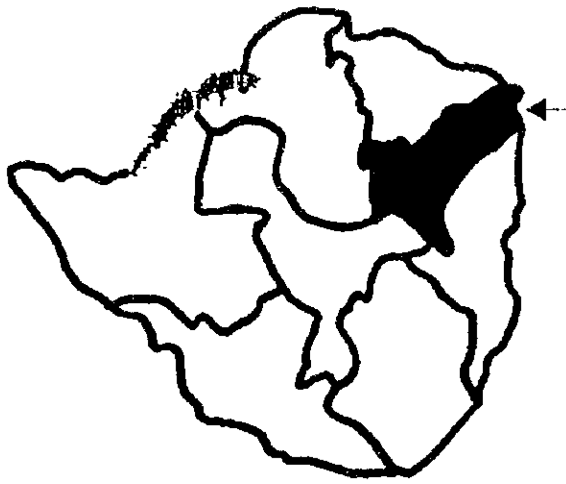
Takayuki Tani
Team Leader
The Study on the Promotion of
Photovoltaic Rural Electrification
In the Republic of Zimbabwe



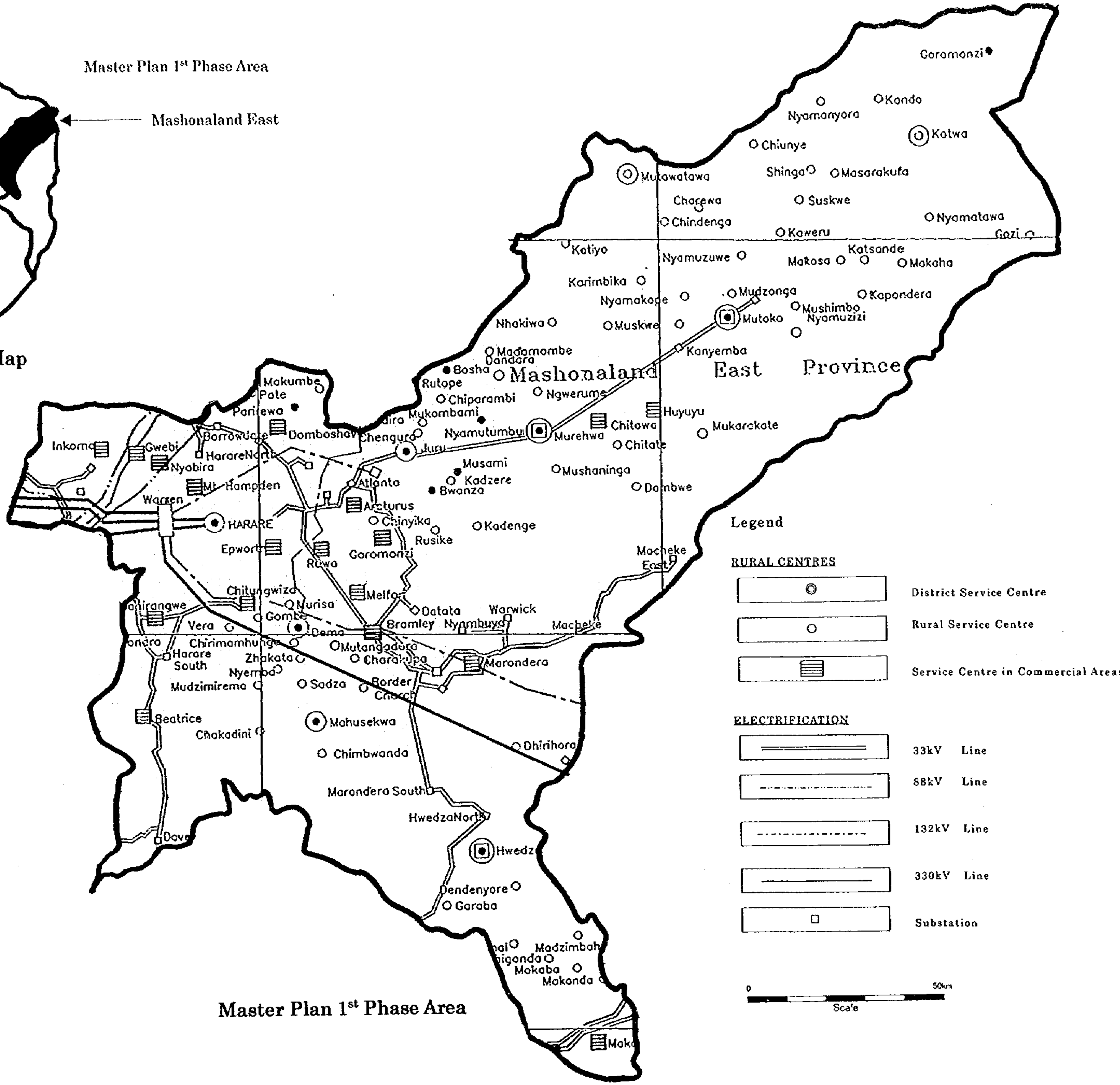
JICA PILOT PROJECT INSTALLATION AREA



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

In The Republic of Zimbabwe

Draft Final Report

Table of Contents

Tables

Figures

Photos

1

INTRODUCTION

1.1 Country Profile

1.1.1 Conditions and Population of Zimbabwe

The Republic of Zimbabwe is a land-locked country lying in the southern part of the African continent. Its northernmost tip is located at 15 degrees south latitude while its southernmost tip is located 22 degrees south. Surrounded by Mozambique, Zambia, Botswana, and South Africa, Zimbabwe's total land area is 390,000 square kilometers, extending 725 km from west to east and 835 km from north to south.

The country's highest point is about 2,600 meters above sea level, while its lowest is 300. Major rivers include the Limpopo and Zambezi, the latter being the main source for the Kariba Dam which is used for power generation and irrigation. There are many rolling plains and the Victoria Falls in the northwestern part of the country is one of the most famous natural landmarks.

The climate is generally mild, although there are four seasons in a year. November to April is considered the rainy season, while May to October are the dry months. The two "transition" periods between the dry and rainy seasons are equivalent to spring and autumn, and are generally regarded as the most comfortable in the year as temperature hovers between 20 and 30 degrees Celsius.

The amount of rainfall differs from area to area, but the national average is about 400 mm. For so-called wet areas, i.e., places that generally receive more rain than typical for the country, the average is about 800 to 1000 mm, while in dry areas (mainly in the south), it is about 200 mm. Savanna forests can be found in the highlands, but a large portion of these areas are used for farming. In the "medium highlands," similar conditions exist, although there is less natural diversity because there is generally less rainfall. In the lowlands it is dry due to the higher temperatures and limited amount of rainfall. About 13% of the country's land area is devoted to national parks where many kinds of animals like lions, cheetahs, and elephants thrive.

According to the last census held in 1992, the total population of the Republic of Zimbabwe was 10,410,000. Of this figure, residents in the urban areas totaled around 2,830,000 or 27.2%, while residents of rural areas totaled around 7,580,000 or 72.8%. According to the same census, the total number of families was about 2,160,000, with 760,000 living in the urban areas and the remaining 1,400,000 residing in the rural areas. The national average size of each household for the same year was 4.8. For urban areas, the average was slightly lower at 4.2, while it was higher for rural areas at 5.8. Regarding the physical characteristics of local households, about 40% were traditional indigenous buildings made with brick walls and thatch roofs. About 39% were western style structures, similar to the European, American, and Japanese stand alone type of housing.

1.1.2 Industry and Economy of Zimbabwe

In 1996, Real GDP (1990 prices) reached Z$76.2 billion. Per capita GDP was Z$7,187, while the inflation rate was pegged at 21%. The local manufacturing sector (which ranks second to South Africa in the African continent in terms of size) accounted for 16% of GDP for the same period. Agriculture and tourism are also important industries.

Zimbabwe is generally self-sufficient in terms of food supply (although there have been severe droughts in the past that have threatened food security). It exports mineral products like gold, nickel, asbestos, as well as agricultural products like tobacco, cotton, sugar, and beef.

Deforestation is becoming a serious problem with most households using firewood as their primary energy source. Biomass consumption is rather high, accounting for about half of the national energy use figure. Coal is abundant and is therefore also a major source of energy, while petroleum products have to be imported.

Land is classified into two categories – commercial farmlands (owned by private individuals) and communal lands (owned by the government). The farmlands total some 2,500 hectares (or 40% of the total land area) and the soil is generally rich. These lands provide employment for many farmers, and also house some manufacturing and processing factories. Communal lands also occupy about

40% of the total land area, but generally receive less rainfall and is not as productive. Most of these lands are densely populated.

The present government has in place a policy for resettling landless farmers and the urban poor to so-called resettlement farms carved from communal land. To ensure that these farms provide a stable source of livelihood for their occupants, government provides further assistance by helping prepare the soil for farming and lending support to agricultural cooperatives. Major products include maize (the country's staple food), tobacco, cotton, sorghum, groundnuts, coffee, tea, sugarcane, wheat, lemon, and even cut-flowers that are exported to Europe.

In most of the farmlands, there are very limited opportunities for salaried jobs (that provide regular income). Most income is thus derived from agriculture, which is of course seasonal (usually once or twice a year). To address this situation, the Government has been promoting the development of agricultural product processing industries as a means of augmenting the farmers' low incomes and providing a source of livelihood during the off-season.

Zimbabwe has a fairly good road network, with major cities and towns connected by paved roads. In the rural areas, however, many roads have yet to be developed which leads to major problems during the rainy season by delaying the transport of basic goods and the delivery of agricultural products.

The national railway system is about 3,400 km in total length, while domestic air routes cater mainly to the tourism industry. The nearest port is Beira in Mozambique, which is connected by road, railroad and pipeline to Mutare, one of Zimbabwe's major cities.

Water supply in urban areas is sourced from dams, while in rural areas, it generally comes from independent wells. The communication system is not fully developed.

1.1.3 Overall Power Situation in Zimbabwe

(1) Demand

Based on the 1996 Annual Report of the Zimbabwe Electricity Supply Authority (ZESA) and data collected by the Study Team during the study, there are currently about 340,000 domestic power connections throughout Zimbabwe, representing a household electrification rate of slightly over 30%.

In 1992, the overall rate of electrification of urban areas reached about 72%, in contrast to less than 5% in rural areas. In terms of households alone, urban areas posted a 65% electrification rate, while rural areas registered 3.5%. Such figures indicate a strong need for electrification of the country's rural areas.

The following Table 1-1 shows the breakdown of power consumption in 1995/6, with industry accounting for more than one-third of the total, followed by the mining and residential sectors.

Table 1-1 Breakdown of Power Consumption (1995-96)

	Number of Consumers	Power Consumption (GWh)	Ratio	Average Power Consumption (kWh/day)
Ordinary household	338,931	1,734	18.6	14.0
Agriculture	10,094	690	7.4	187.4
Commerce	36,061	1,386	14.8	105.2
Industry	1,836	3,952	42.3	5,897.2
Mining	671	1,579	16.9	6,447.1
Total	387,593	9,341		66.0

Electricity demand estimates released by ZESA are based on three scenarios for Zimbabwe's economic growth, namely: high growth case (GDP growth of 6.5% per year), base case (GDP growth of 4.5% per year) and low growth case (GDP growth of 2.5% per year). The resulting peak demand (MW) and electric power demand (GWh) projections for the period 1996-2013 are shown in Figures 1-1 and 1-2.

Using the base case, both peak and electric power demand in 2013 will be around twice the 1995 level, growing from 1,617MW to 3,200MW and from 10,100 GWh to 19,500 GWh, respectively.

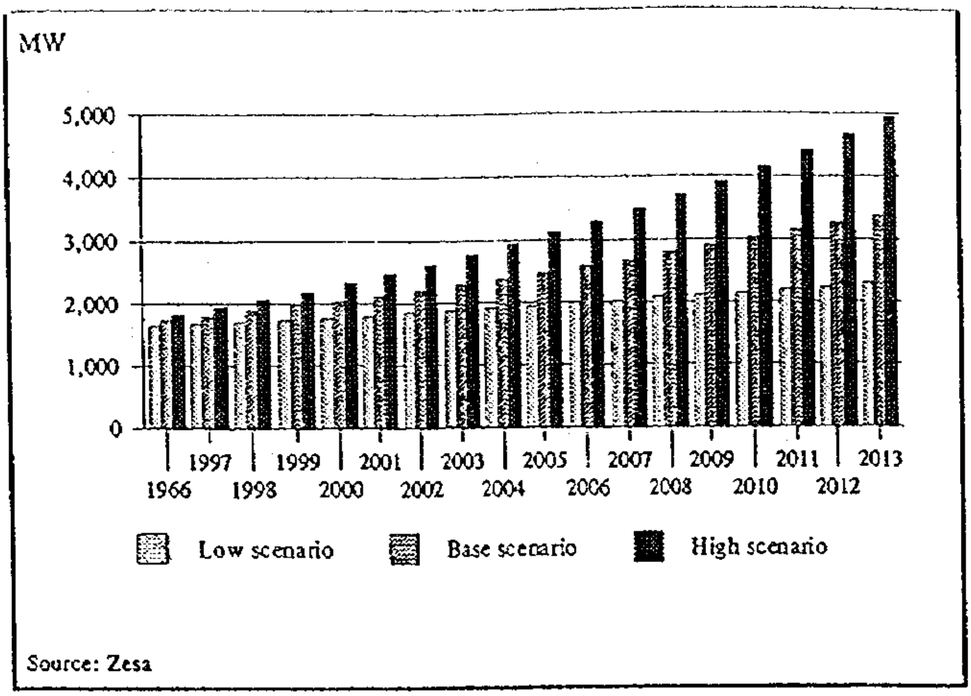


Fig. 1-1 Peak Demand Forecast

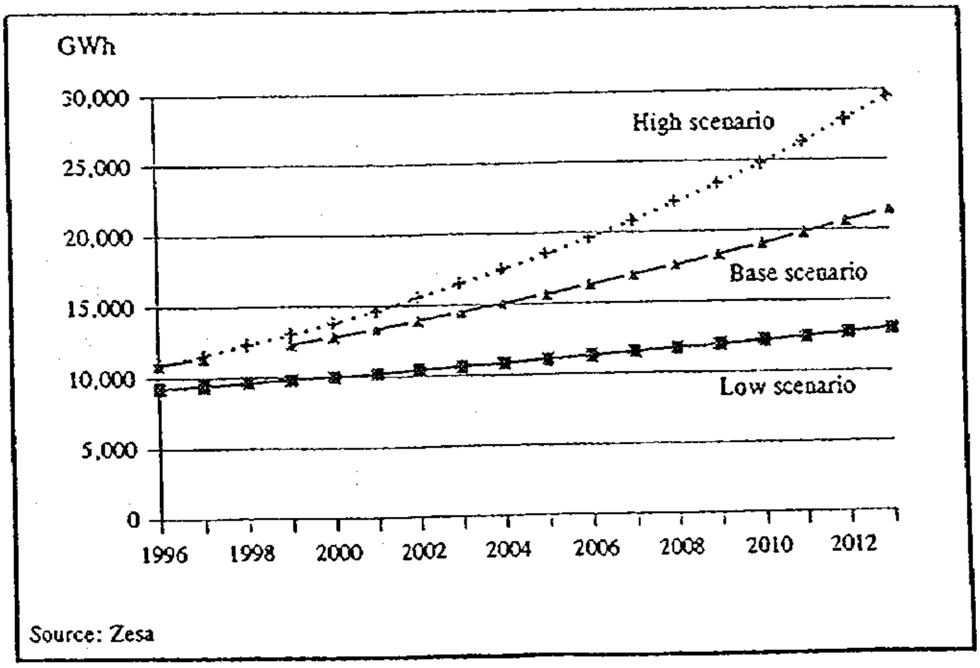


Fig. 1-2 Electric Power Demand Forecast

(2) Electric supply

Fig 1-3 shows existing power plants, transmission lines and power distribution areas in Zimbabwe, while Table 1-2 shows power generation capacities of power plants and total power supplied in 1996. Table 1-3, meanwhile, shows the total length of existing transmission and distribution power lines throughout the country.

In addition to the electric power imported from Zambia and Zaire, Zimbabwe has forged contracts with South Africa, Botswana, and Mozambique for the purchase of additional electricity.

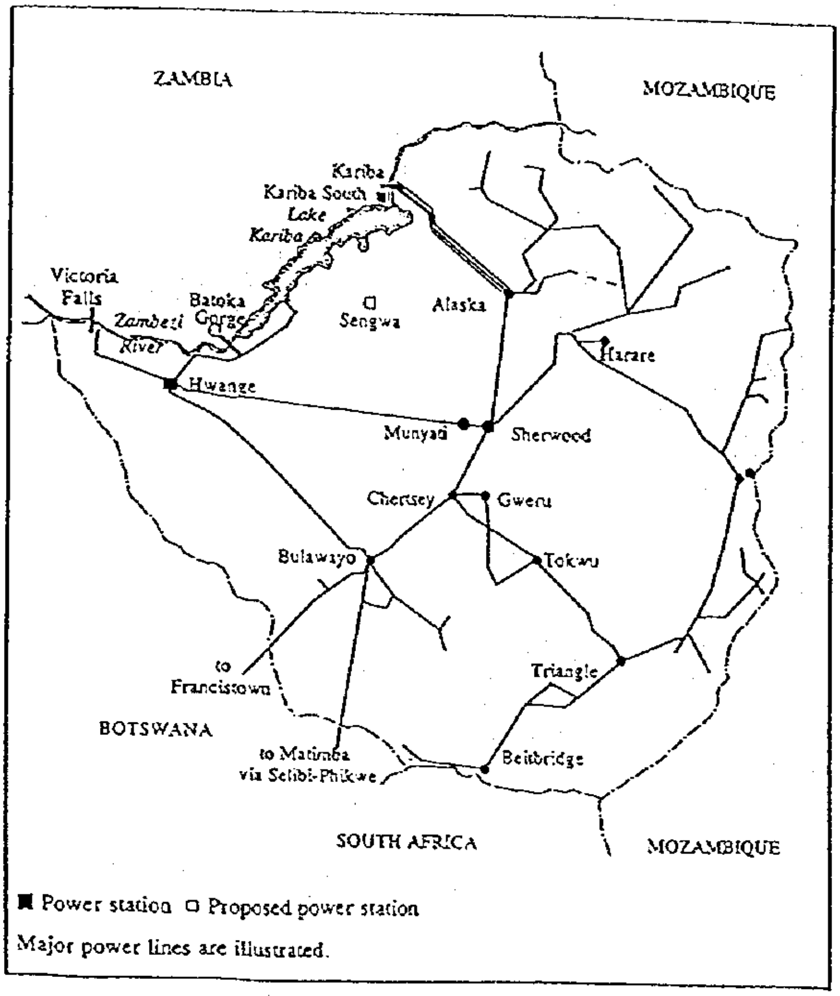


Fig 1-3. Map Showing ZESA Development in Zimbabwe (as at 30 June 1995)

Table 1-2 Capacity of Power Plants and Power Supplied (1995-96)

Power Plant	Capacity (MW)	Power Supplied	Modification Plan
Hwange Thermal	920	4,634.8	
Kariba Hydropower	666	2,163.1	750 MW upgrading
Old thermal stations	375	525.3	120 MW refurbishment
Imported Power (from Zambia/Zaire)	(300)	3,172.0	
Total	1961 + 300	10,495.2	

Table 1-3 Existing Transmission/Distribution Lines

Transmission Lines		Distribution Lines	
Voltage (kV)	Installation Distance (km)	Voltage (kV)	Installation Distance (km)
330	3,500	33	8,200
132	1,280	11	31,000
88	2,150	0.38	12,400
66	185		

Note: 330KV transmission line includes partly 420kV and 220kV of international system.

(3) Incremental plan for electric supply

The following table 1-4 shows capacity additions being planned by ZESA and their planned commencement dates:

Table 1-4 Ongoing ZESA Power Projects (1995-2011)

Project Name	Supply Capacity (MW)	Starting year
Songo-Bindura 330 kV Interconnector (Mozambique)	500	1997
Kariba South Upgrade	84	1998
Hwange Thermal Power No. 7	330	2000
Hwange Thermal Power No. 8	330	2003
Batoka Hydropower Plant (Zimbabwe section)	800	2004
Kariba South Extension - 1st Unit	150	2006
Kariba South Extension – 2nd Unit	150	2008
Senga Coal-fired Power Station – 1st Unit	330	2009
Senga Coal-fired Power Station – 2nd Unit	330	2011

To fund these projects, a total of about US$2,630 million (1995 prices) is needed for the construction of power plants, while US$1,410 million is needed for additional transmission/distribution lines and substations, bringing the total to around US$4,000 million.

To raise these massive capital requirements, the Zimbabwe government established the Zimbabwe Investment Center (ZIC) in 1992 to accelerate foreign investments by creating a more conducive investment environment. The participation of independent power producers (IPPs) is specifically being encouraged through the Southern African Power Pool (SAPP) in which private companies not only from Zimbabwe but also from surrounding countries are pooled.

The following table lists SAPP member countries and their respective national power supply companies, while Figure 2-4 shows the transmission line network in Southern Africa.

Table 1-5 SAPP Member Countries & National Power Supply Companies

Country	National Power Supply Company
Angola	Empresa Nacional de Electricidade (ENE)
Botswana	Botswana Power Corporation (BPC)
Lesotho	Lesotho Electricity Corporation (LEC)
Malawi	Electricity Supply Commission of Malawi (ESCOM)
Mozambique	Electricidade de Mozambique (EDM)
Namibia	South West African Water and Electricity Corporation (SWAWEK) (Nampower)
South Africa	Electricity Supply Commission (ESKOM)
Swaziland	Swaziland Electricity Board (SEB)
Tanzania	Tanzania Electric Supply Company (TENESCO)
Zaire	Society Nationale d'Electricite (SNEL)
Zambia	Zambia Electricity Supply Corporation Ltd. (ZESCO)
Zimbabwe	Zimbabwe Electricity Supply Authority (ZESA)

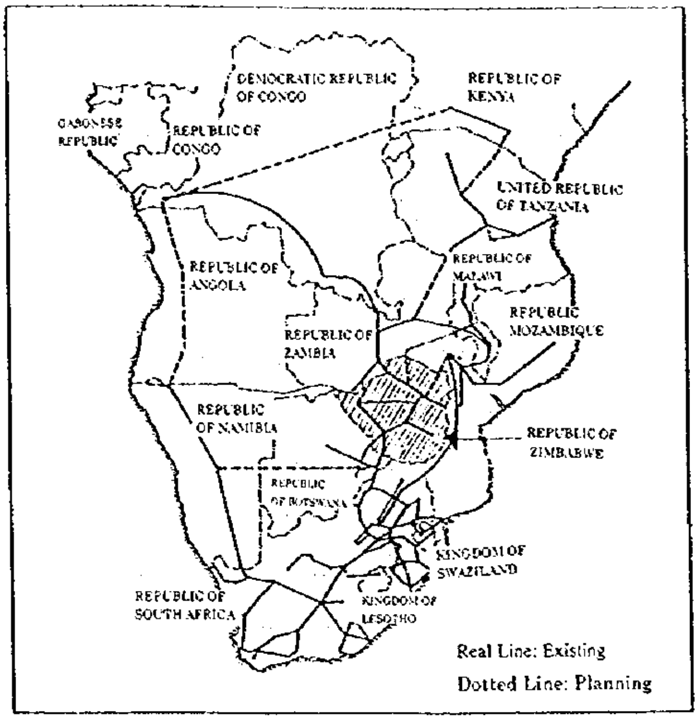


Fig. 1-4 Transmission Line Network in Southern Africa

1.1.4 Rural Electrification in Zimbabwe

(1) National wide electrification in Zimbabwe

The rate of household electrification nationwide is 28%. For urban areas alone, this figure is 72%, while for rural areas, it is less than 4%.

Table 1-6 Electrification by State in Zimbabwe

Province		Household	Electrified(%)		Un-electrified(%)	
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	86.50	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	64.40	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

The combined number of hospitals and clinics throughout the country as of 1995 was 1,378, with clinics totaling 926. Further broken down, the latter figure consisted of 370 government clinics, 451 council clinics, and 105 municipal clinics. Nationwide, the number of the unelectrified clinics was 591 at the end of 1995, broken down by province in the following:

Among these provinces, the GEF project has been promoted PV electrification for the last three years mainly at Manicaland Province, located in the eastern part of the country and at the Mashonaland East Province in the northeastern part of the country. The Swedish Government, meanwhile, has carried out PV electrification in rural areas at Mashonaland Central Province in the north. The last three provinces listed in the table above, namely Matabeleland North, Matabeleland South, and Masvingo, are not being considered since they are located very far away from Harare.

(2) Rural electrification plan in Zimbabwe

Historically, rural electrification in Zimbabwe has mainly supplied electric power to commercial farms, with the needs of communal land inhabitants left practically unattended, resulting in little, if any, economic growth in these areas. With government currently engaged in efforts to lessen the gap between living standards of commercial and communal land farm inhabitants and to control the rapid increase in population in urban areas, rural electrification has been identified as a priority policy measure.

Until the 1980's rural electrification was mainly carried out by the Electricity Supply Commission. It was able to reach a total of 36 rural centers (RCs) through the extension of transmission lines. At that time, however, power consumption per RC was less than 100kW and an average number of connected households in each one was only about 10. The results of this rural electrification effort, therefore, did little to improve the electrification of households.

In 1989, the Zimbabwe government requested a consultant to review the national rural electrification plan (REP) and come up with new measures for a more effective promotion of rural electrification in the country. The main recommendation of this review was that DOE should undertake a rural electrification master plan study with funding from the African Development Bank (AfDB) and conduct a feasibility study on rural electrification using the Water and Power Consultancy Services (WAPCOS) of India acting as consultant and with ZESA as counterpart.

The WAPCOS report proposed electrification through the extension of transmission and distribution lines (33kV, 11kV) to unelectrified districts, ruling out independent power supply sources such as diesel generation and renewable energy. This programme does not include the electrification of rural households.

Table 1-7 DSC & RSC Services in Zimbabwe

	District Service Centre	Rural Service Centre
Government Offices	Council offices District administrator Veterinary Services Agritex offices Ministry of Transport Agricultural demonstrator Social welfare Ministry of Water	Veterinary services, Agritex offices Agricultural demonstrator Rural hospital/clinic Ministry of Water
Area Serviced	Whole district	A few wards within a district
Type of Shops	Large supermarkets Department stores Butcher shops Grinding mills General dealer shops Carpentry and shoemaking shops District council market Beerhalls and bottle stores	Butcher shops Grinding mills General dealer shops Carpentry and shoemaking shops Bottlestores
	Total number of shops: >20	Total number of shops: 10-20

Table 1-8 Rate of Electrification of DSCs & RSCs Per Province

Province Name	Electrified		Unelectrified		Rate of Electrification (%)	
	DSC	RSC	DSC	RSC	DSC	RSC
Mashonaland West	5	3	1	69	83.3	4.2
Mashonaland Central	7	17	0	30	100.0	36.2
Mashonaland East	8	16	1	66	88.9	19.5
Manicaland	4	26	3	53	57.1	32.9
Masvingo	6	22	1	76	85.7	22.4
Midlands	7	25	1	44	87.5	36.2
Matabeleland South	4	14	2	34	66.7	29.2
Matabelelando North	7	6	0	32	100.0	15.8
Total	48	129	9	404	84.2	23.8

(Sources) Referred to materials of WAPCOS & DOE

Based on WAPCOS's feasibility study results, ZESA planned a grid-based electrification project for the aforesaid 413 unelectrified service centers by FY2006 under a total of 172 schemes. The electrification project will be under way in two phases and cost Z$460 million in total. During Phase 1, scheduled from FY1997 to FY2001 (Zimbabwe's fiscal year is July through June), 200 service centers will be electrified under a total of 94 schemes. How many service centers are electrified under a single scheme greatly varies, partly because an electrification method allowing cost minimization is to be selected. Phase 2, slated from FY2002 to FY2007, consists of 70 schemes to electrify 213 service centers. Once this project is over, electrification of all the service centers in Zimbabwe will be completed. No additional projects to electrify distant areas from these "service centers" are presently being considered.

A "service center" is defined as an area clustered with shops, public facilities, and other than household structures. It is the shops and public facilities in such a center, as well as the general households in its immediate vicinity, that will be covered with this project designed to electrify rural service centers. Yet, the exact number of shops, facilities and households to be electrified can hardly be estimated. This is because different service centers contain different numbers of shops and facilities, and because electrification of general households will be limited to those which can afford the cost of electrification by themselves. Usually, a service center contains about ten shops and facilities and, in its vicinity, an estimated 5-10 households which can afford electrification. Accordingly, an estimated 10,000 or fewer households are expected to be electrified by 2007 under this project.

Of Z$460-million funds required for this rural electrification project, Z$254 million will be covered by the Rural Electrification Fund (REF) raised by ZESA by putting a 1% premium on its electricity rates. Z$204 million-worth procurements from overseas will be financed by the government by raising funds abroad. The REF, introduced in 1994, has amounted to Z$81 million to date.

Table 1-9 Electrification Plan by Province (1997/8 – 2006/7)

Province	Number of Schemes	Number of Electrification	Investment Cost(Z$)
Mashonaland West	21	70	75,839,824
Mashonaland Central	14	30	35,206,954
Mashonaland East	31	67	66,380,467
Manicaland	29	57	73,583,074
Masvingo	28	77	80,635,226
Midlands	19	45	54,476,821
Matabeleland South	16	36	39,048,441
Matabelelando North	14	32	38,519,764
Total	172	413	463,690,571

(Source) DOE

Table1-10 Electrification Plan by Year

Year	# of Scheme	# of Electrification	Investment cost (Z$)
1997/8	28	46	38,392,408
1998/9	23	37	31,402,996
1999/0	9	17	34,678,930
2000/1	14	40	48,291,403
2001/2	20	60	59,171,869
2002/3	16	51	64,056,015
2003/4	29	68	67,490,047
2004/5	13	41	50,566,522
2005/6	11	32	45,941,377
2006/7	9	21	23,699,004
Total	172	413	463,690,571

(Source) DOE

1.2 Developments of PV Electrification in Zimbabwe

1.2.1 The Current Situation of PV Electrification in Zimbabwe

Zimbabwe receives as much as 2000kWh/m² a year. Clearly, it can be said that Zimbabwe is a country rich in solar energy. Historically the country is eager to use solar energy such as through the utilization of PV systems. In 1993, the UNDP/GEF project started in Zimbabwe with the purpose of the project being to install 9,000 individual PV systems (assuming each system would have 45Wp of panel capacity). In 1996, the World Solar Summit was held in Harare and the summit adopted a declaration on "Sustainable development of Solar energy". "The Zimbabwe Solar programme 1996-2005" was created in line with the World declaration and the programme included plans to install PV water pumping systems, PV systems for public use, min-grid PV systems and individual PV systems for households.

1.2.2 PV related enterprises and Finance System

Within the previously mentioned GEF/UNDP project about 50 companies that were accredited as competent to install household PV systems. All of them were members of the local PV industry association called SEIAZ (Solar Energy Industry Association of Zimbabwe). In order to become a SEIAZ member, a company has to meet specific technical and financial standards.

Of the 50 UNDP/GEF accredited companies, about 15 actively installed systems under the GEF project, while 5 have been manufacturing or importing PV components. The following table lists these 5 companies and their respective products.

Table 1-11 PV Component Manufacturers/Importers in Zimbabwe

Name of Company	PV Components
Battery World	Charge controllers, automobile batteries, deep-cycle batteries
Sollatek	Charge controllers, fluorescent lamp components, fluorescent lamps, voltage droppers
Solarex	Charge controllers
Sollacom	Fluorescent lamp components, PV panels
Impact Solar System	Fluorescent lamp components, PV panels

To serve the interests of end-users, the GEF Project Management Unit (PMU) set standard prices for PV system components for the local market. Installers were allowed to include a gross profit of 30% or less on this standard price, with the actual price to the purchaser on certain factors such as distance to the installation area, size and number of systems to be installed, and so on. For credit purchases, potential PV system users presented price quotations made by installing companies when they applied for loans. Installers must purchase the PV systems and complete the installation before receiving the money from the loan proceeds. This means that the installation companies must have sufficient working capital to purchase the systems and install them before being paid. This is a considerable burden for the installers who are mostly small enterprises.

1.2.3 Quality Control of PV system components in Zimbabwe

For the JICA pilot project, the team purchased PV system and related parts from local suppliers in Zimbabwe for evaluation and test. In the evaluation process, the team found a number of problems which need to be resolved before future large scale PV electrification can succeed. The details are covered in Chapter 3and 4.

(1) PV system components.

The PV components that the JICA team purchased in Zimbabwe are the PV module, charge/discharge controller, battery, voltage reducer and fluorescent lamp. Included in the project were a charge/discharge controller and fluorescent lamp of Japanese design which were assembled on trial in Zimbabwe by the JICA team.

1) PV module

The modules purchased included 25Wp Anit (Italy) and 83Wp Solarex (USA) panels purchased through the PMU. These modules were both manufactured in industrialized countries and met international test standards. These foreign modules were imported by GEF and sold to the JICA project since GEF had the right to import them duty-free. The imported modules were only visually checked with quality reliance based on the international test certification. Local checks would have been impossible in Zimbabwe because of the lack of the expensive equipment necessary to properly test panels. The JICA study team checked samples of the delivered panels to generally confirm the specifications and characteristic curves for voltage and current using portable measurement equipment. Using these simplified tests, There were no discrepancies noted between the manufacturer's test results and the characteristics observed by the JICA team.

2) Charge Controller

Charge controllers purchased initially were from a local manufacturer. A number of problems were observed. The set points were not accurately set to the specification provided by JICA, there was poor quality control in the assembly of the units with plastic shavings and other debris left inside the controllers which could cause problems with the relay contacts which were exposed in the unit and the power demand was too high for the small PV systems being installed.

3) Fluorescent equipment and light

Fluorescent lights made by a relatively large Zimbabwe company were purchased and checked. They were found to be satisfactory as were fluorescent light imported from the USA and European

4) Battery

In a PV system, the quality of the Battery largely determines the quality of the whole system. Due to the very high cost of imported solar batteries (such as used by the GEF project) the JICA team adopted locally manufactured batteries to try in the pilot project and purchased the approximately 100 Batteries from a local manufacturer. Unfortunately, the quality control of the local batteries was found to be inadequate with major manufacturing errors, such as mislabeling of terminal polarity and by some batteries having one type of cell cap while others have a different type. Further, the manufacturer could not supply the needed technical characteristics of the batteries supplied.

(2) System installation

The installation operation in the JICA Pilot Project relied on local companies which had been certified by the GEF project. The installation operation for the household use PV systems relied on two local companies and the installation for public use PV systems relied on a third local company. After the installation operation was finished, the JICA team checked their operation by inspecting the materials and tools for their work and the overall quality of the installation. In general, the quality of their work did not satisfy the JICA team. Problems included irregular angles of panel installation, mounting poles were not consistently vertical and some house walls were damaged by the use of the wrong tools when holes were made for the mounting poles.

(3) Delivery time of the parts

The JICA Study Team met with significant problems due to suppliers who did not meet delivery schedules. This resulted in significant project delay, added cost and inconvenience for users who experienced several visits of installers in order to complete the systems and increased cost of installation due to installers having to visit sites several times to complete the installation. For example, in the case of batteries, the supplier was unable to meet a delivery schedule at all consistent with the installation schedule despite initial promises of being able to do so. Therefore initially many installations had to use a temporary batteries. When the delivery of the proper deep discharge batteries was made several months later, the installation crews had to return to the sites, remove the temporary battery and install the proper battery.

2

SURVEY SCHEME OF JICA PROJECT

2.1 Outline of GEF Project in Zimbabwe

2.1.1 Activities of UNDP/GEF Project in Zimbabwe

The UNDP/GEF project that purposed to install 9,000 PV systems in Zimbabwe commenced to install the PV systems in 1993 and operated for five years. The project finished in 1997. In October 1997, the project was evaluated by consultants contracted by the UNDP/GEF project and the report on the project was submitted. In February 1998, the annual report for the project was published by the PMU. According to the report, 9800 PV systems (a system was defined as equivalent to one with a 45Wp panel and included solar lanterns and DIY kits) were supplied to Zimbabwe by the project. The features of this project as quoted from the report are summarized below:

(1) Main objective of the project

The main objective of the UNDP/GEF project was to promote rural electrification using PV, thereby uplifting the living standards of the Zimbabwe's rural population, and at the same time, addressing the problem of global warming.

(2) The objectives of the project

- Establish a low-interest loan system for end-users and raise public consciousness about PV;
- Promote rural electrification based on PV system through co-operation of other organizations including ZESA, NGOs, local district councils and cooperatives.
- Raise the technical capability of PV system technicians in local PV companies;
- Increase interest in unelectrified households in PV systems.
- Establish industry standards and raise technical capabilities of local PV companies;
- Install a total of 9,000 systems (equivalent to 45Wp each) in rural areas;

(3) Project Output

- Expansion of the solar home system market;
- Growth and development of a secondary industry involved in the production and assembly of PV parts;
- Increase in the number of employees engaged in PV installation, maintenance, repair, and parts sales;
- Increase activities of PV system installation approaches other than GEF and promote activities of other rural area development plans.

(4) The activities of the project as of December 1997

(Information from GEF · PMU 1997 annual report).

- As of December 1997, a total of 8,500 PV systems (45Wp equivalent systems calculated by dividing the total number of panel Watts installed under the project by 45), were stated to have been installed under the project. Other organizations are carrying out installation work under the UNDP/GEF Project. These include the national electric utility (ZESA), NGOs and CBOs. ZESA was scheduled to install 500 systems, BUN 60 systems and ORAP 100 systems. The project claim also included the JICA project as 200 systems.
- The organization to manage the project's loan scheme is the Agricultural Finance Corporation (AFC), which makes credit available to rural households and communities at lower than commercial interest rates. The number of the AFC credit users under GEF are 4,200 and the total amount of the loans made under GEF is Z$31,000,000.
- The project, through its Project Management Unit (PMU), has certified a total of 50 companies as PV system installers. These companies employ 500 persons. GEF provided them with technical training.
- As part of the project's public information campaign, two workshops were held, and the project's results have likewise been displayed in a number of trade fairs and shows.
- Raised local producing capability of PV system related parts, including PV panels, controllers, batteries and fluorescent lights. The project assisted marketing the products and PV systems such as solar lanterns and DIY kits.

- The Solar Energy Industry Association of Zimbabwe (SEIAZ) and the Standards Association of Zimbabwe (SAZ) are preparing standards for installation and specification of PV systems and components. A testing laboratory for PV systems and components is to be established for Zimbabwe by the cooperation of Denmark.

2.1.2 Evaluation of GEF Project by JICA Study Team

(1) Contributed to improve and promote technologies of PV system

- The project proved that thousands of PV systems could be installed in un-electrified rural areas of Zimbabwe in a relatively short time and that the PV systems were very effective for the dwellers.
- PV manufacturing and support companies benefited by training, increased sales and access to improved technology.
- The Zimbabwe Electricity Supply Authority (ZESA) is the implementing agency for national electrification in the country. It has in place a rural electrification program. Through the GEF project, ZESA has seen that PV systems can be one means of successful and sustainable rural electrification in Zimbabwe.

(2) Problems pointed out by GEF project

- A very significant problem is that the project has benefited mostly rich farmers, rather than the rural poor, its intended beneficiaries. This is presumably due to certain terms of the project's credit scheme, such as the short repayment period of 2-3 years and the need for a 15% down payment.
- The second problem involves the substandard quality of locally-made components. The GEF project's initial strategy was to use locally manufactured parts for the project. Unfortunately, low quality parts dominated the market and often caused system problems. Quality control was poor and testing not carried out by companies. Eventually, imported parts had to be used as the reliability of the installed systems (particularly after the project ends) was recognized as a more important consideration than using local components.
- The third problem involves the system installation technique. At the outset, GEF set guidelines on the proper way to install the systems. It was learned in subsequent inspections, however, that many local installers did not follow the standards that had been set, and used their own techniques in carrying out their

tasks. To counteract this a very expensive and not very effective inspection arrangement was established significantly increasing installation cost.

- The fourth problem involves the lack of manpower in the Project Management Unit (PMU), which UNDP set up to oversee the project. The project was national in scope and therefore the project installations were spread out across the country. So it was almost impossible for the very small PMU staff based in Harare to maintain control over all applications, carry out installation inspections and provide follow-up maintenance.
- The maintenance was most often done by the system owners themselves (who have very limited technical knowledge), particularly after the one-year guarantee period provided by the system installer expired. User maintenance is notoriously variable and generally unsatisfactory and the long term sustainability of the systems therefore lowered.

2.2 The Study Scheme of JICA Team

(1)The objective of the JICA program is to provide general rural electrification through photovoltaics which includes all economic segments, especially low income segments, of the rural populace.

(2) It was a policy of the JICA project to use domestic produced PV system and parts as much as possible for maximum sustainability. Therefore JICA developed and provided an improved type of charge/discharge controller for local manufacture which is suited particularly to low power systems due to its low internal power consumption. Transfer of this controller technology has been made to local companies through trail manufacture in the companies and workshop type training.

(3)The JICA project established a continuous PV system maintenance organization. The organization maintains and controls the PV systems, and insures that the dwellers will have reliable use of the PV systems indefinitely into the future.

(4) The JICA project provides the maintenance of the PV systems by arranging for trained local technicians to reside in the service areas.

(5)JICA assisted the Kwekwe Technical College to establish a long term, locally based technical training capability for solar PV technicians and installers in order to support long term maintenance.

The scheme of JICA and GEF projects are as Figure 2-1, Figure2-2 and Table 2-1.

Table 2-1 Comparison of GEF scheme and JICA scheme

	GEF Project	JICA Project
Basic Concept	Sale of PV system by installment	Supply electricity through PV system belongs to the organization
Managing Institution	GEF-PMU(Governmental)	DOE-BUN(NGO)
System belongings	Customer after completion of payment	JICA(Study period) to DOE(after Study) then BUN
System Capacity	Nominal 45W, average 65W	25W - 56W
Method of Subsidy	Subsidy of interest for easy payment	Lend of PV system to BUN
Area of Customer	Whole country	Limited area that a local technician can cover for maintenance
Maintenance	Customer or installer	A trained local technician
Maintenance Cost	Customer	Covered by monthly fee
Installation Fee /Monthly Fee	Z$1,500/200 (in case of 50W in 5 years payment), without replace cost for battery and controller	Z$750/75 (25w), Z$1000/120 (56w) including replace of battery and controller

GEF: Global Environment Facility

PMU: Project Management Unit

BUN: Biomass Users Network

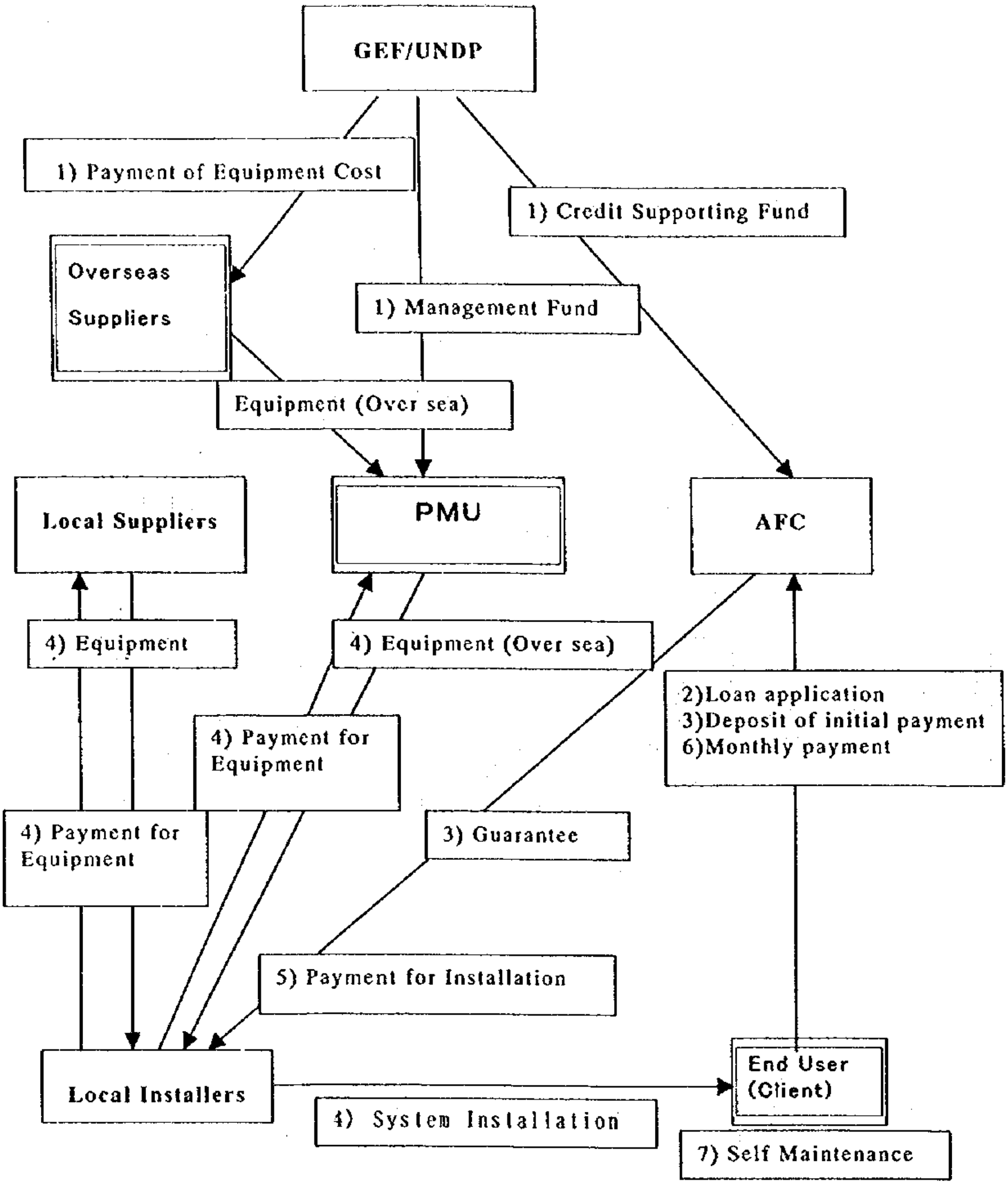


Fig. 2-1 Organizational Scheme of the GEF Project

1) GEF/UNDP provide money and set lower-interest loan
2) Client who want to buy the system apply for loan to AFC
3) AFC check the client and inform guarantee to installers, User deposits the down payment
4) System Installer install the system by purchasing system parts from PMU and local companies
5)AFC pay the installation fee to local installers
6) User pays monthly payment
7) User maintenance the system

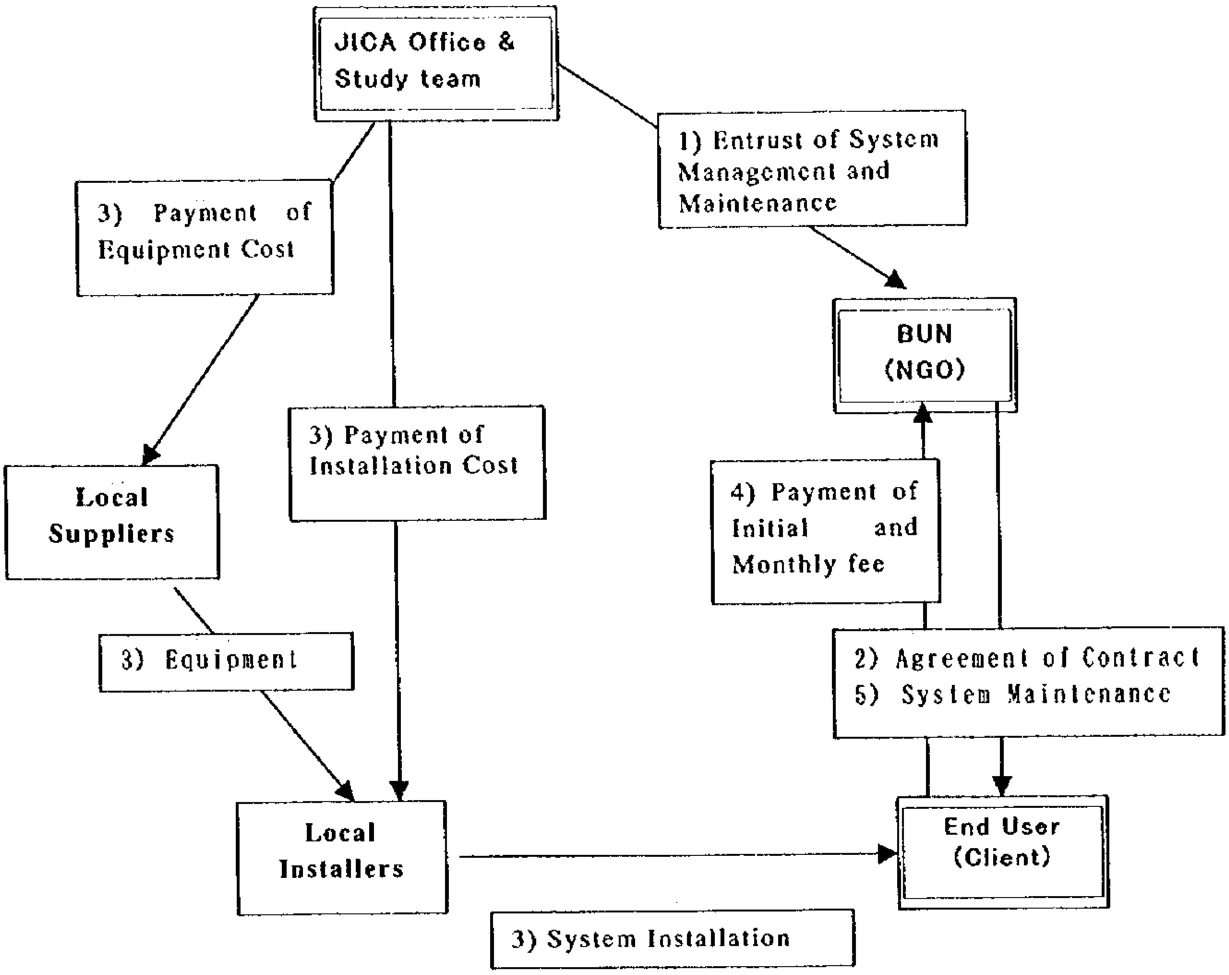


Fig. 2-2 Organizational Scheme of the JICA Project

1) JICA entrusted BUN to provide system maintenance

2) BUN contracts with clients who want to receive basic electrical service

3) JICA asks system installer to install system by providing main equipment and specifications

4) System installer installs the system

5) BUN maintains the system

2.3 The Outline of JICA Project Study

The main objective of this JICA study is to formulate a sustainable master plan for rural electrification of Zimbabwe using photovoltaics, taking into careful consideration the problems stated above. To come up with an effective Master Plan for the widespread dissemination of PV in rural Zimbabwe, it was necessary to investigate the local situation from a technical and management perspective. It was also necessary to study existing socio-economic conditions, as well as conduct an evaluation from both a financial and an economic perspective.

To determine whether or not such a master plan can be successfully carried out technically and institutionally, the Study Team embarked on a pilot project, under which 100 systems were installed in households and 12 in clinics and schools located in selected unelectrified rural areas. To provide for sustainable maintenance, the project includes a charge for the electrical service provided. The maintenance organization is entrusted to an NGO and overseen by DOE.

In preparing for the pilot project, PV systems and parts from local companies were purchased by the team. Then during the initial stages of the JICA Study, the team carried out a comprehensive examination of the quality and characteristics of these locally-manufactured products, the results of which were used as the basis for determining the balanced and optimal system configuration. The Team also evaluated the level of technical skill of local installers (whom the Team utilized to install the pilot systems). Maintenance and monitoring problems were also identified and a local organization was contracted to carry these out after all installations were completed.

It bears mentioning that the JICA Study Team and its counterpart, that is the Zimbabwe Department of Energy, organized an Advisory Committee to facilitate the open exchange of opinions. The members included ZESA, the Solar Energy Industries Association of Zimbabwe (SEIAZ), which represents the country's PV-related companies, PMU, the Agricultural Finance Corporation (AFC), which is in charge of the project's credit scheme, and local non-government organizations (NGOs) involved in PV.

2.4 The Contents of the Survey and Methodologies

The survey flowchart which JICA team used in carrying out the survey for creating the rural electrification master plan is shown in Figure 2-3. For evaluation of the maintenance ability and technical level, PV systems for 100 ordinary households and 12 public institution were installed and the system configuration, standards enforcement, maintenance and operation of the systems are monitored. The main items surveyed are the following items.

[The survey of institutional items]

Determining how to operate and manage the Pilot Project in terms of institutional structure. The institutional arrangement needs to be one, which will meet the goals of the JICA project for the long term.

[The survey of technical items]

Design, installation and maintenance of the PV systems for the Pilot Project and training methods for staff should be evaluated.

[The socio-economic survey]

The socio-economic survey, undertaken by a local organization, basically sought to determine the electricity needs and ability of potential end-users to pay a regular electric fee in un-electrified rural villages as well as examination of average income, population density and electricity needs.

[The survey and evaluation of the financial system]

Financial support systems were studied in order that PV systems can be installed in target households within their available financial resources.

[The economic evaluation]

For the economic evaluation, an analysis of the economics of the use of PV systems for rural electrification was studied then the impact of PV electrification on the country's economy was also identified and analyzed.

(1) Institutional study contents and methods

The areas and households where PV systems were installed for the pilot project were selected with the cooperation of our counterpart and relevant local organizations.

The fee to be charged was decided using the analysis of the survey of target rural societies as well as the GEF project results. An NGO which had prior experience in PV-system installation and management was selected to manage the pilot project for the JICA team. The managing organization was required to collect management-related data, such as system maintenance and charge collection information. Collected data would be analyzed, then considered during the preparation of rural electrification programs.

In order to solve the problem faced by the GEF project of reaching only the wealthier percentage of the rural households, the JICA PV system was designed much smaller, almost half of the standard 45W system employed in GEF project, so that the system cost could be lowered. In addition, because purchasing a system with a short-term loan involves payments that are too high for the lower-income classes, a long-term service system was introduced. For the pilot project, during the first five years, an electricity charge, in which the repair cost and maintenance/inspection costs are included, are collected from the users. At the end of the pilot project, the users are allowed to choose one of the three options below (a or b or c) dependent on whether or not a larger scale project is implemented.

a. To receive the same service as in the five preceding years, and continue to pay an electricity service charge.
b. To revise the contract terms upon consultation, and decide the content of service and the charge to be paid.
c. To keep the system, stop paying the charge, and not to receive the maintenance & inspection services.

The problem of widespread geographic distribution of systems making maintenance too expensive was solved by narrowing down the target areas to clusters of at least 50 houses each. For post-installation maintenance, young people were selected among the residents in the target areas through testing and interviews. They were given the necessary training to act as local technicians. In order to keep this management system operational for the full five years, the charge was set to allow full payback of the costs of maintenance and repair including administrative costs.

(2) Technical study contents and methods

For the pilot project, the system design, the selection of system parts, control of installation work, and training and guidance for maintenance were planned. During the study, operating and maintenance conditions were analyzed from the records of data loggers, local technician reports, service records, etc. The analysis results were reflected on the preparation of proposed future rural electrification programs.

The problem of poor quality components from local suppliers can be solved in the pilot project by importing components. For larger scale projects it will be necessary for local companies to take advantage of technical and financial assistance to improve the quality of their products to an acceptable level. The study team provided technical transfer in the manufacture of controllers and fluorescent lamps but much more needs to be done in the future.

To analyze the state of use of the installed systems objectively, several PV systems were equipped with a data logger capable of automatically recording the operating conditions. At the same time, the local technicians responsible for the maintenance service were provided with a checklist of items to record during their maintenance visits. The data logger and maintenance technician records were analyzed so that a better program could be prepared out for full-scale PV electrification.

The problem of low quality in installation work was addressed both by on-the-job assistance by the NGO technician and members of the study team and through the training course provided at Kwekwe Technical College. Because it was clear that installation teams were not providing users with proper information about the use of the systems, user educating procedures were included in the training course...

(3) Rural survey contents and methods

Rural areas were surveyed in order to estimate user ability to pay, the size of system needed and the probable demand for systems. The survey contract was awarded to a local consultant, and made in a questionnaire style. The targets were 200 each of unelectrified households and households already equipped with PV systems. Also surveyed were 50 each of unelectrified and PV equipped public facilities. Given that the ultimate PV-based electrification program would cover the whole country, the survey covered several provinces. Specific characteristics of individual provinces, such as average income, population density and electricity needs, were examined as well.

(4) Financing system study contents and methods

In the hopes of proposing a more effective financing system for both the users and system providers (those who provide or install PV systems), a study was conducted on the existing loan systems involved in the GEF project, as well as those loan systems employed in other developing countries in their rural electrification projects. A questionnaire was sent to the local PV-related firms in Zimbabwe in order to identify what problems they had with the existing loan systems. Then, consideration was given as to how to solve such problems. For the users, financial supporting systems to help the low-income class buy PV systems or services were considered.

(5) Economic Evaluation study contents and methods

The economics of PV systems for rural electrification was considered by comparing the economics of extending the utility grid to the use of individual PV systems. The study verified the economic superiority of PV system in those rural areas characterized by limited electricity needs and significant distance from the existing grid. The local and national economic effect of the spread of PV systems was analyzed in terms of how an increase in the added value through PV system installation could contribute to GDP of the country.

The flow of the surveys and studies described above is illustrated in Fig. 2-3.

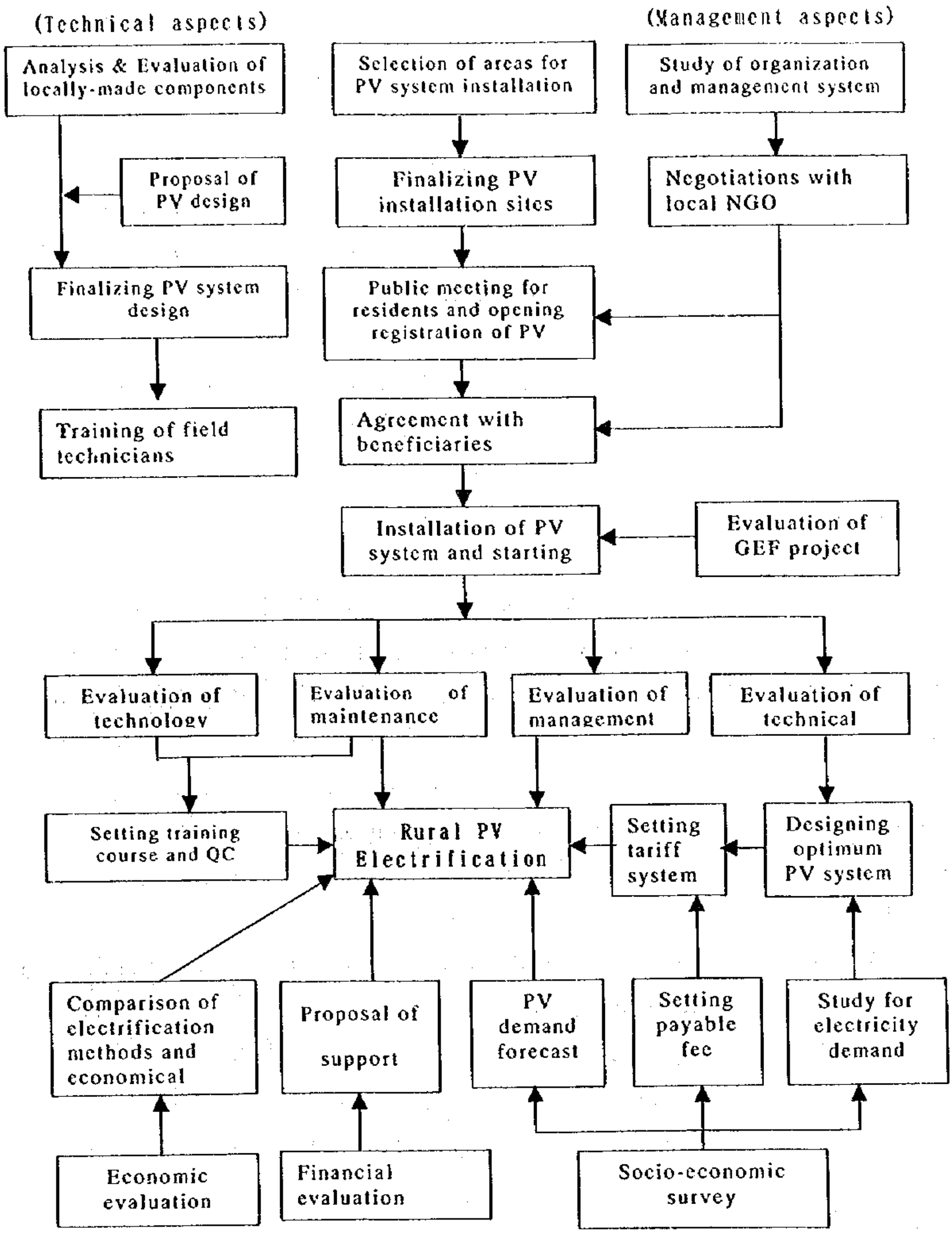


Figure 2-3 Diagram of JICA Study Scheme

2.5 The outline of the objective areas and facilities which PV systems to be installed

2.5.1 Selection of the targeted areas

The targeted areas for PV system installations are those that are not included in future grid extension plans but are located as near as possible to metropolitan Harare (for easy access). The areas selected were in Sanyati, Turf, and Manyoni in Kadoma district in Mashonaland West Province and Gokwe in Midlands Province. These two Provinces area adjacent. The sites for households were selected by taking the surrounding circumstances into consideration. In Kadoma, Sanyati includes commercial farm areas and Turf is primarily a resettlement farm areas. Sites for the public institutions were selected in Kadoma (5 clinics and 2 schools) and in Gokwe (5 clinics).

Mashonaland West Province, Kadoma which lies some 90 km west-southwest of Harare, can be accessed via the national road A4, (Harare-Bulawayo Road). Mashonaland West Province has a total population of 1.11 million, or 11% of the national figure. Its urban population is around 270,000, while the rural population is about 840,000. 21% of total households are electrified (61% in urban areas, 7% in rural). 44% of total households are of the traditional type (this figure is 59% in the rural areas). Most of the province's farming land is classified under Region II (based on rainfall volume and soil characteristics), putting the province at the top among Zimbabwe's eight provinces and two special cities (Harare and Bulawayo) in terms of agricultural output. Its major farm products include maize, wheat, cotton, sorghum, tobacco, sunflower, soybeans, and groundnut.

The combined total number of hospitals and clinics in Mashonaland West Province was 150 as of 1995, or 11% of the national total. Clinics totaled 127.

The population of Kadoma (composed of Kadoma town, Sanyati district, and Turf, Manyoni district) was registered to be 219,000 in 1992. Of this figure, 178,000 lived in rural areas. As of 1996, the total number of households was 44,000, of which 19,000 were located in rural areas. Electric power is supplied by grid by the Zimbabwe Electric Supply Authority (ZESA) in the central part of both Kadoma town and Sanyati district, but surrounding rural areas remain unelectrified. The total number of clinics in Kadoma district, Sanyati ,Turf, and Manyoni as of 1996 was 11. The number of schools in the Sanyati district was 33 (27 elementary schools and 6 secondary schools) while it was 34 in the Turf, and Manyoni district (27 elementary schools and 7 secondary schools).

The second candidate area is Gokwe South in the Midlands Province, which lies next to Mashonaland West Province in the southwest. Gokwe South lies some 100 km west from Kadoma via the A4 and the principal road (Kwekwe-Gokwe line). The Midlands Province has a population of 1.31 million (13 % of the national population). 24% of households are electrified (75% in urban areas and 4% in rural areas). The province is classified as Region Ⅲ (on the basis of rainfall volume and soil characteristics). Its major farm products include maize, wheat, cotton, and groundnut. Compared to other provinces and cities, however, agricultural output is not so good. Throughout the province, the total number of hospitals and clinics as of 1995 was 223, or 16% of the total country figure. Clinics numbered 191.

The specific target area in Gokwe South is Gokwe town, which registered a population of 240,000 in 1992. As of 1996, it had a total of 18 clinics and 84 schools (42 elementary schools and 42 secondary schools). Electric power is supplied by grid by ZESA to the central part of Gokwe town, but this accounts for only 1% of total households. The surrounding rural areas (which constitute 99%) remain un-electrified.

2.5.2 Households

The typical house in Zimbabwe is made up of 5 to 7 one-room structures used for cooking/dining, storage, and sleeping quarters. The traditional shape of these structures is round, with a diameter of 5-7 meters, made of brick walls (the inner and outer surface of this wall is covered by cement and/or plaster) and the house has a conical thatch roof. Most of them have small glazed windows. On the average, about 40% of families in Zimbabwe live in this kind of house. Recently, many modern, independent types of housing (consisting of 3-5 rooms separated by interior walls) similar to the European, American, and Japanese type have been put up across the country. The ratio of this type of housing to the national figure is about 39%. With regard to traditional housing in rural areas, the ratio to the total households is usually high. For instance, it is 59% in Mashonaland West Province, and 69% in the Midlands Province.

2.5.3 Clinics

The average clinic in Zimbabwe has 4-5 staff members, consisting of 1-2 nurses (either State Registered Nurses (SRNs) or the State Certified Nurses (SCNs)), 1-3 nursing aids, and one environment and health technician. There is usually no resident doctor.

The nurses and nursing aids usually live in official quarters that form part of the clinic site. Their functions include patient examination, diagnosis, and administration of medication. For more serious cases requiring detailed examination, patients are usually referred to the nearest hospital which can be contacted by telephone or radio. Very few clinics provide an ambulance service. Currently, there are a few clinics which receive periodic visits from volunteer doctors in nearby hospitals (e.g. on a fortnightly basis).

Most clinics are open from 7:30 to 16:30 on weekdays, and from 7:30 a.m. to 12:00 or 13:00 p.m. on Saturdays. They are usually closed on Sundays, but some clinics stay open from 7:30 a.m. to 10:00 a.m. or 12:00 noon. Clinics generally receive emergency cases any time. The number of individuals covered by one clinic differs from area to area but the general range is from 5,000-10,000 persons. The maximum clinic to individuals recorded is 1:23,000.

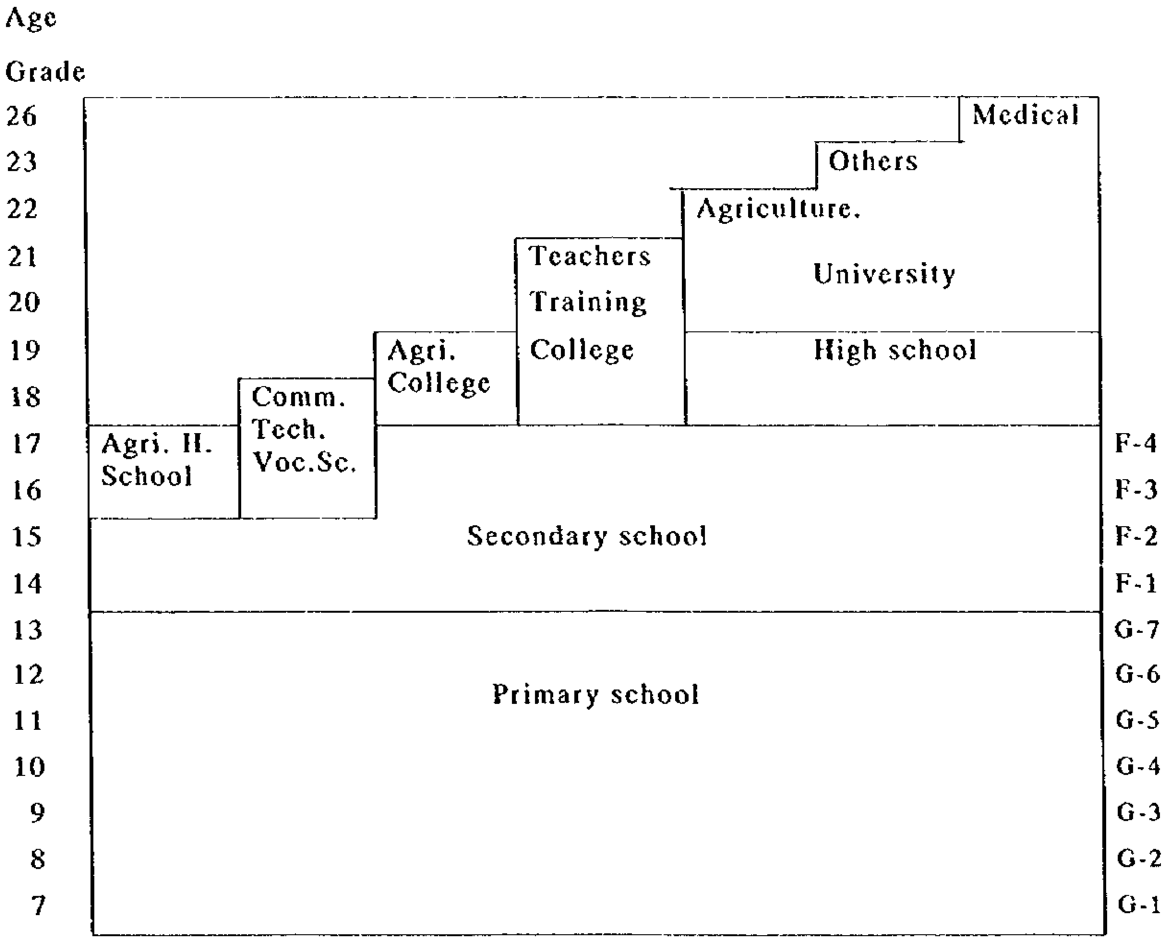
Though it may differ somewhat from area to area, the average clinic is made up of reinforced concrete, covered by a composition tile roof. The size of one building is generally 15 meters wide by 5-6 meters long. One or two buildings generally make up one clinic. If there are two buildings, there is usually a connecting corridor in the middle, resulting in an H type structure. In some cases, the two buildings are connected by a staff washroom (adjacent to a toilet) at one end, resulting in a Π type structure The usual number of rooms is 10-12, serving the purposes of consulting/examination, waiting/sanitation, education, injection, staff quarters, child labor and delivery, toilet and shower room for pregnant women (usually out of use because of absence of water supply and/or waste treatment facilities), storage of gas refrigerator containing vaccine and steam sterilizer, medicine storage, linen and bandage storage, men's ward, and ladies' ward. Lavatories and incinerators are generally located in separate structures away from the main building at the clinic site.

2.5.4 Schools

The first level in the educational system of Zimbabwe is primary school, where students study for 7 years (Grades 1-7), beginning at 7 years of age. This is usually followed by 4 years of secondary school. In the case of students planning to enter vocational school (3 years) or an agricultural institute (2 years), only 2 years in secondary school is required. For those who finish 4 years of secondary school, 2 more years of high school or a 2 year course in an agricultural college are the next steps. Those who finish high school can then go on to study for a 4-year ordinary university course. For the agriculture department, however, the course takes 3 years, and for the medicine department, 5 years. For those intending to teach at the primary and secondary school levels, a 4-year course (2 years classroom education and 2 years on-site training) at a teacher training college is required after completing secondary school. The following figure shows Zimbabwe's educational system.

In both primary and secondary schools in the rural areas, the average number of students per school is rather high, ranging from 400 to 1,000. This is not surprising, considering that children 15 years old and younger roughly constitute 45% of the total national population. As a result, many schools utilize a 2-classes a day system or a so-called "blue sky classroom" system, wherein classes are conducted outside. Most schools start classes at 7:15 or 7:30 in the morning, and finish at 15:00 or 16:00 in the afternoon. For schools using the 2-classes a day system, the first session usually ends at 13:00. It generally takes students 1-1.5 hours to reach school on foot (one way). Almost everyday, teachers give students homework, which takes them 1-2 hours to complete in their homes. Given the considerable amount of time it takes to and from the school, there is clearly a big need for electricity in homes if students are to satisfactorily complete these daily homework requirements. In addition to this, there is a growing demand for night school to cater to adults who work during the day.

Individual primary and/or secondary schools are usually composed of 4 to 6 buildings made of reinforced concrete and covered by a composition tile roof. These buildings house teacher's rooms (one for the school master, one for the headmaster, one for teachers, and another one for administration), and classrooms (usually one building consisting of 3-5 classrooms (7-8 meters wide by 20-40 meters long)). Two blackboards are placed both in the front and rear of the classroom.



Note:

Primary school :	Grade 1 ~ 7 ,
Secondary school :	Form 1~ 4 , Lower 1 , Upper 2,
Agricultural Institute:	2 years system (Min. of Agriculture) ,
Vocational School:	3 years system (Min. of Human Resources) ,
Agriculture College:	2 years system (Min. of Agriculture) ,
Teacher Training College:	4 years system,
:	2 year lesson & 1 year training consisting of twice (Min. of Education)

Figure 2-4 Educational System in Zimbabwe

3

JICA PV SYSTEM

3.1 JICA PV System Specification

3.1.1 Target Recipients

Original plans targeted 10 clinics and 100 households for PV system installation and monitoring in Zimbabwe. Following discussions with DOE and after several field surveys two schools were added to the target list.

(1) Rural Clinics

Rural Clinics in Zimbabwe are of two basic types. The basic design is a one-building structure consisting of 6-8 rooms and a toilet. The second, larger design consists of two buildings situated about 6 meters apart, each one having 6-8 rooms. Photograph 3-1 shows an example of a clinic visited during the first field study.

The number of fluorescent lamps powered by the PV system which was installed is relative to the importance of the room and of lighting in that room to the functions of the clinic.

(1) Household (Photograph 3-2～3-4)

Households in rural Zimbabwe can be classified into two basic types: the traditional one-room type with a circular or rectangular shape (one household typically has 5 to 7 of these structures) or the more modern rectangular structure consisting of several rooms, similar to clinic staff quarters.

Families residing in the traditional type of house usually have several individual units or structures each with a different function. Typically, one is used as a kitchen and dining area, one serves as the master bedroom, and another functions as the children's room. These three units are considered the most important and thus have priority for lighting.

Photo 3-1 A clinic in a typical Zimbabwean rural community

Photo 3-2 Round houses in a typical Zimbabwean agricultural village

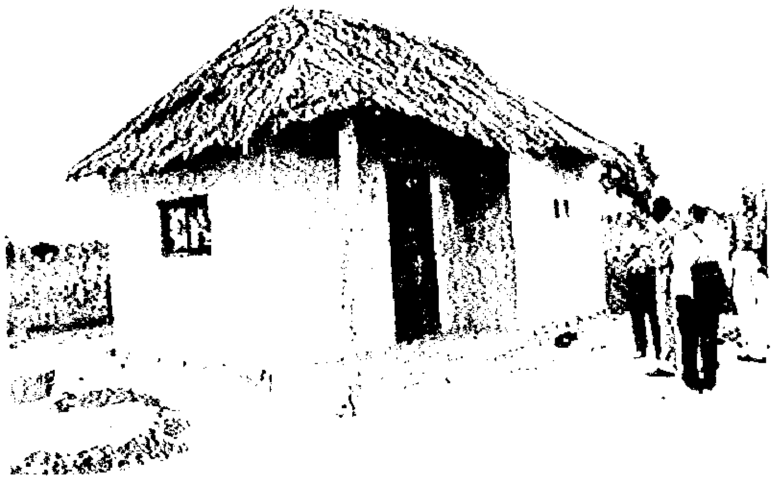


Photo 3-3 Rectangular house in a Zimbabwean village

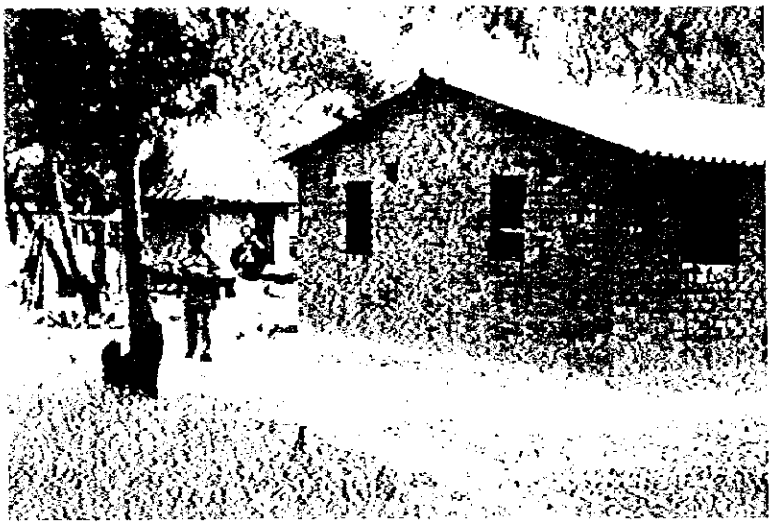


Photo 3-4 A relatively large house in a Zimbabwean rural farm community

For families residing in the modern type of multi-room house, lighting needs are also for the kitchen and dining area, living area and bedrooms.

3.1.2 Data Requirements for System Design

To prepare a system design suitable for the project site, specific kinds of data had to be obtained:

(1) Meteorological and Geographical Data

Prior to the Study Team's first field study in Zimbabwe, basic data on Zimbabwe were collected from the Japan Meteorological Association. More up-to-date information was obtained during the first field study, particularly on solar irradiation values. Average figures for each month are as follows:

Table 3-1 Horizontal Irradiation Values - Monthly Averages

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Irradiation (MJ/m^2)	22.32	20.80	20.54	19.70	18.18	17.04	17.51	20.47	23.02	23.95	23.40	21.26	20.68
Irradiation (kWh/m^2)	6.20	5.78	5.71	5.74	5.05	4.73	4.86	5.69	6.39	6.66	6.50	5.91	5.75

(2) Power Requirement Estimates

a) Clinics

The Study Team requested the Kadoma RDC to provide a floor plan of the clinics located in the proposed study area. Unfortunately, none were available and a rough sketch prepared during the first field study was used for reference.

Objectively, it was found to be rather difficult to estimate the lighting requirements of clinics. The importance of lighting maternity rooms as well as examination rooms for malaria patients was a clear need stated by all the visited clinics. But since deliveries or malaria cases do not occur regularly, they are difficult starting points from which to measure lighting requirements.

When patients come to the clinics for examination or treatment, rooms are used for an average of 5-6 hours per day. However, it is very likely that even when there are no patients, the clinics continue to use rooms (with lighting) for an undetermined amount of time. Given such a situation, the system had to be designed to meet such unpredictable patterns of electricity use.

b) Households

No universal estimate of power requirements could be done for households, as each one has its own living and power consumption patterns. It is sufficient to note that the kitchen, dining room, and bedrooms are typically the most utilized and thus most important rooms in the house.

Although specific data on the operational results of the ongoing UNDP/GEF project were not available, it has been assumed that the typical household uses lighting for around four hours per day. It was also noted that among households already using PV systems that there is a common desire to use appliances other than TVs or radios such as radio cassettes. This information was taken into consideration in this project.

c) Schools

Rural Schools are made up of classrooms, offices and staff rooms. The classrooms are around 60-80m^2 in area with blackboards 5-6m wide located at the front and rear of each room. For this project, two classrooms, offices and staff rooms were targeted to be lighted by the PV systems.

Given the size of the classrooms, it was estimated that four lamps are needed to adequately illuminate one classroom during the evening. Based on discussions with the counterpart organization regarding the night time use of classrooms for evening study and adult classes (and assuming that classes begin after sunset and end around 9 or 10 in the evening) the estimated length of use is 3 to 4 hours per day.

Unlike clinics, lighting requirements of schools are considered to be more stable and predictable, especially when a program for night classes has been finalized.

(3) Technical Data

In order to construct a well-balanced system that utilizes locally-procured parts and takes into consideration meteorological and load conditions at the study areas, it is important to determine not only the nominal values of the system components such as solar cells and batteries but also their technical characteristics. Normally, such kind of data can be obtained from manufacturers.

In Zimbabwe, although the UNDP/GEF project has records of PV installations and system performance over the past 5 years, the technical information mentioned above (which is necessary in designing a new system) has not been recorded since project commencement. Specific data on voltage, characteristics of solar cells and charge/discharge characteristics of batteries thus had to be measured independently by the Study Team. It should be noted, though, that design work at the study areas was greatly facilitated by utilizing the standard assembly system of the UNDP/GEF project.

One important factor in designing a system is the charge controller, which, as its name implies, controls battery over-charge and over-discharge. The most important features that should be taken into consideration regarding this system component include low internal power consumption and accuracy of voltage and current level setting for protection against over-charge and over-discharge, respectively.

No detailed technical information was available concerning charge controllers used in the UNDP/GEF project. The Study Team thus had to independently conduct its own evaluations. Actual measurement of voltage, PV module current (current/voltage or I/V characteristics), and battery discharge characteristics, and results obtained during the first field study are shown in Photographs 3-5 to 3-9 and Figures 3-4 to 3-5.

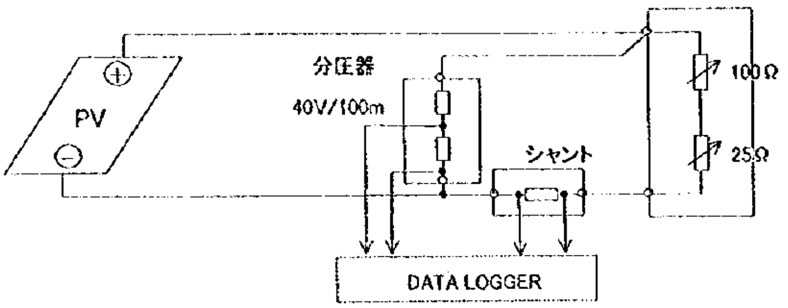


Fig.3-1 Measuring Circuit for PV Module

Type:	MM250-A	Voc:	21.4 V	Vmp:	16.9 V
Ser. No.:	D961025	Isc:	1.69 A	Ipm	1.53 A
Maker:	Eurosolare(Italy)	Pmax:	25.8 W	NOCT	43 deg

Vpm =	13.45 V	Irradiance:	1.017 kW/m2 (on module surface)
Ipm =	1.49 A	Mod. temp	60 ℃
Pm =	19.99 W	Tilt angle	18 deg N

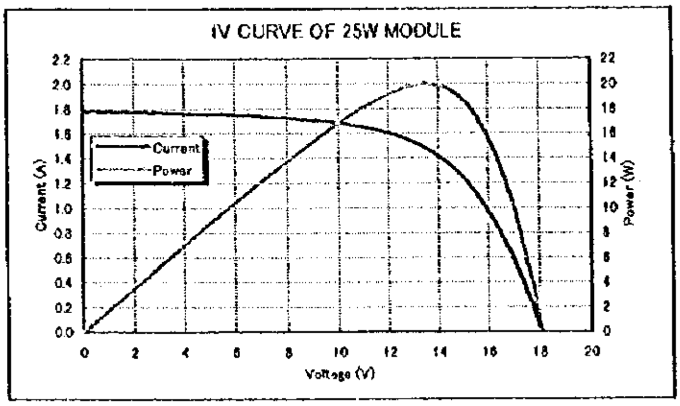


Fig. 3-2 IV Curve of Model MM 250-A

Type:	MSX83	Voc:	21.4 V	Vmp:	16.9 V
Ser. No.:	FW95K28691440	Isc:	5.35 A	Ipm	4.91 A
Maker:	SOLAREX(USA)	Pmax:	83 W	NOCT	49 deg

Vpm =	12.9 V	Irradiance:	1.017 kW/m2 (on module surface)
Ipm =	4.74 A	Mod. temp	61 ℃
Pm =	61.2 W	Tilt angle :	18 deg N

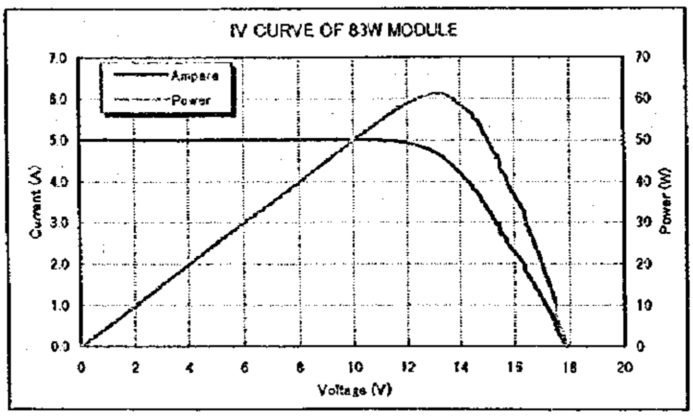


Fig. 3-3 IV Curve of Model MSX83 Photovoltaic Cell Module

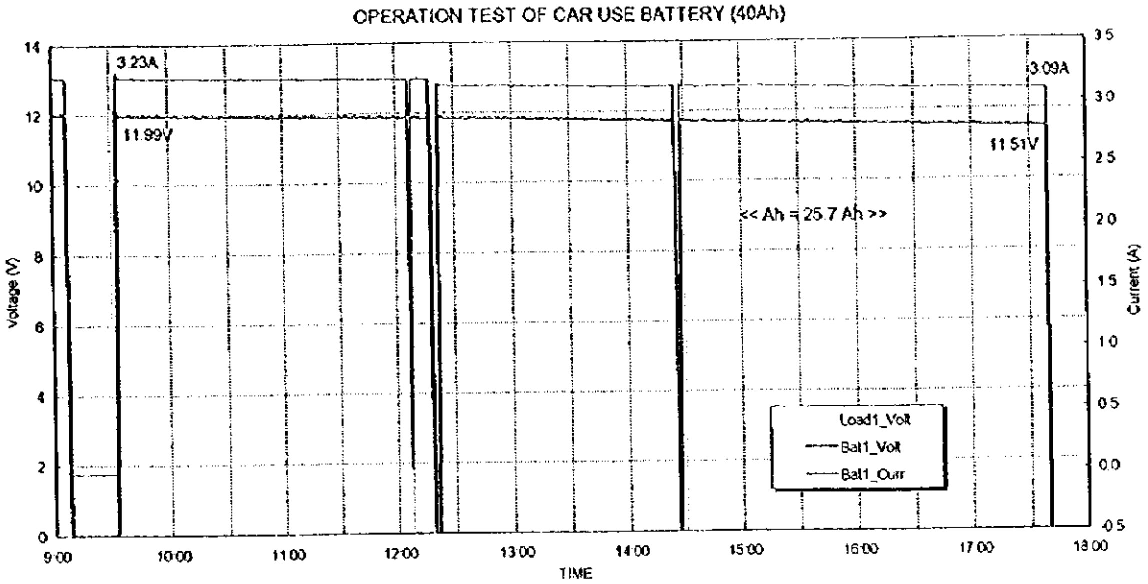


Fig. 3-4 Discharge Characteristics of a 40-Ah Automotive Storage Battery (Locally Manufactured Battery)

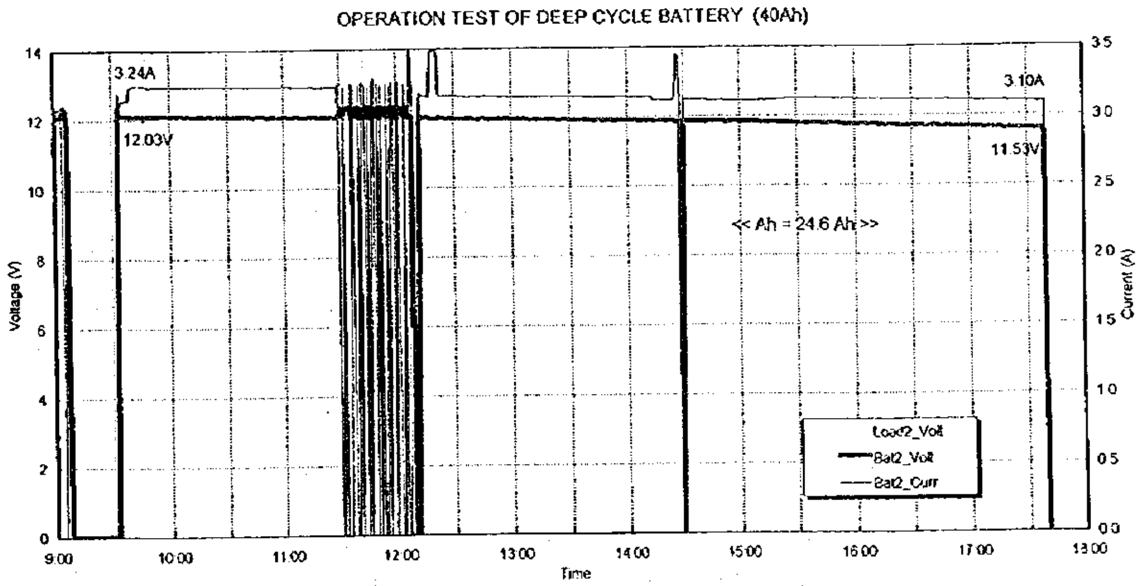


Fig. 3-5 Discharge Characteristics of 40-Ah Storage Battery Designed Specifically for use wit PV Systems (Locally manufactured battery) (Deep-cycle type battery)

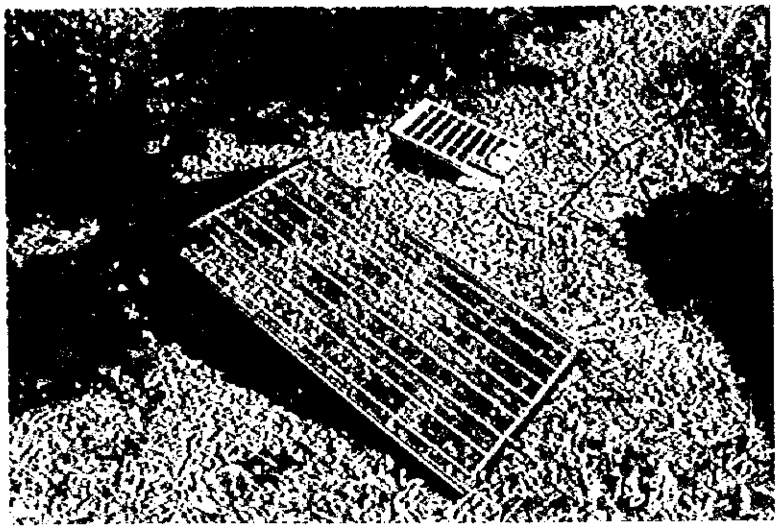


Photo 3-5 Determination of the characteristics of PV (photovoltaic) cell modules (Modules are shown)

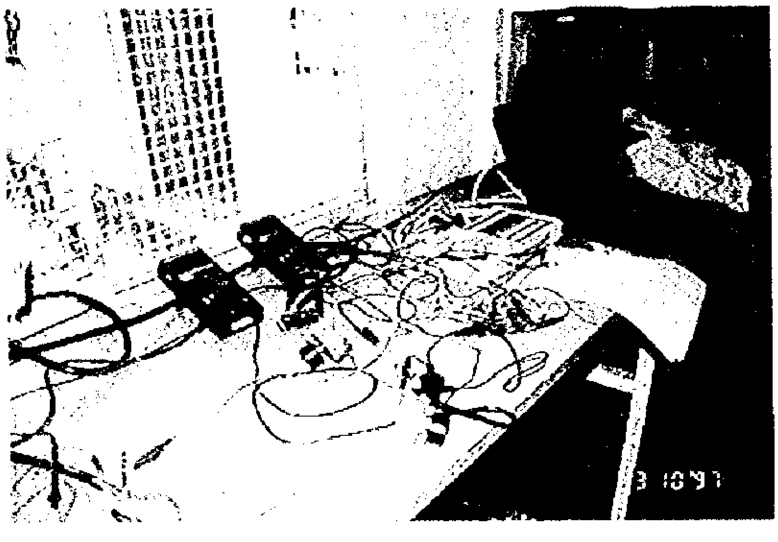


Photo 3-6 Determination of the characteristics of PV cell modules (Measurement equipment is shown)

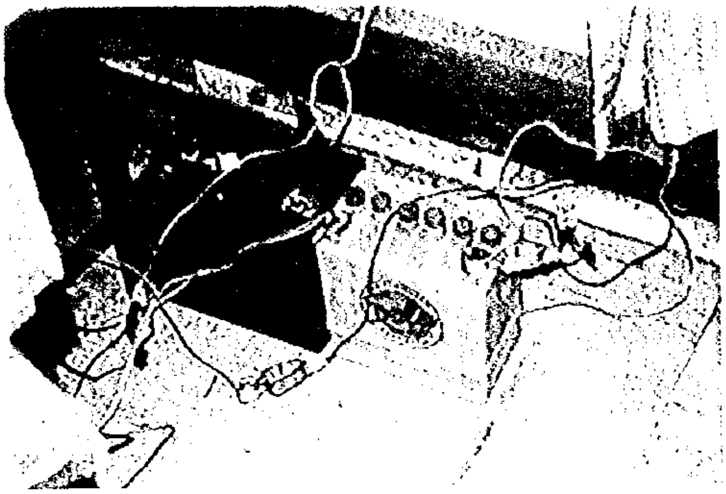


Photo 3-7 Determination of the Charge/Discharge Characteristics

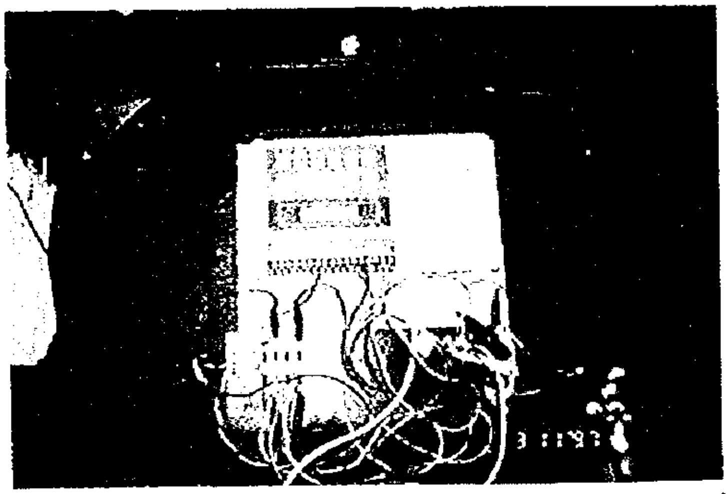


Photo 3-8 Determination of the Charge/Discharge Characteristics of storage batteries (Measurement equipment is shown)

Photo 3-9 Determination of the Charge/Discharge Characteristics of storage batteries (Work performed in teamwork with our counterpart)

Current/Voltage (I/V) characteristics of panels are generally determined by using a special (and expensive) measuring instrument. Such an instrument was not locally available, however, and given the circumstances, was also deemed unnecessary for this particular project. Putting more emphasis on local engineering capability, it was decided that a portable data logger could be used for evaluation of actual conditions. The same method was used in determining battery charge/discharge characteristics.

(4) Conditions that must be satisfied by key PV-system components

To achieve favorable operating characteristics on a PV system, it is desired that major individual components which makes up the system possess certain specific characteristics. The items which exert significant influence on system operation characteristics include solar photovoltaic panels, charge controllers, storage batteries and fluorescent-lamps.

・ Solar photovoltaic panels

a. Since solar photovoltaic panels are used in combination with 12-volt storage batteries, they should be installed in the form of modules, each consisting of 36 solar cells. In other words, a single module should measure approximately 21 V in open-circuit voltage (Voc) conditions.

b. Other module characteristics need to be selected depending on the power output of a module as required by a given system, the mounting arrangements for the module, its, cost and other non-technical requirements.

・ Charge controllers

Charge controllers are particularly important to the system and need to be carefully selected. Conditions that each charge controller are required to meet fall under two categories; those that are concerned with a system's electrical operating characteristics and those that are related to the life of the charge controller itself. From this point of view, we list the following necessary conditions:

a. When the battery voltage has reached the upper limit of the operating voltage range and is at the high voltage disconnect (HVD) voltage, the current from the photovoltaic (PV) module should be disconnected reliably. Following the disconnection of the PV module, when the battery voltage falls to a predetermined voltage, called the high voltage reconnect (HVR) voltage, the charge controller should reliably re-connect the PV module for resumption of charging.

As a general rule, lead-acid storage batteries are used for solar photovoltaic power systems. For PV systems intended for ordinary households, the HVD is generally set at about 14.5 V while the HVR is set at around 13.5 V or approx. 1.0 V below HVD. In the case of these voltage settings, the battery voltage when at full charge will hover in the neighborhood of 14 V, which is close to the voltage at which the electrolyte of the storage battery starts generating gas bubbles.

If we raise the HVD setting a little higher to approximately 15.0 V, the battery recovers faster and battery life may be increased. However, in this case, the gassing of the electrolyte intensifies and the rate of electrolyte loss increases significantly. This means that frequent maintenance becomes necessary to insure that the electrolyte does not fall beyond a safe level. If no one is available to check electrolyte levels frequently, the battery stands a chance of losing an excess of electrolyte and being damaged. For this reason, it is important to set HVD and HVR at a level which allows the battery to come to nearly full charge but not to generate excessive gas. That has been found to be approximately 14.5 V and 13.5 V, respectively.

The smaller the difference between HVD and HVR becomes, the better the control of the battery charge and the nearer the average voltage of the storage battery is to its set voltage value. However, if a relay is used for HVD control, unacceptably frequent ON/OFF operations will occur and the life of the relay contacts becomes shortened. To prevent this from happening, for relay type controls it is appropriate to set the HVR about 1.0 Volt lower than the HVD, or within the range of approximately 13.0 V to 13.5 V.

In the case of a controller using semiconductors as switching devices, the frequency of switch operations does not matter, and no HVR setting is needed.. In this case, effectively the HVR becomes the storage battery's control target value, and it becomes possible to implement control in such a manner that the battery voltage will become equal to the charge controller's voltage setting.

b. When the battery voltage has dropped beyond the lower limit, called the low voltage disconnect (LVD) voltage of the operating range of the battery, the controller must disconnect the load. Subsequent to the disconnection of the load, when the battery voltage has recovered to a predetermined voltage, called the low voltage reconnect (LVR) voltage, the controller must reliably re-connect the load.

The LVD setting is determined by the usable voltage range of the storage battery installed. In the case of typical lead-acid storage batteries, the discharge final voltage and the minimum usable voltage are usually assumed to be 10.8 V (1.8 V per cell) and 11.4 V (1.9 V per unit cell), respectively. Hence, in applications where lead-acid storage batteries are used, the LVD is typically set at approximately 11.5 V. For re-connection following a LVD condition, the user may want to use the load as soon as possible but it is undesirable to start supplying power to the load before the battery has at least partially recovered its charge otherwise the LVD will again soon cut off power and also the battery life will be decreased due to extended time at a low charge level. Considering the tradeoff between the two, the low voltage reconnect (LVR) voltage is usually set at approximately 12.5 V or about 1.0 V higher than the LVD. From the standpoint of system maintenance, it is preferred that the LVR be set at 13.0 V to 13.5 V or even higher to more fully recover the battery before the load is reconnected.

c. The amount of energy consumed by the system for its own use should be negligibly small as compared to the daily amount of energy delivered by the panel.

In the case of a 25 Wp PV system, up to several Ah of power is acceptable per day. If we assume that about 5 percent of daily power generation may be tolerated as an average energy consumption for charge controller, it is required that the average current demand of the controller be limited to 15 mA/h or less.

d. To help the user operate the solar system most effectively, an indicator which indicates the state of charge of the battery can be used. For small PV systems, this indicator should not consume power making it necessary to install a push button for the user to press when information about the level of charge is desired.

e. Since the charge controller is connected to a PV panel installed outdoors, it is exposed to possible damage by induced voltages from nearby lightning strikes. Since lightning strikes are relatively frequent in Zimbabwe, the charge controller should not vulnerable damage or improper operation of the controller due to lightning.

In particular, if a latching relay is used, the controller design needs to be one which will automatically reset the relay to the proper operational condition if disturbed by induced voltages from lightning.

f. When the battery voltage of the charge controller is lower than the LVD voltage, it is important that the PV panel be connected to the battery at all times and the load continuously disconnected. This requirement should be satisfied irrespective of the voltage level of the storage battery even if the voltage is too low to operate the electronic circuitry of the controller. In other words, it is desired that the above condition be met even if the battery voltage measures zero volts. Among the various charge-controller configurations, this condition is satisfied only when relays are used as switching devices. The contact configuration of relays capable of satisfying the condition is as follows: "Normally Closed" on the PV module side (charge side) and "Normally Open" on the load side (discharge side). Figure 3-6 shows this desired charge-controller contact configuration. In the case of this contact configuration, one relay should always be energized during system operation—which cannot be called the best solution from the viewpoint of energy conservation. To satisfy the power-savings requirement, a latch-type relay on the load side can be used to meet the requirement for fail safe operation even at zero battery voltage while not requiring continuous power during normal operation.

If semiconductor devices are employed as switching devices, the circuit cannot possibly operate when the battery voltage has dropped beyond a certain level and the PV module cannot charge the battery. For this reason, it becomes absolutely necessary to implement good system management so as to prevent the battery voltage from falling to an unacceptably low value.

As a general rule, it is necessary to operate the system in such a way that the battery voltage will not fall significantly below the load's cutoff voltage (LVD voltage).

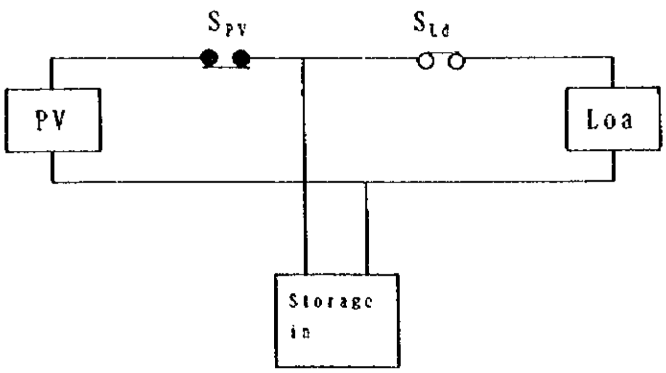


Figure 3-6 Basic configuration of charge controller

- Storage batteries

Storage batteries represent one of the most important components of self-contained PV systems. It is desired that storage batteries for PV systems satisfy the following technical conditions:

- Charge/discharge characteristics should be stable and predictable.
- Life should be long under the relatively deep discharge conditions found in solar installations.
- Maintenance should be easy. Where possible, it is desirable that the need to replenish the electrolyte with distilled water be eliminated.
- It is desired that battery terminals be rectangular in shape and wires connected by bolts through the terminals rather than the clamp type terminals that need to be used with round posts commonly used with automotive batteries. This is because clamped connections tend to increase resistance

over time much more than bolted connections and power losses increase unacceptably.

Evaluations of a battery cannot be made by studying its initial characteristics alone. This is because its life and operating characteristic changes over time cannot be determined from spot characteristics testing. For this reason, it is important to use field-proven products. Furthermore, the use of storage batteries that are designed with deep discharge conditions in mind can lead to improved stability in long-term charge/discharge characteristics and therefore increased longevity with associated improvement of operating economics.

Storage batteries which can be most easily obtained in rural regions are ones that are those intended for automotive use. Since these car batteries are inexpensive, this type of battery is often employed in cases where initial investment in PV systems is desired to be kept low or as replacements by the owner when the original higher quality battery fails. Automotive batteries are designed to quickly deliver large currents when starting a vehicle's engine and are not designed for long life under the conditions found with solar PV systems. To deliver the high currents needed for starting a car their plates are thinner and the number of plates is greater than those in storage batteries that are designed with lower current delivery and deeper discharge levels in mind. Thus the longevity available with deep discharge type batteries cannot be expected of automotive batteries when used in PV systems even when they are oversized so their average discharge depth is reduced

On the other hand, storage batteries that are suited for use with solar photovoltaic power generation systems are designed with emphasis on maximizing the number of charge/discharge cycles and are not expected to provide high rates of current delivery Their plates are thick and generally enclosed to cope with the stresses of a large number of charge/discharge cycles, and the number of plates is usually smaller than those of a comparably sized automotive battery. Batteries having special construction to minimize gas loss or are completely sealed are also available to eliminate the need for electrolyte refilling maintenance but are generally at considerably higher cost and often trade life for their low maintenance characteristic.

When regular maintenance cannot be assured it may be rational to adopt maintenance-free and sealed batteries for solar in rural districts despite their higher cost. In the case of the Zimbabwe JICA project, frequent preventive maintenance is provided as part of the user fee and the lower cost, and generally longer life, open cell type battery was selected as the best economic choice.

- Characteristics which fluorescent-lamp ballasts should incorporate

Generally speaking, fluorescent lamps for use with solar PV systems are required to meet requirements of high luminous efficiency, maximum longevity of bulbs and ballasts, small physical size, and low price. Specific characteristics include:

- Luminous efficiency should be as high as possible.
- Waveforms at the tube terminals should be balanced and sinusoidal in nature and remain stable over time.
- Circuitry should be simple in configuration, and should not create safety hazards in the event of a failure.
- Price should be low.

Safety features need to include failure modes which do not result in high current flows or overheating of any components to a level which might result in fire or damage to adjacent materials. To prevent high currents and overheating from an accident, a simple approach is to install a fuse in each ballast with an amperage rating commensurate with the capacity of the ballast. The main fuse which is installed at the battery or the controller is generally too high in value to properly protect the light ballasts and therefore the ballasts need separate protection.

3.1.3 PV System Design

(1) Basic Concept

1) PV Sizing and Load Determination

A variety of methods can be used when determining the appropriate size of a PV system. These can be grouped roughly into the following two categories:

i. Use of a simulation method in which it is assumed that the strength of solar irradiation can be described by a sine wave based on data on the amount of solar irradiation, and then use an assumed load pattern to determine the module voltage, module current, module temperature, etc., throughout the day.

ii. Estimate the electric energy which can be supplied by the selected module by using solar radiation data and a system loss coefficient or using the same method in reverse, determine the module size needed to provide an assumed energy requirement.

Procedure ii. (which is most often used when designing PV systems) was employed for designing the JICA pilot project PV system due to considerations such as the need for the system to be of a compact size, the difficulty of obtaining detailed technical data, and the need for as much as possible of the system being easy to obtain locally. When deciding on the PV module to be selected, the formula shown in Equation 3-1 is used to determine how much electric energy can be supplied, this being the usable power load (PL) per day.

Equation 3-1 PL = (Pmod) x (Tz) x (Ksys) x (I/As) (Wh/day)

Where:

Pmod : Capacity of module (W)

Tq = Q : Equivalent power generation effective duration per day (Irradiation value per day Q $kWh/m^2/day$ value)

As = I : Design flexibility

Ksys = K1×K2×K3×K4×K5×K6×K7×K8

Where:

K1 = 0.9 : Coefficient of temperature rise of the PV module

K2 = 0.8 : Difference of actual operating point from maximum power point of the PV module. (Determined by the characteristics of solar cells and charging voltage of the batteries)

K3 = 0.95: Coefficient due to dirt on the module

K4 = 0.95: Coefficient due to the difference from the optimum value for the module installation orientation

K5 = 0.92: Loss coefficient due to surface reflection of module at non-normal angles

K6 = 0.95: Coefficient due to lost performance with age

K7 = 0.8 : Average charge/discharge efficiency of the batteries

K8 = 0.9 : Average loss due to wiring and controller losses

The amount of solar irradiation (Q) used in this equation is presented as the normal value for a horizontal surface, that is to say as the global irradiation value. The amount of solar irradiation used when designing the PV system is the total irradiation value actually received by the surface of the PV module. As will be discussed later, for the project site the energy entering the PV module is optimized by setting it at an angle of about 17.5 degrees (the latitude of Harare is 17.5 degrees south) and with the tilted face to the north The amount of solar irradiation on a tilted surface estimated according to the global irradiation data for Harare is listed below. The tilt angle of the PV module used for the estimate is 17.5 degrees and facing north.

Table 3-2 Calculated Amount of Solar Irradiation on a Tilted Surface

Month	1	2	3	4	5	6	7	8	9	10	11	12	Average
Irradiation ($MJ/m^2/day$)	20.56	19.97	20.84	21.55	21.40	20.82	21.10	23.45	24.37	23.50	21.78	19.47	21.57
Irradiation ($kWh/m^2/day$)	5.71	5.55	5.79	5.99	5.95	5.78	5.86	6.51	6.77	6.53	6.05	5.41	5.99

When demand for energy is known, the size of the module necessary can be calculated by means of the following equation: Equation 3-1.

2) Storage Battery

The main factors that determine the most appropriate size for the battery to be used to store the electrical energy generated by the PV module include the following:

i. It should have sufficient capacity to store at least the amount of electricity generated by the PV module in one day.

ii. It should have sufficient capacity to supply power to cover the anticipated load on consecutive days when electricity generation will be low due to clouds.

iii. To ensure service life, the storage battery should be used within its design discharge limits.

iv. If the charge in the storage battery has dropped to the minimum design level (the LVD has activated), it should be possible to recharge the battery with the PV module within an acceptable time period.

A battery with larger capacity is preferable to satisfy conditions through i to iii. However, if the battery is too large, recharging with the PV module takes excessive time and condition iv cannot be satisfied.

Taking these factors into account, the storage battery capacity was calculated by using the equation below.

B >= Ksun * Plah/Kdod (Ah) .... Equation 3-3

In this equation, B is the required storage battery capacity (Ah), Ksun is the number of consecutive low-sunlight days, PLah is the load (Ah) per day, and Kdod is the permissible discharge level for the storage battery (0.8). The anticipated number of consecutive low-sunlight days was provisionally set at five in order to decide on the battery capacity. After defining the storage battery capacity in this manner, it was next necessary to confirm the required charge recovery as shown below.

Trec = B x Kdod / Ppvah .... Equation 3-4

In this equation, Trec is the number of days required for the storage battery to recover its charge, B is the capacity of the storage battery used, Kdod is the discharge level (0.8), and Ppvah is the amount of electricity generated by the PV module (Ah) per day. The following equation can be used to obtain Ppvah, the electricity generated by the PV module (Ah).

Ppv = Pmod x Tq x Kpv (Wh) .... Equation 3-5

Ppvah = Ppv'/ 12..... Equation 3-6

Where, Ppv = Design amount of power generation by the PV module per day (Wh), Pmod = Capacity of PV module (W), Tq = Equivalent power-generation duration (which is the same as the irradiation amount Q), and Kpv = Factor of loss concerned with power generation by the PV module, which can be obtained by the following equation: Kpv = K1 x K2 x K4 x K5 = 0.629 (Refer to Equation 3-1 for the values of K1, K2, K4, and K5.)

(2) Determining the Module Tilt Angle and Estimating the Amount of Solar Irradiation on the Tilted Surface

An estimate for Harare of the relationship between the module tilt angle and the amount of solar irradiation on the tilted surface was made based on the global irradiation figures for Harare, and are listed in Table 3-3 below. Table 3-4 shows the calculated change in the amount of solar irradiation on the tilted surface when the tilt angle is changed in winter (June) and in summer (December). Reports from the Japan Meteorological Association were used to produce these estimates.

Table 3-3 Module Tilt Angle and Amount of Solar Irradiation on the Tilted Surface

Tilt angle (degrees)	5.0	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35
Maximum of irradiation (kWh/m²/day)	6.66	6.65	6.67	6.71	6.75	6.77	6.78	6.79	6.78	6.77	6.81	6.83	6.85
Minimum of irradiation (kWh/m²/day)	5.07	5.23	5.38	5.52	5.50	5.41	5.31	5.21	5.11	4.99	4.88	4.76	4.63
Average of irradiation (kWh/m²/day)	5.86	5.90	5.93	5.96	5.98	5.99	5.99	5.99	5.97	5.95	5.92	5.88	5.83

Table 3-4 Changes in the Tilt Angle and Amount of Solar Irradiation on the Tilted Surface in June and December

Tilt angle (degrees)	5.0	7.5	10	12.5	15	17.5	20	22.5	25	27.5	30	32.5	35
Irradiation in June (kWh/m²/day)	5.07	5.23	5.38	5.52	5.66	5.78	5.90	6.01	6.10	6.19	6.27	6.34	6.40
Irradiation in December (kWh/m²/day)	5.80	5.73	5.66	5.58	5.50	5.41	5.31	5.21	5.11	4.99	4.88	4.76	4.63

Figures 3-7 and 3-8 are graphical representations of the relationships for the above data. It is well known that for most sites, the tilt angle at which the average amount of solar irradiation is maximized throughout the year is roughly equivalent to the latitude of the location in which the system is installed (17.5 degrees in the case of Harare). However, the tilt angle at which the minimum values for the amount of solar irradiation is maximized is reportedly slightly less than the latitude of the installation location. Based on Figure 3-7, we can estimate that this angle would be 12.5 to 15 degrees in the case of Harare. When installing PV systems in Zimbabwe, handling is easiest if the design is based on a unified standard for the entire country that takes its geographical characteristics into account. The territory of Zimbabwe extends from approximately 15.6 to 22.4 degrees south in latitude, which is not particularly far in the north-south direction. Considering the solar irradiation conditions, if a south latitude of 19 degrees, which is in the center of the country, is used for the whole, the variation from the ideal at the northern and southern extremities is no more than 3.5 degrees. When determining the tilt angle for the PV modules, the value that will result in the maximum electricity generation for the entire year is desirable. In other words, the tilt angle at which the average daily amount of solar irradiation is greatest should be used. From this standpoint, then, a tilt angle of 17.5 degrees is desirable for Harare and one of about 19 degrees for the central portion of Zimbabwe. Another condition to be borne in mind when deciding the tilt angle for the PV modules is the need to minimize variation in the amount of power generated at different times of year. In other words, the tilt angle that will produce the highest minimum amount of solar irradiation on the tilted surface should be used. From this standpoint, the tilt angles for Harare should be between 12.5 and 15 degrees, and that for the central portion of Zimbabwe should be between 14 and 16 degrees. Considering these factors together, the recommended PV module tilt angle for the JICA monitoring system was set at 17.5 degrees to match the latitude of Harare, with a permissible variation range of between 15 and 20 degrees. The amount of solar irradiation on the tilted surface in this case is shown in Table 3-2. Based on this data, a value of 5.41 $kWh/m^2/day$, which corresponds to a tilt angle of 17.5 degrees, was used.

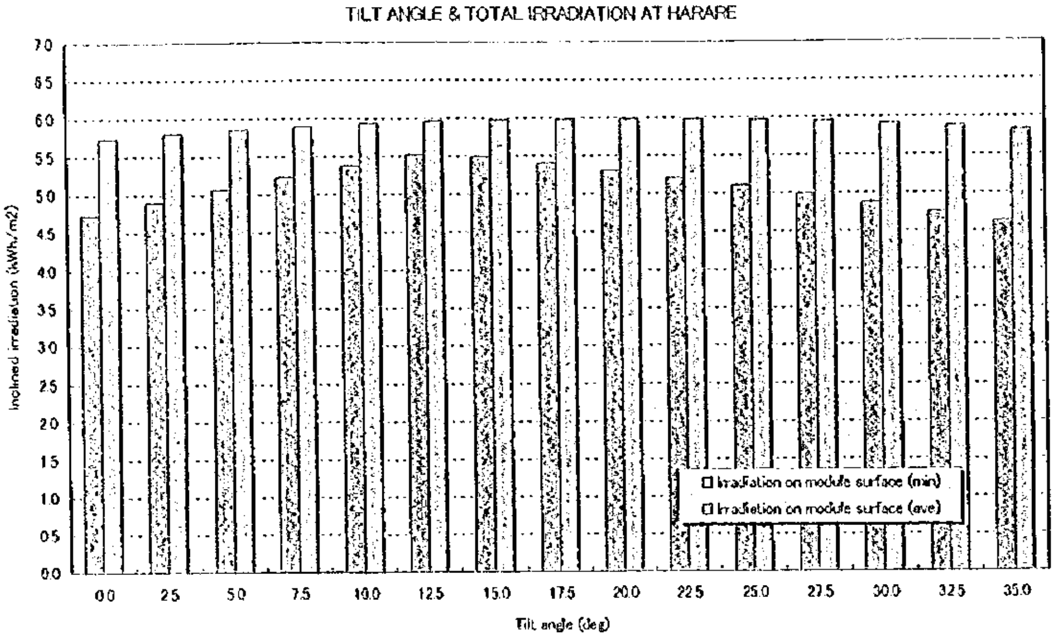


Fig. 3-7 Relationship between the angle of inclination and the amount of total solar irradiation on inclination in Zimbabwe

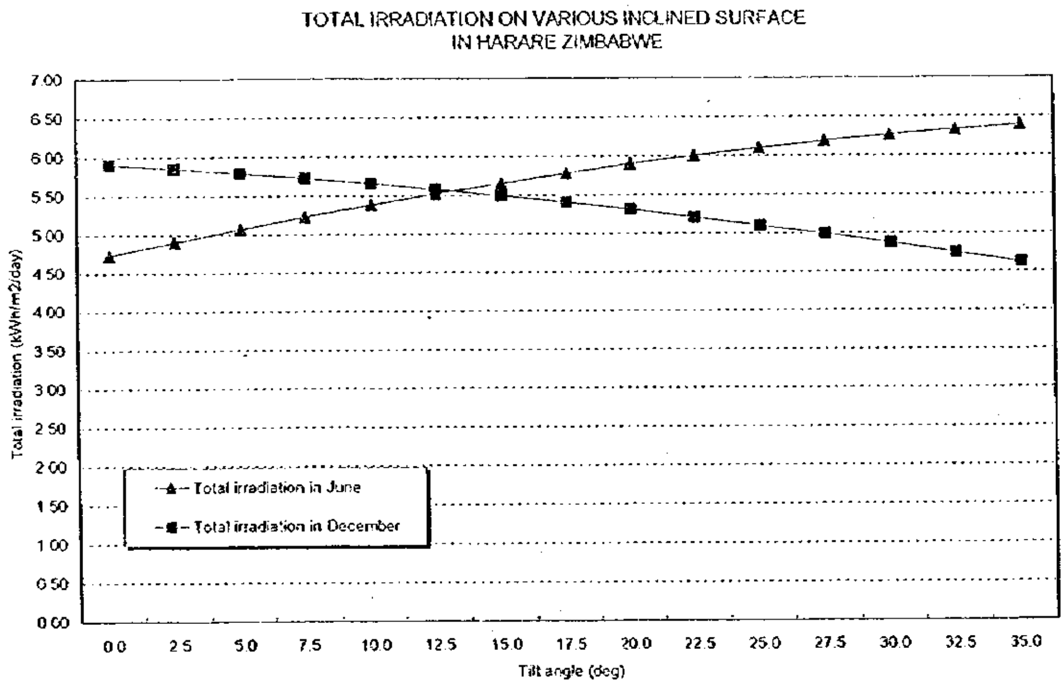


Fig. 3-8 Relationship between the angle of inclination and the amount of total solar irradiation on inclination in June and December

(3) Determining the Design Load and Storage Battery Capacity

The PV systems to be used in the project had a specified capacity of 20 to 25 Wp, in the case of systems for home use, and 120 to 150 Wp, in the case of use in clinics. Therefore, to decide the size of the PV systems we calculated the power that could be supplied based on the solar irradiation at the sites. This then became the basis for determining the capacity of the storage batteries.

1) Calculating the Design Load

It was decided to use panels of 25 Wp for homes and 83 Wp for clinics as those PV modules were easy to obtain in Zimbabwe and the balance of the system components for those size modules would also be available locally. It was also decided that 83 Wp PV systems would be made the standard for schools and clinics and sufficient separate 83Wp be installed to meet the design load. The energy that can be supplied by each system is listed in Table 3-5 which includes that calculated using Equation 4.2-1 and based on the use of 25Wp and 83Wp modules. The value used for the solar irradiation is the tilted surface solar irradiation from Table 3-2.

Table 3-5 Tilted Surface Solar Irradiation and Usable Load

	Q	Available load (25W sys)		Available load (83W sys)		25W sys	83W sys
Month	Total irradiation ($kWh/m^2/d$)	PL (Wh/day)	PL (Ah/day)	PL (Wh/day)	PL (Ah/day)	Battery capacity (Ah)	Battery capacity (Ah)
Jan	5.71	58.4	4.86	193.8	16.2	30.4	100.9
Feb	5.55	56.7	4.73	188.3	15.7	29.5	98.1
Mar	5.79	59.2	4.93	196.4	16.4	30.8	102.3
Apr	5.99	61.2	5.10	203.2	16.9	31.9	105.8
May	5.95	60.8	5.06	201.8	16.8	31.7	105.1
Jun	5.78	59.1	4.93	196.2	16.4	30.8	102.2
Jul	5.86	59.9	4.99	198.9	16.6	31.2	103.6
Aug	6.51	66.6	5.55	221.1	18.4	34.7	115.1
Sep	6.77	69.2	5.77	229.8	19.1	36.0	119.7
Oct	6.53	66.7	5.56	221.5	18.5	34.8	115.4
Nov	6.05	61.9	5.15	205.4	17.1	32.2	107.0
Dec	5.41	55.3	4.61	183.5	15.3	28.8	95.6
Average	5.99	61.2	5.1	203.3	16.9	31.9	105.9

The energy that can be supplied was decided based on the lowest (December) tilted surface solar irradiation (total irradiation). The actual design load was based on the estimate of load listed in the table below.

Table 3-6 Electrical Equipment Current Consumption

Type	Spec		Current Consump.(A)
Fluorescent lamp	FL 11W	11W	0.92
Fluorescent lamp	FL 9W	9 W	0.75
Fluorescent lamp	FL 7W	7 W	0.59
Radio	9V / 5W	5 W	0.56

- 25 W home system

Permissible load: 4.61 Ah

Design load: 4.6 Ah

(Detail)

Type	Spec	Lighting Hour	Current consumption (Ah)
Fluorescent lamp	FL 7W #1	4.0 h	2.36
Fluorescent lamp	FL 7W #2	0 h	0
Radio	9V / 5W	4.0 h	2.24
Total			4.6

- 83 W clinic system

Permissible load: 15.3 Ah

Design load: 14.53 Ah

Type	Spec	Lighting Hour(h)	Current consumption (Ah)
Fluorescent lamp	FL 11W #1	4 h	3.68
Fluorescent lamp	FL 11W #2	4 h	3.68
Fluorescent lamp	FL 9W #1	4 h	3.00
Fluorescent lamp	FL 9W #2	1 h	0.75
Fluorescent lamp	FL 7W #1	1 h	0.59
Fluorescent lamp	FL 7W #2	1 h	0.59
Radio	9V / 5W	4 h	2.24
Total			14.53

2) Determining the Storage Battery Capacity

The results of our calculation of the required storage battery capacity, using Equation 3-3 and assuming the number of consecutive low-sunshine days to be five and the permissible depth of discharge (DOD) of the storage battery to be 80 percent, are shown in Table 3-5. The solar irradiation level at its lowest (December), was used making the required storage battery capacity to be 28.8 Ah or more in the case of 25 Wp systems and 95.6 Ah or more in the case of 83 Wp systems. Based on this, locally available batteries of 40 Ah for home use and 100 Ah for clinic use were selected.

For the storage battery capacities determined as above, verification of recovery charge was determined using Equation 3-4 as follows. The amount of PV power generation which contributes to recovery charging is calculated using Equation 3-4. Letting total solar irradiation on the tilted surface, Q, in December (which is the month of the smallest solar irradiation) be 5.41 $kWh/m^2/day$, the amount of power generation per day is calculated as 7.1 Ah/day for 25-Wp systems intended for ordinary households and as 23.5 Ah/day for 83 Wp systems for use by clinics. Using Equation 5.2-4, the time required for the battery to recover is calculated as 4.5 days for home systems and as 3.4 days for clinic systems. However, it goes without saying that if power is used to drive a load in course of recovery charging, recovery further lags behind. For this reason, if and when a shutdown of a PV system has occurred, due to over-discharge of the battery it is important that the user of the system takes appropriate action for several days subsequent to the system shutdown by making minimum use of power from the battery.

(4) Determining the Basic Specifications of the PV System

1) PV Module Characteristics

The PV modules used in systems employing a 12 V storage battery, generally have an open circuit voltage (Voc) around 21.6 V. Such modules consist of 36 PV cells connected in series.

The parameters used for specifying PV modules are:

Open circuit voltage (Voc), short circuit current (Isc), maximum output (Pm), maximum output operating voltage (Vpm), maximum output operating current (Ipm), conversion efficiency (η).

These values are determined under standard test conditions which are rarely found in actual use and panel characteristics are almost always observed to be poorer than the specified values. Standard conditions are defined as a cell temperature of 25 degrees Celsius; solar irradiation of 1000 W/m^2; irradiation at right angles to the cell surface, and the spectral distribution that of daylight at air mass 1. In the case of small-scale self-contained PV systems, DC load systems using 12-volt storage batteries are predominantly used. In the case of utilization in 12 V DC circuitry, PV modules have similar voltage characteristics irrespective of their capacity ratings — typically 21 V to 22 V open-circuit voltage and the peak output voltage. They differ primarily in their current characteristics, which depends on their Wp capacity ratings. For ordinary circuit designs, this current characteristic alone suffices, but for PV system design, it is required to know the voltage-vs.-current characteristics, or I-V curves, of the PV modules in order to match loads, such as storage batteries, with the panel for maximum energy transfer.. Since these curves were unavailable for the panels to be used, the JICA study team has made the required measurements.

Although special-purpose measurement equipment is best used for the determination of the current-vs.-voltage (IV) characteristics of PV modules, that equipment was not available to the study team so we have conducted simplified characteristic measurements using a solarimeter and a data logger. This operation is good enough to get a reasonable idea of the PV characteristics for our design purposes. Fig.3-2 and Fig.3-3 show the settings in which IV characteristic measurements were conducted.

The specifications of the PV modules that were used in the JICA pilot project systems are as follows:

System for clinics: 83 Wp panels:

Open-circuit voltage (Voc): 21.4 V   Voltage at maximum power point (Vpm): 16.9 V

Short-circuit current (Isc): 5.35 A	Current at maximum power point (Ipm): 4.91 A
Peak output power (Pm): 83 W	

System for homes: 25 Wp type

Open-circuit voltage (Voc): 21.4 V	Voltage at maximum power point (Vpm): 16.9 V
Short-circuit current (Isc): 1.69 A	Current at maximum power point (Ipm): 1.53 A
Peak output power (Pm): 25 W	

2) Determining the Storage Battery Characteristics and Charge Controller Specifications

When determining the operating specifications for the charge controller, it is important to have accurate data on the characteristics of the battery. However, we were unable to obtain any technical data for the locally produced batteries to be used in the project.

Consequently, we carried out simple discharge tests to measure the discharge capacity and voltage drop characteristics of the batteries to be used. Based on the results of these tests, the voltage level settings of the charge controller were determined as listed below, in order to match the observed battery characteristics.

High-voltage disconnection (HVD): 14.5 V	Low-voltage disconnection (LVD): 11.5 V
High-voltage reconnection (HVR): 13.5 V	Low-voltage reconnection (LVR): 12.5 V

We note that the above voltage setting levels, i.e. high-voltage cutoff (HVD) and low-voltage cutoff (LVD) at 2.417 V and 1.917 V, respectively, per unit cell are appropriate values suited for the normal operation of lead-acid storage batteries in general.

It is obvious that the smaller the power of the charge controller consumes for its own use, the better. Considering that the smallest PV system is rated at 25 Wp, it was necessary to keep the charge controller's average self-consuming current to 15 mA/h or less since the expected output of the 25 Wp PV system is approximately 85 Wh/day (corresponding to 7.1 Ah for a 12-volt system) and we allow the charge controller's self-consumption be no more than 5 percent of the total energy available, this corresponds to 360 mAh, or 15 mA average current for 24-hour continuous use.

3) Determining the Basic Specifications of System and Equipment

Based on the results of the tests described above, the specifications for the pilot project PV systems were determined. They are listed below.

a) Clinic System

Either two or three PV systems were installed per clinic, depending on the size, the room layout and the intended application.

PV module to be used : 83 Wp, single panel
Required battery capacity : 100 Ah/12 V (deep cycle type)
Usable load : Max. 180 Wh/day (15 Ah/day)
Number of fluorescent lamps and usable illumination duration: two 11 W lamps, 4 hours each; two 9 W lamps, 4 hours each; two 7 W lamps, 1 hour each

b) General home system

PV module to be used : 25 Wp, single panel
Required battery capacity : 40 Ah/12 V (40 Ah deep cycle type, 50 systems; 60 Ah automobile type, 50 systems)
Usable load : Max. 55 Wh/day (4.6 Ah/day)
Number of fluorescent lamps and usable illumination duration: two 7 W lamps, max 2 hours each

c) School system

For schools, systems identical to the clinic systems were used with the number of systems determined by the size of the school and its needs for lighting.

Table 3-7 is a listing of the parts procured for use in the systems decided upon.

3.2 Monitoring System

3.2.1 Methodology

There were two methods used for monitoring the PV systems.

First, data loggers were installed to record technical data such as current, voltage, irradiation values, energy generated, energy used by the loads, and the charge/discharge characteristics of the battery. The data loggers were powered by integral dry batteries and could record data for about half a year before batteries needed to be replaced. Collection and analysis of data was done during the Study Team's scheduled field studies in Zimbabwe, assisted by the counterpart as part of the technical transfer aspect of the study. The data logger was securely placed inside an interface box to prevent tampering. The method of connecting the data recording system is shown in Figure 3-12.

Second, using the services of local technicians, PV systems were periodically checked and maintained. Details of these regular surveys are discussed in the following section.

3.2.2 Scope

Monitoring has been carried out by BUN. In the initial phase (following approval of the contents of the investigation and survey methodology at Harare), however, the Study Team accompanied the BUN representatives for a few days. Subsequent monitoring was done on a monthly basis by the BUN technicians. During every investigation, basic data like the owner's name, data and time of investigation, weather on the day of investigation and two days before, and temperature was recorded. Specific items surveyed are as follows:

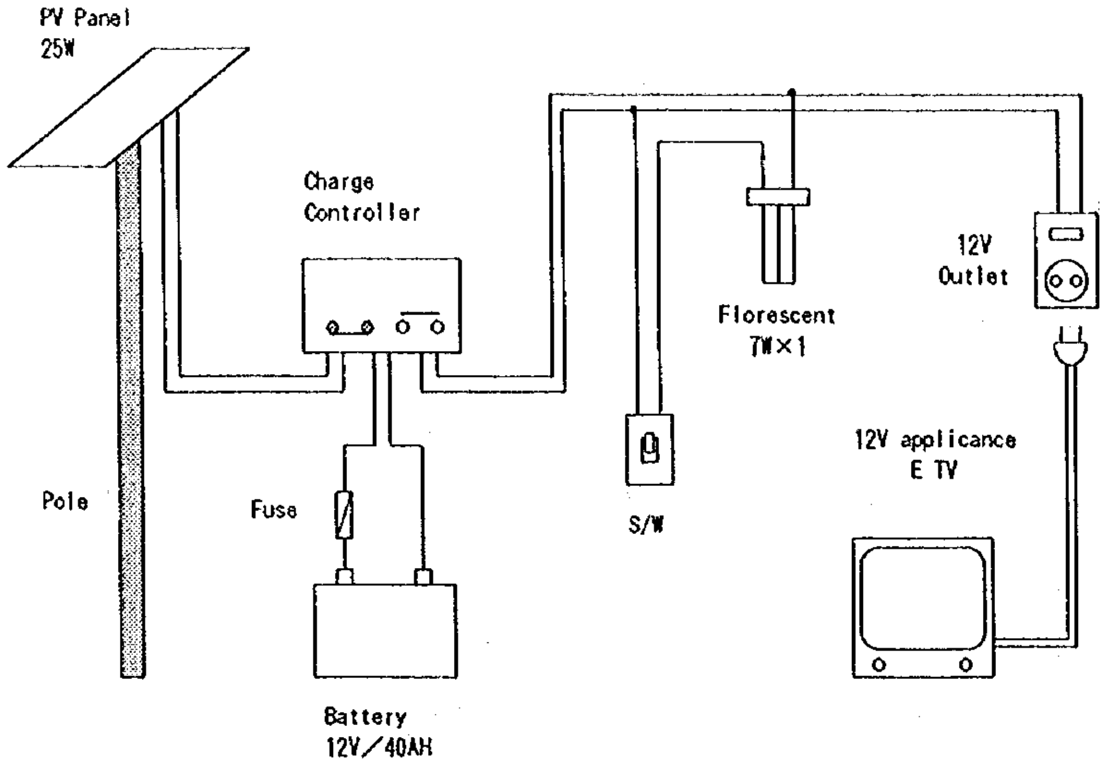


Fig.3-9 General Household Use PV System (1)

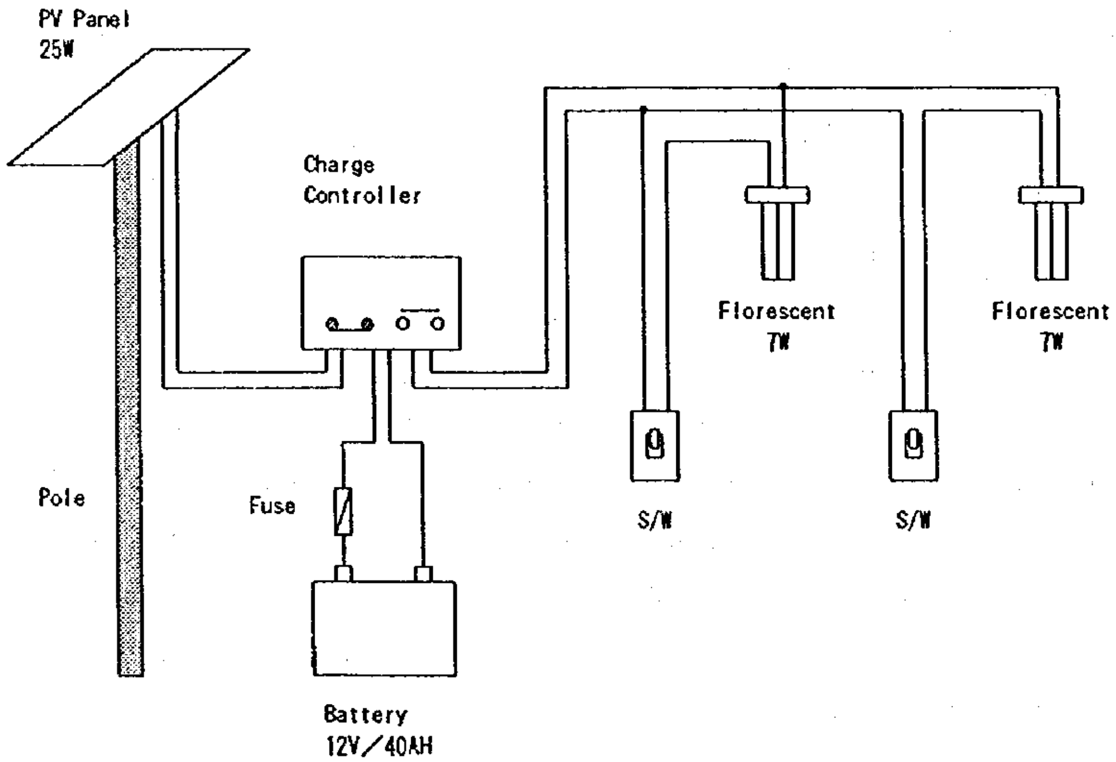


Fig.3-10 General Household Use PV System (2)

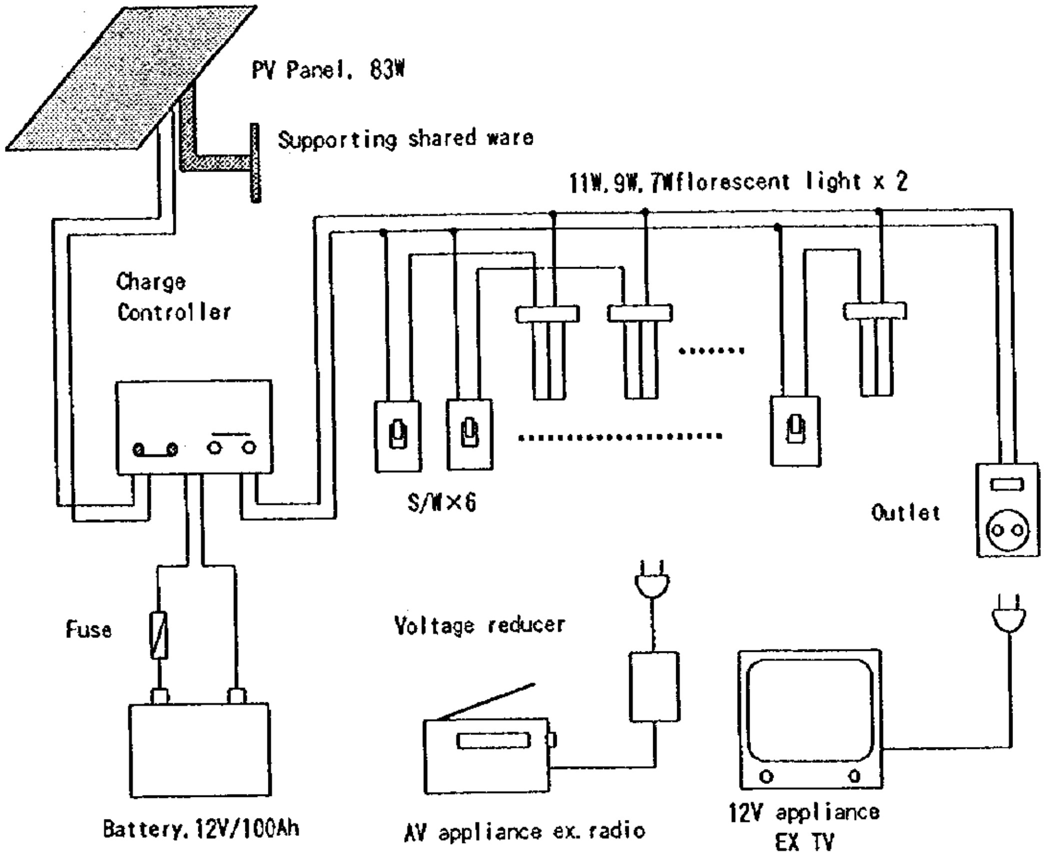
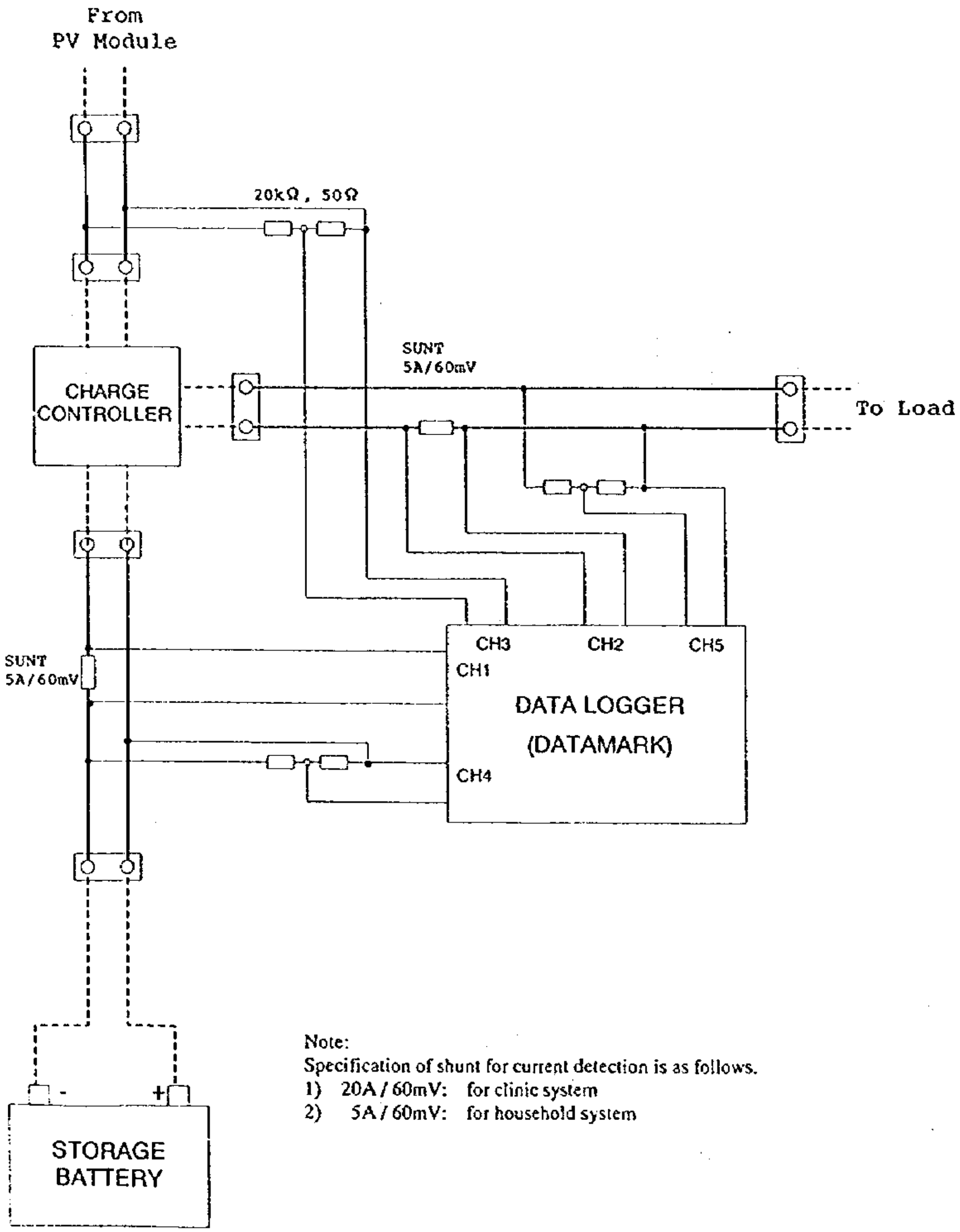


Fig.3-11 Clinic PV System configuration



Note:
Specification of shunt for current detection is as follows.
1) 20A / 60mV: for clinic system
2) 5A / 60mV: for household system

Fig3-12 Conenction Diagram of an Interface For a Data Acquisition System

Table 3-7 (A) Material List for PV Monitoring System (For 10 clinics)

Number of set 30

No.	Name of instrument	Type or specification	Maker	Q'ty/unit		Total Q'ty		Note
1	PV module	MSX83 83W	Sollatek	1	pieces	30	pieces	
2	Battery	12V, 100Ah (deep cycle MF type)	Battery world	1	pieces	30	pieces	
3	Charge controller	SOLAR REGULATOR (Modified Type for JICA)	Battery world	1	pieces	30	pieces	LVD=11.5V±0.05V, LRC=12.5V±0.05, HVD=14.5±0.05V, C/CRC=13.5V±0.05
4	Fluorescent light	11W, 12Vdc with inverter (for 4pins) Model: SLH	Sollatek	2	pieces	60	pieces	
	Fluorescent light	9W, 12Vdc with inverter (for 4pins) Model: SLH	Sollatek	2	pieces	60	pieces	
	Fluorescent light	7W, 12Vdc with inverter (for 4pins) Model: SLH	Sollatek	2	pieces	60	pieces	
5	Voltage dropper	For radio (Vin: 12V, Vout: 9V), with ac plug and dc plug for radio	Sollatek	1	pieces	30	pieces	Voltage dropper shall be plug connected type (ac plug and dc plug for radio)
6	Battery box	Made of wood (W D H) for 1 pieces of 100Ah batteries	Battery world	1	pieces	30	pieces	
7	Fluorescent light bulb for spare parts	11W, 12Vdc for 4pins	Philips	3	pieces	90	pieces	
	Fluorescent light bulb for spare parts	9W, 12Vdc for 4pins	Philips	3	pieces	90	pieces	
	Fluorescent light bulb for spare parts	7W, 12Vdc for 4pins	Philips	3	pieces	90	pieces	
8	Fuse for spare parts	5A for car use (For FL lamp)		3	pieces	90	pieces	Car type fuse
9	Fuse for spare parts	20A for car use (For battery)		3	pieces	90	pieces	Car type fuse
10	Distilled water for battery			5	litter	150	litter	
11								
12	Material for installation	All necessities for installation except mentioned below	Installer	1	sets	30	sets	Tilt angle of PV array shall be 17.5 degree ±2.5 degree.
13	Ditto	Wall socket	Installer	1	pieces	30	pieces	
14	Ditto	Fuse (5A) with socket for FL lamp	Installer	6	pieces	180	pieces	Car type fuse
15	Ditto	Fuse (20A) with socket for battery	Installer	1	pieces	30	pieces	Car type fuse
16								
17	Installation work	Above 2×83W PV, 12 lights and 2 wall socket system	Installer	1	sets	30	sets	12 lights system
18	Transportation to the site	km	Installer	1	sets	30	sets	

Table 3-7 (B) Material List for PV Monitoring System (For 2 schools)

Number of set 8

No.	Name of instrument	Type or specification	Maker	Q'ty/unit		Total Q'ty		Note
1	PV module	MSX83 83W	Sollatek	1	pieces	8	pieces	
2	Battery	12V, 100Ah (deep cycle MF type)	Battery world	1	pieces	8	pieces	
3	Charge controller	SOLAR REGULATOR (Modified Type for JICA)	Battery world	1	pieces	8	pieces	LVD=11.5V±0.05V, LRC=12.5V±0.05, HVD=14.5±0.05V, C/CRC=13.5V±0.05
4	Fluorescent light	11W, 12Vdc with inverter (for 4pins) Model: SLH	Sollatek	2	pieces	16	pieces	
	Fluorescent light	9W, 12Vdc with inverter (for 4pins) Model: SLH	Sollatek	2	pieces	16	pieces	
	Fluorescent light	7W, 12Vdc with inverter (for 4pins) Model: SLH	Sollatek	2	pieces	16	pieces	
5	Voltage dropper	For radio (Vin: 12V, Vout: 9V), with ac plug and dc plug for radio	Sollatek	1	pieces	8	pieces	Voltage dropper shall be plug connected type (ac plug and dc plug for radio)
6	Battery box	Made of wood (W D H) for 2 pieces of 100Ah batteries		1	pieces	8	pieces	
7	Fluorescent light bulb for spare parts	11W, 12Vdc for 4pins	Philips	3	pieces	24	pieces	
	Fluorescent light bulb for spare parts	9W, 12Vdc for 4pins	Philips	3	pieces	24	pieces	
	Fluorescent light bulb for spare parts	7W, 12Vdc for 4pins	Philips	3	pieces	24	pieces	
8	Fuse for spare parts	5A for car use (For FL lamp)		3	pieces	24	pieces	Car type fuse
9	Fuse for spare parts	20A for car use (For battery)		3	pieces	24	pieces	Car type fuse
10	Distilled water for battery			5	litter	40	litter	
11								
12	Material for installation	All necessities for installation except mentioned below	Installer	1	sets	8	sets	Tilt angle of PV array shall be 17.5 degree ±2.5 degree.
13	Ditto	Wall socket	Installer	1	pieces	8	pieces	
14	Ditto	Fuse (5A) with socket for FL lamp	Installer	6	pieces	48	pieces	Car type fuse
15	Ditto	Fuse (20A) with socket for battery	Installer	1	pieces	8	pieces	Car type fuse
16								
17	Installation work	Above 2×83W PV, 12 lights and 2 wall socket system	Installer	1	sets	8	sets	12 lights system
18	Transportation to the site	km	Installer	1	sets	8	sets	

Table 3-7(C) Material List for PV Monitoring System (For 100 housholds)

Number of set 100

No.	Name of instrument	Type or specification	Maker	Q'ty/unit		Total Q'ty		Note
1-1	PV module	MM250-A, 25W	Anit	1	pieces	100	pieces	
2-1	Battery	12V, 60Ah (For car use)	Battery world	1	pieces	50	pieces	
2-2	Battery	12V, 40Ah (For deep cycle MF type)	Battery world	1	pieces	50	pieces	
3-1	Charge controller	SOLAR REGULATOR (Modified Type for JICA)	Battery world	1	pieces	50	pieces	LVD=11.7V±0.05V, LRC=12.7V±0.05, HVD=14.5±0.05V, C/CRC=13.5V±0.05
3-2	Charge controller	SOLAR REGULATOR (Modified Type for JICA)	Battery world	1	pieces	50	pieces	LVD=11.5V±0.05V, LRC=12.5V±0.05, HVD=14.5±0.05V, C/CRC=13.5V±0.05
4	Fluorescent light	7W, 12Vdc with inverter (for 4pins), Model: SLH	Sollatek	2	pieces	200	pieces	
5	Voltage dropper	For radio (Vin: 12V, Vout: 9V), with ac plug and dc plug for radio	Sollatek	1	pieces	100	pieces	Voltage dropper shall be plug connected type (ac plug and dc plug for radio)
6	Battery box	Made of wood (W D H) for 60Ah battery	Battery world	1	pieces	100	pieces	
7	Fluorescent light bulb for spare parts	7W, 12Vdc for 4pins	Philips	5	pieces	500	pieces	
8	Fuse for spare parts	5A for car use (For FL lamp)		5	pieces	500	pieces	Car type fuse
9	Fuse for spare parts	10A for car use (For battery)		5	pieces	500	pieces	Car type fuse
10	Distilled water for battery	1 litter bottle		1	litter	100	litter	
11								
12	Material for installation	All necessities for installation except mentioned below	Installer	1	sets	100	sets	Tilt angle of PV array shall be 17.5 degree ±2.5 degree.
13	Ditto	Wall socket	Installer	1	pieces	100	pieces	
14	Ditto	Fuse (5A) with socket for FL lamp	Installer	2	pieces	200	pieces	Car type fuse
15	Ditto	Fuse (10A) with socket for battery	Installer	1	pieces	100	pieces	Car type fuse
16								
17	Installation work	Above 25W PV, 2 lights and 1 socket system	Installer	1	sets	100	sets	Two lights and one wall soket with voltage dropper system.
18	Transportation to the site	km	Installer	1	sets	100	sets	

(1) Battery

- ❑ Terminal voltage;
- ❑ Specific gravity and temperature of battery electrolytic solution; and,
- ❑ Level of battery electrolytic solution.

For safety considerations, checking of the above items was carried out after extracting the fuse to cut of charging and load currents.

(2) Condition of the PV system

- ❑ Whether the system is operating or not
- ❑ Whether fluorescent lamps have been damaged or not, or if the tube has been replaced or not
- ❑ Whether the system has been shut down due to low voltage or not
- ❑ Whether or not there have been any loose terminals found
- ❑ Other unusual conditions noted or complaints by users

(3) Site Inspection

- ❑ Whether the PV module is facing north or not
- ❑ Confirmation of the charge controller indicator (where present)
- ❑ Cleanliness of batteries
- ❑ Time patterns of electricity use

  Kitchen, Bedroom, Radio, etc. (Households)

  Consultation room, office, etc. (Clinics)

  Classroom, staff room, others, etc. (Schools)

(4) Inspection of PV system component parts and spare parts

- ❑ Whether all items appear normal or not; and

Confirm whether any parts are lost or not.