

**JAPAN INTERNATIONAL COOPERATION AGENCY
MINISTRY OF MINERALS, ENERGY AND WATER
RESOURCES
ENERGY AFFAIRS DIVISION
THE REPUBLIC OF BOTSWANA**



Republic of Botswana

**FINAL REPORT
FOR
THE MASTER PLAN STUDY
ON
PHOTOVOLTAIC RURAL ELECTRIFICATION
IN
THE REPUBLIC OF BOTSWANA**

FEBRUARY, 2003

**UNICO INTERNATIONAL CORPORATION
ELECTRIC POWER DEVELOPMENT CO., LTD.**

Preface

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

JICA sent to Botswana a study team headed by Mr. Isao Shizuma, UNICO International Corporation, and organized by UNICO International Corporation and Electric Power Development Co., Ltd. from September 2000 to February 2003.

The team held discussions with the officials concerned of the Government of Botswana and conducted a series of field study. After its return to Japan, the team conducted further studies and compiled the results in this report.

I hope this report will be utilized for contributing to the master plan formulation and implementation of photovoltaic rural electrification in Botswana.

I wish to express my sincere appreciation to all those who participated in this study project for their close cooperation with the team.

February 2003



Takao Kawakami

President

Japan International Cooperation Agency

February 2003
President
Japan International Cooperation Agency
Tokyo, Japan

Dear Mr. Kawakami

Letter of Transmittal

We are pleased to submit to you a final report on “ The Master Plan Study on Photovoltaic Rural Electrification in the Republic of Botswana.” The report reflects opinions and views of the Energy Affairs Division of the Ministry of Minerals, Energy and Water Resources, and other government offices and organizations, as well as Japanese government offices and organizations concerned.

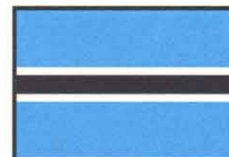
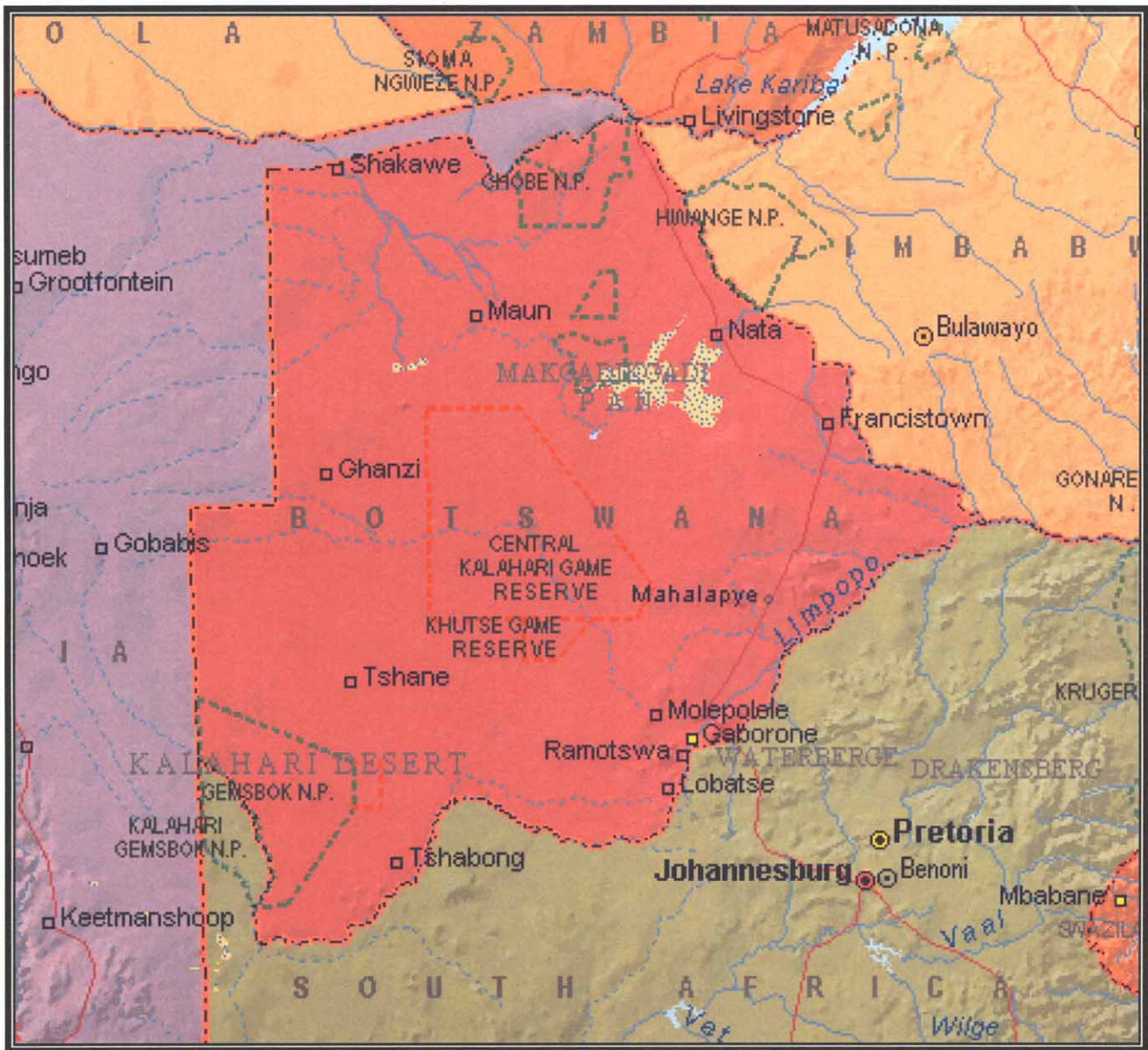
The report proposes a photovoltaic rural electrification plan for the entire country and an implementation plan to carry out rural electrification as a feasible project. We firmly believe that the plan will contribute greatly to promotion of social equality and rural development. In particular, when the proposal made in this report is realized as part of the Ninth National Development Plan, which will start in 2003, it will help promote the rise in standards of living and industrial development in the country.

Finally, we would like to express our gratitude to your agency, the Ministry of Foreign Affairs, and the Ministry of Economy and Industry for extensive support and guidance.

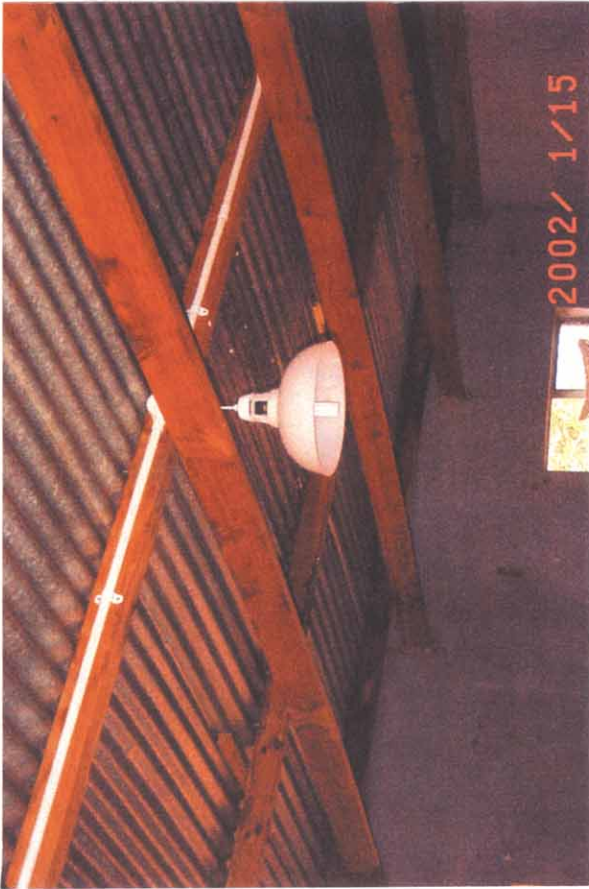
Very truly yours,

静間 勇夫

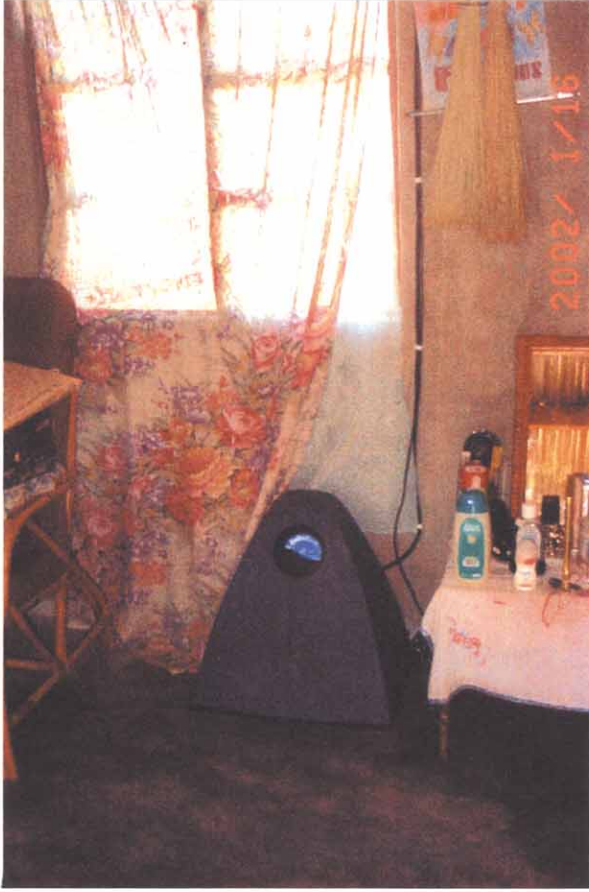
Isao Shizuma
Team Leader,
The Master Plan Study on
Photovoltaic Rural Electrification
in The Republic of Botswana



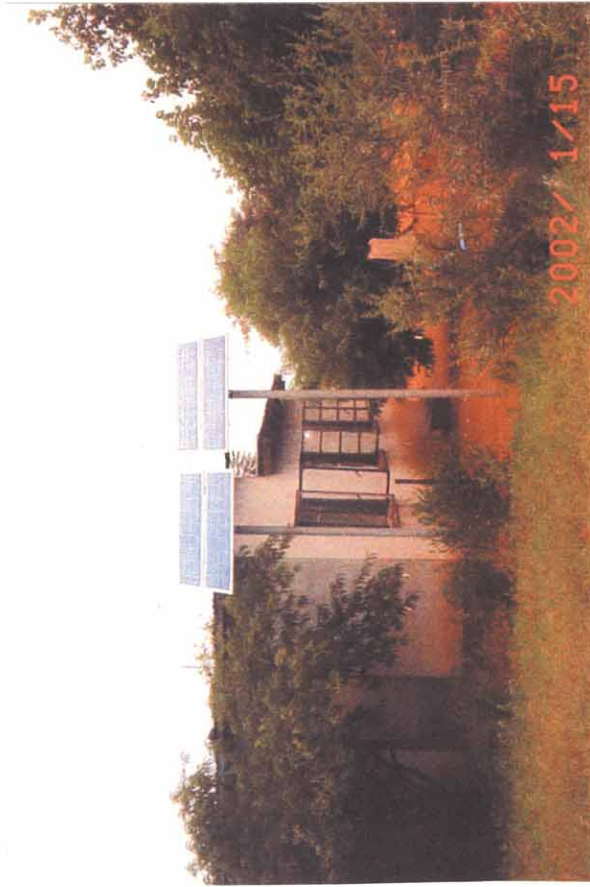
**REPUBLIC
OF
BOTSWANA**



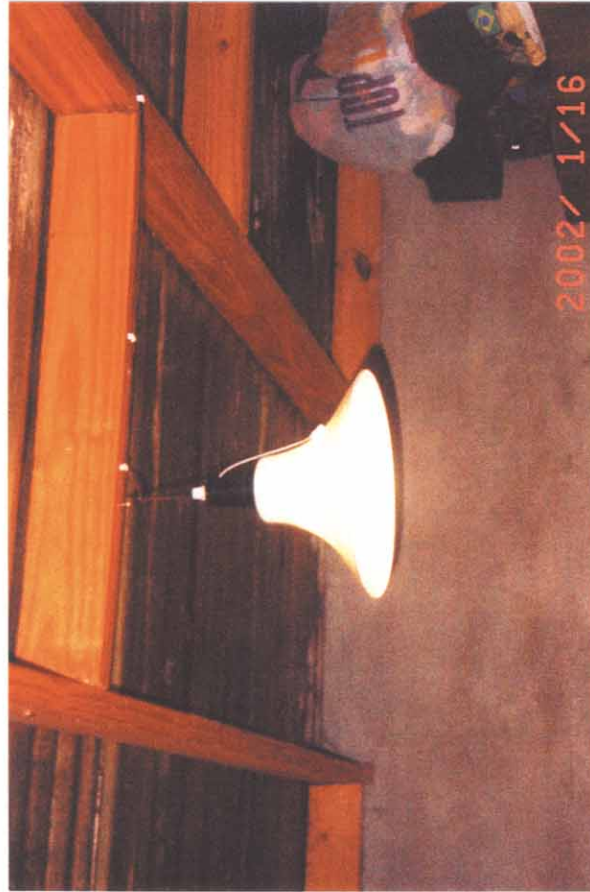
AC Light (11W)



Prepaid Card System (Battery/Controller are contained inside)



200Wp SHS AC (50Wp x 4 panels)

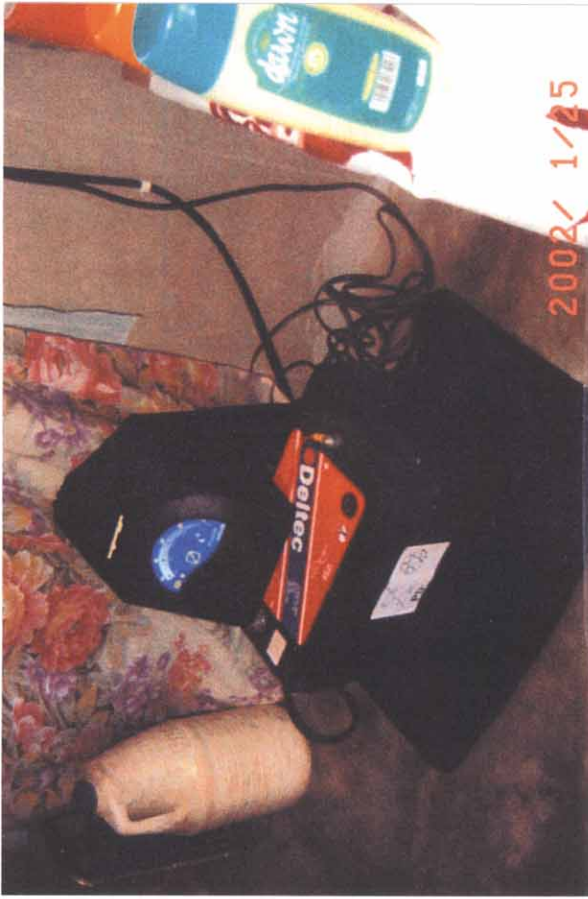


DC Light (11W)



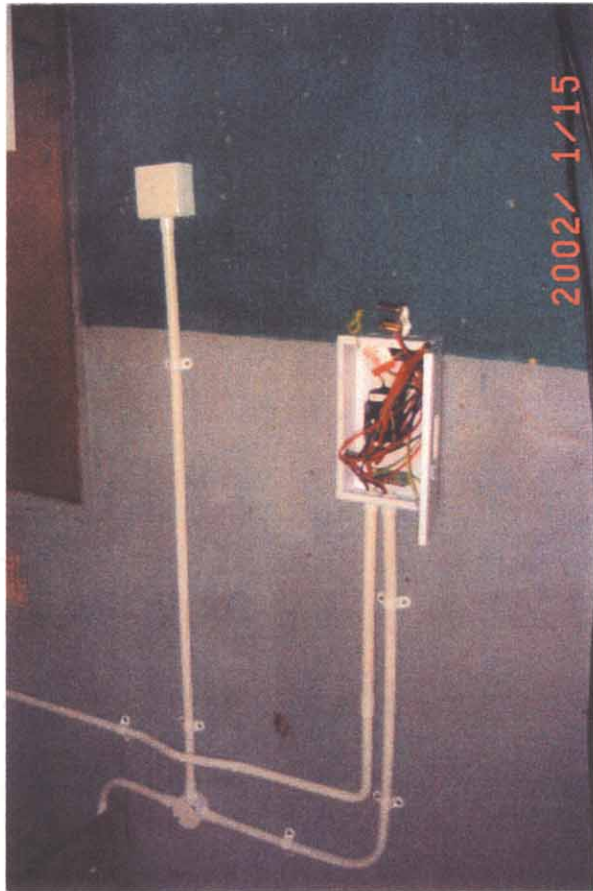
2002/ 1/16

50Wp SHS DC



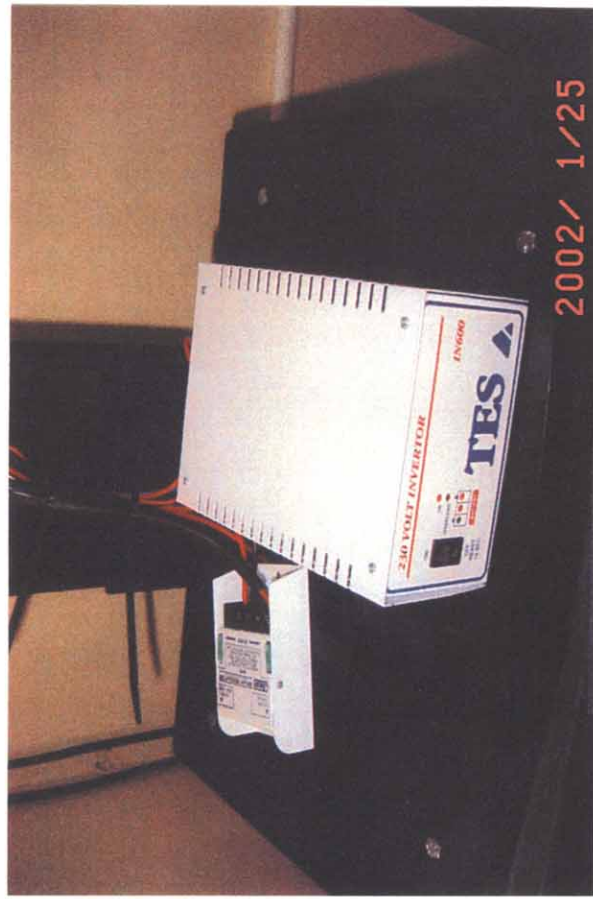
2002/ 1/25

Prepaid Card System (DC system, Battery/Controller are contained inside)



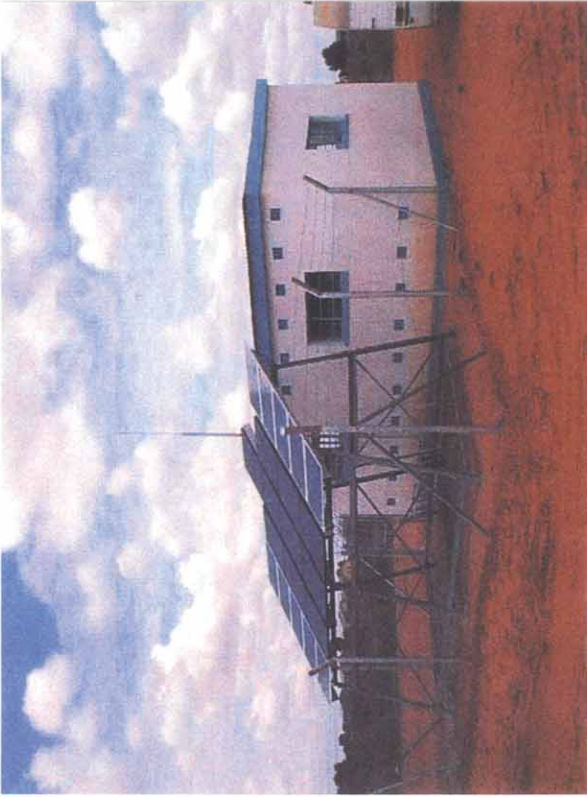
2002/ 1/15

AC interior wiring

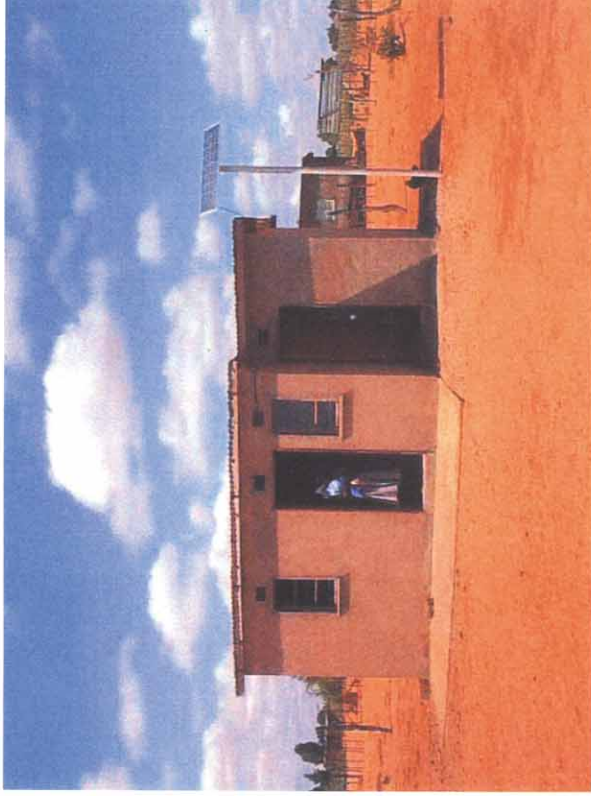


2002/ 1/25

Prepaid Card System (AC system, Inverter/Controller are contained inside)



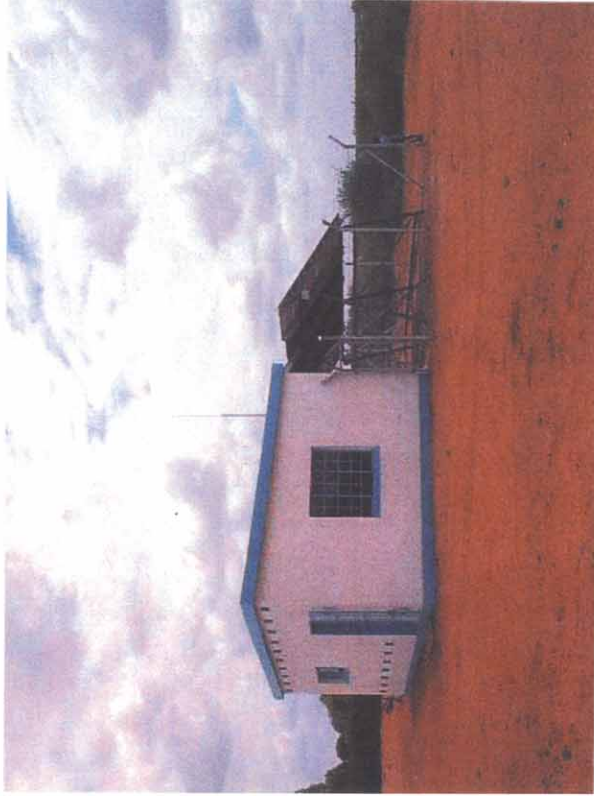
Battery Charging Station PV panels
(60Wp multi-crystalline x 10 panels, 50Wp Amorphouse x 10 panels)



50Wp SHS whole view



Indoor view of Battery Charging Station



Battery Charging Station whole view

Acronyms & Nomenclature

(1/2)

Acronyms	Nomenclature
AC	Alternating Current
BCS	Battery Charge Station
BEMP	Botswana Energy Master Plan
BOS	Balance of System
BoTeC	Botswana Technology Center
BPC	Botswana Power Corporation
BTC	Botswana Telecommunication Corporation
DC	Direct Current
DEMS	Department of Electrical and Mechanical Services
DVET	Department of Vocational Education and Training
DWA	Department of Water Affairs
EAD	Energy Affairs Division of MMEWR
EIRR	Economic Internal Rate of Return
ESCO	Electricity Supply Company
ESMAP	The Energy Sector Management Assistance Program sponsored by WB and UNDP with financial participation from public and private donors
FED	Final Energy Demand
FIRROI	Financial Internal Rate of Return on Investment
GDP	Gross Domestic Product
GEF	Global Environmental Facility
HIES	Households Income and Expenditure Survey made in 1993/1994
IEC	International Electrotechnical Commission
IFC	International Finance Corporation
IMF	International Monetary Fund
IRR	Internal Rate of Return on Investment
JICA	Japan International Cooperation Agency
LPG	Liquefied Petroleum Gas
MCST	Ministry of Communications, Science and Technology
MFDP	Ministry of Finance and Development Planning
MLG	Ministry of Local Government
MLHE	Ministry of Lands, Housing and Environment
M/M	Minutes of Meeting
MMEWR	Ministry of Minerals, Energy and Water Resources
MOA	Ministry of Agriculture
MOE	Ministry of Education
MSP	Ministry of State President
MWTC	Ministry of Works, Transportation and Communication
NCC	National Crafts Certificate
NDP	National Development Plan (Currently NDP8 : The 8th NDP)
NGO	Non Governmental Organization
NPV	Discounted Net Present Value
NPV-REP	National PV - Rural Electrification Program
NRSE	New and Renewable Sources of Energy
PES	Primary Energy Supply
PV	Photovoltaic Electricity
RCS	Rural Electrification Collective Scheme

Acronyms & Nomenclature

(2/2)

Acronyms	Nomenclature
RE	Rural Electrification
RIIC	Rural Industries Innovation Center
RIPCO	Rural Industries Promotion Company
ROI	Return on Investment
RSA	Republic of South Africa
S/W	Scope of Work
SADC	Southern African Development Community
SAPP	Southern African Power Pool
SHS	Solar Home System
TC	Technical College
T/L	Transmission Line
TV	Television
UN	United Nations
UNDP	United Nations Development Program
USD	United States Dollar
VAC	Village Advisory Committee
VDC	Village Development Committee
VTC	Vocational Training Center
WB	World Bank

Unit

Acronyms	Nomenclature	Conversion Factor
\$	Unites States Dollar	
P	Pula	Exchange Rate \$1 = P6.5
Th	Thebe	1/100 P
R	Rand (RSA)	R1 = ¢ 100
T	Tera	10^{12}
G	Giga	10^9
M	Mega	10^6
k	kilo	10^3
h	hour	
m	month	
y	year	
A	Ampare	
V	Volt	
W	Watt	
Wp	Watt peak of PV module	
J	Joule	$1\text{kWh} = 3.6 \times 10^6 \text{ J}$

Table of Contents

Chapter 1 Introduction

1.1	Background and Objective of the Study.....	1 - 1
1.2	Objective of the Study.....	1 - 3
1.3	Study Area.....	1 - 3
1.4	Implementation Phases.....	1 - 3
1.5	General Outline of the Report	1 - 3

Chapter 2 Overview of Botswana, Energy and Power Sector

2.1	Overview of the Country of Botswana.....	2 - 1
2.1.1	Political and Administrative Situation.....	2 - 1
2.1.2	Geographical Situation	2 - 2
2.1.3	People	2 - 3
2.1.4	Economic Situation	2 - 4
2.1.5	Current Government Vision and Policies on the Development Program.....	2 - 4
2.2	Overview of Energy Sector	2 - 6
2.2.1	Overview of Botswana Energy Sector.....	2 - 6
2.2.2	Energy Policy	2 - 8
2.2.3	Overview of the Power Sector in Botswana.....	2 - 10
2.2.4	Overview of Grid and Diesel Mini-grid Rural Electrification.....	2 - 13
2.2.5	Overview of PV Rural Electrification	2 - 15

Chapter 3 Goals and Objectives of PV Rural Electrification Master Plan

3.1	Role of PV Electrification	3 - 1
3.2	Goals for PV Rural Electrification Master Plan	3 - 2
3.3	Objectives for PV Rural Electrification Master Plan	3 - 3

Chapter 4 Development Process for the Master Plan for PV Rural Electrification

Chapter 5 Institutional Framework for Promotion of PV Rural Electrification

5.1	Present Division of Authority and Responsibility Among Administrative Entities.....	5 - 1
-----	---	-------

5.2	Establishment of the New Institutional Framework for Implementation of PV Rural Electrification	5 - 4
5.2.1	Management Lessons Learned from Ongoing PV Projects in Botswana and Other Countries.....	5 - 4
5.2.2	The Proposed Institutional Framework: Desirable Division of Responsibilities and Roles and Effective Alliance with Related Organizations.....	5 - 6
5.2.3	Selection of the PV-based Rural Electrification Project Implementation Body	5 - 8
5.2.4	Evaluation of the Candidate Organizations	5 - 9
5.2.5	Alliance with Related Organizations.....	5 - 11

Chapter 6 Socio-Economic Situations and PV Potential in Botswana Rural Areas

6.1	Definitions of Urban, Urban Villages, Rural Villages and Localities.....	6 - 1
6.2	Socio-Economic Survey	6 - 7
6.2.1	Object Areas of This Study	6 - 7
6.2.2	Surveyed Items and Methods	6 - 7
6.2.3	Socio-Economic Status.....	6 - 11
6.3	Survey on Localities.....	6 - 30
6.4	Socio-Economic Survey for Participants in the Dissemination Project	6 - 31
6.5	PV Market Potential	6 - 42
6.5.1	PV Demand by Size in Households.....	6 - 42
6.5.2	PV Demand by Size in Public Facilities.....	6 - 43
6.5.3	Willingness/Ability to Pay Curve Adopted	6 - 44

Chapter 7 Selection of the Target Villages for PV Electrification

7.1	PV Electrification Rate and Tariff Level.....	7 - 1
7.2	Least-cost Options for Rural Electrification.....	7 - 2
7.2.1	Rural Household Electricity Consumption.....	7 - 2
7.2.2	Cost Comparison of SHS Versus the Grid-based Electrification	7 - 4
7.2.3	Comparison of Cost Recovery of SHS Versus the Grid.....	7 - 5
7.2.4	Cost Comparison of SHS with PV Mini-grid Electrification	7 - 7

7.2.5	Selection of the Least Cost Option	7 - 8
7.3	Criteria for The Village Selection for PV Rural Electrification	7 - 9
7.4	Selection of PV Electrified Villages.....	7 - 10
7.4.1	Current Electrification Status of Villages and Localities	7 - 10
7.4.2	Selection of PV Electrified Villages.....	7 - 11
7.5	10-year PV Electrification Program	7 - 19
7.6	Total Electrification Rate achieved	7 - 25

Chapter 8 PV System Design and Environmental Measures

8.1	Current State of PV Related Technologies and Their Commercial Availability.....	8 - 1
8.2	Adequate Technology for PV Rural Electrification	8 - 1
8.3	Environment and Health Protection	8 - 3
8.3.1	Environmental Benefits of Solar Home Systems	8 - 3
8.3.2	Negative Environmental Impact.....	8 - 4
8.3.3	Recycling Required by Environmental Law	8 - 5

Chapter 9 Operation and Management of the PV Electrification System and Service

9.1	Service Delivery System	9 - 1
9.2	Organization of the Implementation Body	9 - 3
9.2.1	Establishment of the PV Project Management System and Division of Responsibilities:.....	9 - 3
9.3	Customer Service to be Provided by the Implementation Body and Tariff System	9 - 9
9.3.1	Content of Service	9 - 9
9.3.2	Tariff System	9 - 10
9.4	Contract and Operation Manuals.....	9 - 12
9.5	Supplier Contract.....	9 - 12
9.5.1	Scope and Duration of the Supplier Contract	9 - 12

Chapter 10 Manpower Development

10.1	Present Status of Manpower Development for PV Electrification.....	10 - 1
------	--	--------

10.1.1	Manpower Development in Central and Local Government Level.....	10 - 1
10.1.2	Manpower Development in the District Councils for PV Electrification.....	10 - 2
10.1.3	Needs of Manpower Development for the PV Electrification.....	10 - 3
10.2	The Status of Vocational Training.....	10 - 4
10.3	Strategies for Manpower Development.....	10 - 8

Chapter 11 Financial Planning

11.1	Situation of the Finance Sector of Botswana.....	11 - 1
11.2	Possibilities of Financing from the Financial Sector.....	11 - 4
11.2.1	Lending Conditions of Financial Institutions.....	11 - 4
11.2.2	Possibilities of Financing PV Rural Electrification.....	11 - 4
11.2.3	Possibilities of Direct Finance.....	11 - 5
11.3	Financial Planning.....	11 - 5

Chapter 12 PV Rural Electrification Project Planning and Implementation

Procedures

12.1	Project Planning and Implementation Procedures.....	12 - 1
12.2	Implementation Schedule.....	12 - 4

Chapter 13 PV Rural Electrification Project Planning Model and

Financial/Economic Analysis

13.1	Project Model.....	13 - 1
13.1.1	Objective of the Project Model.....	13 - 1
13.1.2	Project Model.....	13 - 1
13.2	Financial Analysis.....	13 - 10
13.2.1	Basic Assumptions for Financial Analysis.....	13 - 10
13.2.2	Case Study.....	13 - 11
13.2.3	Financial Analysis.....	13 - 14
13.3	Economic Analysis.....	13 - 32
13.4	Recommendations.....	13 - 38

Chapter 14 Implementation Strategies for PV Rural Electrification

14.1 Institutional and Policy Support Measures for Promotion of the Ongoing PV Rural Electrification Project	14 - 1
14.2 Recommendations on Policy Framework and Incentives.....	14 - 6
14.3 Objectives and Strategies for PV Rural Electrification Master Plan.....	14 - 7
14.3.1 Objective-1: To supply solar electricity, quickly and under affordable conditions, to households in rural areas that cannot benefit from grid electrification and other energy supply services.....	14 - 7
14.3.2 Objective-2: To implement the PV rural electrification project at the least practicable cost and in a financially feasible and sustainable manner.....	14 - 8
14.3.3 Objective-3: Integration with infrastructure projects required for a specific region or area.....	14 - 9
14.3.4 Objective-4: Expansion of environmentally friendly energy use	14 - 10

【List of Tables】

Table 2.2-1	Generated Power by Power Station Facilities.....	2 - 11
Table 2.2-2	Sales Growth (%).....	2 - 12
Table 2.2-3	Credit Scheme of RCS	2 - 14
Table 2.2-4	PV Rural Electrification Projects in Botswana	2 - 17
Table 6.1-1	Administration Districts.....	6 - 1
Table 6.1-2	Census Districts.....	6 - 2
Table 6.1-3	Population of Urban Villages.....	6 - 3
Table 6.1-4	Population in Botswana	6 - 4
Table 6.1-5	Population Movement of Towns, Villages, Localities.....	6 - 5
Table 6.1-6	Population Movement of Large Village.....	6 - 6
Table 6.2-1	10 Villages for Socio-economic Survey	6 - 8
Table 6.2-2	Number of Income Source of Households	6 - 12
Table 6.2-3	Cash Income Distribution by Income Source (Percent)	6 - 13
Table 6.2-4	Total Cash Income Distribution (P/m).....	6 - 14
Table 6.2-5	Households Expenditure in Month.....	6 - 15
Table 6.2-6	Fuel for Lighting Expenditure.....	6 - 16

Table 6.2-7	Energy for Appliances and Expenditure Levels.....	6 - 16
Table 6.2-8	Willingness to Pay by Village.....	6 - 17
Table 6.2-9	Time Frame for PV Demands by Village	6 - 19
Table 6.2-10	System Size for which Households are Able to Pay	6 - 20
Table 6.2-11	Max. Deposit and Max. Monthly Payment (unit : P)	6 - 20
Table 6.2-12	Public Facilities Surveyed.....	6 - 22
Table 6.2-13	PV Lighting Requirements in Public Facilities.....	6 - 24
Table 6.2-14	Appliance PV Requirements for Public Facilities	6 - 24
Table 6.2-15	Economic Activities for which PV can be used as Energy Source.....	6 - 25
Table 6.2-16	Reasons Given by Public Facilities for Willing to Use PV System.....	6 - 25
Table 6.2-17	System Size Preferred by Public Facilities	6 - 26
Table 6.2-18	Main Income Source of PV System Owners.....	6 - 27
Table 6.2-19	Income Ranges by Income Source.....	6 - 28
Table 6.3-1	The Localities Surveyed.....	6 - 30
Table 6.4-1	Number of Samples.....	6 - 31
Table 6.4-2	Occupation	6 - 32
Table 6.4-3	Ownership of Premises	6 - 32
Table 6.4-4	Housing Structure	6 - 33
Table 6.4-5	Family Size, No. of Rooms, No. of Lighting Points.....	6 - 33
Table 6.4-6	Number of Income Source	6 - 34
Table 6.4-7	Cash Income Distribution by Income Source	6 - 35
Table 6.4-8	Cash Income Distribution	6 - 36
Table 6.4-9	Household Expenditure in a Month	6 - 38
Table 6.4-10	Expenditure for Fuels.....	6 - 39
Table 6.4-11	Expenditure Level for Electric Appliance.....	6 - 40
Table 6.4-12	Awareness on PV System	6 - 40
Table 6.4-13	Willingness to Pay	6 - 41
Table 6.4-14	PV Demand by Size in the Dissemination Project.....	6 - 41
Table 6.5-1	PV Demand by PV size.....	6 - 42
Table 6.5-2	Min. and Max. Demands for Public Facilities per One Village.....	6 - 43
Table 6.5-3	PV Demands of Public Facilities	6 - 44
Table 6.5-4	Dissemination Project: Monitoring Results Summary.....	6 - 45
Table 6.5-5	Willingness/Ability to pay (yearly movement).....	6 - 47

Table 7.2-1	Power Consumption Ladder.....	7 - 3
Table 7.2-2	Comparison of Grid Extension and SHS (Case Study in 72 Village Electrification)	7 - 6
Table 7.4-1	Current Electrification Status of Villages and Localities.....	7 - 12
Table 7.4-2	Villages and localities that are eligible for grid electrification	7 - 12
Table 7.4-3	Priority Setting Parameters	7 - 15
Table 7.4-4	Rating of Villages and Localities by Number.....	7 - 16
Table 7.4-5	Rating of Villages and Localities by Population (2001 Population Census).....	7 - 16
Table 7.5-1-1	Preliminary Selection of Villages and Localities by Zone and Year	7 - 20
Table 7.5-1-2	Preliminary Selection of Villages, Localities and Population by Zone and Year	7 - 21
Table 7.5-2	PV System Installation Plan.....	7 - 23
Table 7.6-1	Total Electrification Rate by means of Grid and PV Electrification.....	7 - 26
Table 8.3-1	Greenhouse Gas Generation Reduction	8 - 4
Table 9.2-1	The Scope of Works and Split of Responsibilities for Implementation of PV Rural Electrification	9 - 7
Table 9.3-1	Fee for Services.....	9 - 11
Table 11.1-1	Assets of Commercial Banks.....	11 - 2
Table 11.1-2	Assets of Major Parastatal Development Banks	11 - 2
Table 11.3-1	Total Required Fund for PV Rural Electrification.....	11 - 5
Table 13.1-1	PV Electrification Plan.....	13 - 2
Table 13.1-2	Manning Schedule.....	13 - 9
Table 13.2-1	Case Study	13 - 12
Table 13.2-2	Effect of Base Case	13 - 15
Table 13.2-3	Comparison of Electrification Methods for Village Households.....	13 - 32

【List of Figures】

Figure 2.2-1	Botswana Primary Energy Supply 1997/98	2 - 7
Figure 2.2-2	Final Energy Demand in 1997/98	2 - 8
Figure 2.2-3	BPC’s Electricity Generation and Purchase.....	2 - 10
Figure 2.2-4	BPC’s Sales Disposition	2 - 12
Figure 2.2-5	Movement of RCS Electrification Rate	2 - 14
Figure 3.3-1	Objectives of PV Rural Electrification Master Plan	3 - 4
Figure 4.1-1	Process of PV Rural Electrification Master Plan Study	4 - 2
Figure 5.1-1	Organizational Structure of the Rural Electrification Frame Work	5 - 3
Figure 6.2-1	Location of 10 Villages to be Surveyed.....	6 - 8
Figure 6.2-2	Occupation	6 - 11
Figure 6.2-3	Number of Income Source of Households	6 - 12
Figure 6.2-4	Cash Income Distribution by Income Source (Percent)	6 - 13
Figure 6.2-5	Ratio of Said Income as a Main Income	6 - 14
Figure 6.2-6	Cash Income Distribution by Village.....	6 - 15
Figure 6.2-7	Willingness to Pay	6 - 18
Figure 6.2-8	Reason why do not want to use PV System.....	6 - 18
Figure 6.2-9	Time Frame for PV Demands by Village	6 - 20
Figure 6.2-10	Max. Payable Deposit (10Villages)	6 - 21
Figure 6.2-11	Max. Payable Monthly Payment (10Villages).....	6 - 21
Figure 6.2-12	Monthly Energy Expenditure.....	6 - 29
Figure 6.2-13	Monthly Saving Amount.....	6 - 29
Figure 6.4-1	Cash Monthly Income of Participants of Dissemination Project	6 - 37
Figure 6.5-1	Willingness/Ability to Pay for the Monthly Charge Adopted in Master Plan	6 - 48
Figure 7.2-1	Break-even Distance from Grid for Grid Versus SHS.....	7 - 5
Figure 7.2-2	Comparison of Life Cycle Cost of SHS Versus PV Mini-grid (Break-even Consumption Level).....	7 - 8

Figure 7.4-1	Correlation between criteria for area selection for PV electrification and parameters for first and second selection and rating scores	7 - 15
Figure 7.4-2	Number of Villages and Localities by Score	7 - 17
Figure 7.4-3	Percentage of No. of Villages and Localities by Score.....	7 - 17
Figure 7.4-4	Population of Villages and Localities by Score	7 - 18
Figure 7.4-5	Percentage of Population of Villages and Localities by Score	7 - 18
Figure 7.5-1	PV Installed Capacity (SHS, Public, BCS).....	7 - 24
Figure 7.5.2	Total PV kWp Installed.....	7 - 25
Figure 8.3-1	Proposed Recycling Route for Waste Lead-Acid Batteries	8 - 6
Figure 9.2-1	Organization of Implementation Body for PV Rural Electrification	9 - 6
Figure 11.1-1	GDP (1999/2000).....	11 - 1
Figure 11.1-2	Interest Rate and Inflation Trends.....	11 - 3
Figure 12.1-1	PV Rural Electrification Project Planning and Implementation Procedures.....	12 - 3
Figure 12.2-1	Implementation Schedule for the PV Rural Electrification Project	12 - 4
Figure 13.1-1	No. of Villages and Localities PV Electrified (Base Case: SHS/BCS:40/20%).....	13 - 4
Figure 13.1-2	Number of Households Electrified with SHS/BCS (Base Case: SHS/BCS:40/20%).....	13 - 4
Figure 13.1-3	Organization.....	13 - 8
Figure 13.2-1	Total Electrification Rate per BCS Electrification.....	13 - 13
Figure 13.2-2	Total Number of Households Electrified	13 - 13
Figure 13.2-3	Total Installed PV Capacity	13 - 14
Figure 13.2-4	Sensitive Analysis on Subsidy Ratio.....	13 - 16
Figure 13.2-5	Sensitivity Analysis on Subsidy Ratio (with the BCS Electrification Rate of 20%)	13 - 16
Figure 13.2-6	Sensitivity Analysis on Subsidy Ratio (with the BCS Electrification Rate of 30%)	13 - 17

Figure 13.2-7	Required Subsidy for Project Life	13 - 18
Figure 13.2-8	Change in Subsidy for 10 Years	13 - 18
Figure 13.2-9	Accumulated (Equity + Capital Increase + Long Term Loan) and Net Profit.....	13 - 19
Figure 13.2-10	Sensitivity Analysis on Tariff Level	13 - 20
Figure 13.2-11	Sensitivity Analysis on Tariff Level	13 - 20
Figure 13.2-12	Cash Generation per Tariff Variation	13 - 21
Figure 13.2-13	Total Installed PV Capacity per Demand Pattern Projection.....	13 - 22
Figure 13.2-14	Sensitive Analysis per Demand Pattern Projection.....	13 - 23
Figure 13.2-15	Installed Capacity Ratio.....	13 - 24
Figure 13.2-16	Effect of Public Demand on IRROI.....	13 - 25
Figure 13.2-17	Total Investment Cost Breakdown for 20 Years.....	13 - 26
Figure 13.2-18	Investment Cost Breakdown Ratio.....	13 - 26
Figure 13.2-19	Sensitive Analysis for Investment Cost: IRROI	13 - 27
Figure 13.2-20	Effect of BPC Cost on IRROI.....	13 - 28
Figure 13.2-21	Average PV Capacity per Household	13 - 29
Figure 13.2-22	Average Required Investment Cost per SHS and BCS User	13 - 30
Figure 13.2-23	IRROI Improvement of SHS/BCS System per 30% Cost Down of BCS Investment Costs	13 - 31
Figure 13.3-1	EIRR per SHS/BCS Electrification Rate	13 - 36
Figure 13.3-2	EIRR per Tariff Variation	13 - 36
Figure 13.3-3	EIRR per Investment Cost Variation	13 - 37
Figure 13.3-4	EIRR Per Demand Pattern	13 - 37
Figure 14.1-1	Comparison of Subsidy per Household.....	14 - 5

【Appendix】

Appendix 1 Summary of the Activities for the Master Plan Study

1.1	Establishment of Study.....	A1 - 1
1.1.1	Counterpart and Steering Committee Member.....	A1 - 1
1.1.2	Organization and Assignment of Study Team.....	A1 - 1
1.2	Progress of the Study in the Fiscal Year 2000.....	A1 - 2

1.2.1	First Field Survey	A1 - 2
1.2.2	Second Field Study.....	A1 - 2
1.2.3	Key Activities in Basic Study.....	A1 - 3
1.2.4	Third Field Survey.....	A1 - 4
1.2.5	The Fourth Field Survey.....	A1 - 6
1.2.6	The Fifth Field Survey.....	A1 - 6
1.2.7	The Sixth Field Survey	A1 - 7
1.2.8	The Seventh Field Survey	A1 - 8
1.3	Summary of Activities During Fiscal Year 2000 and 2001	A1 - 8
1.3.1	Activities that have been Accomplished During the Period.....	A1 - 9
1.4	Summary of Activities in Fiscal Year 2002	A1 - 10

Appendix 2 Overview of Botswana, Energy and Power Sector

2.1	Overview of the Country of Botswana	A2 - 1
2.1.1	Political and Administrative Situation.....	A2 - 1
2.1.2	Geographical Situation	A2 - 8
2.1.3	People	A2 - 12
2.1.4	Economic situation	A2 - 13
2.1.5	Current Government Vision and Policies on the Development Program.....	A2 - 15
2.2	Overview of Energy Sector	A2 - 25
2.2.1	Overview of Botswana Energy Sector.....	A2 - 25
2.2.2	Energy Policy	A2 - 26
2.2.3	Overview of the Power Industry in Botswana.....	A2 - 29
2.2.4	Overview of PV Rural Electrification	A2 - 30
2.3	PV Projects in the Selected Developing Countries.....	A2 - 35
2.3.1	Schemes and Features of PV Projects in the World	A2 - 35
2.3.2	Lessons Learned from PV Projects in Developing Countries and Consideration on Botswana PV Projects	A2 - 38
	Appendix Document 2	AD2 - 1

Appendix 5 Institutional Framework for Promotion of PV Rural Electrification

5.1	Present Scheme for PV Rural Electrification	A5 - 1
5.1.1	Organizations Involved in PV Electrification	A5 - 1

5.2	Study on the Implementation Body for PV Rural Electrification.....	A5 - 5
5.2.1	Management Lessons Learned from Ongoing PV Projects in Botswana and Other Countries.....	A5 - 5
5.2.2	Selection of the PV-based Rural Electrification Project Implementation Body	A5 - 8

Appendix 6 Socio Economic Situations and PV Potential in Botswana Rural Area

6.1	The Population Movement in Botswana	A6 - 1
6.2	General Situations	A6 - 4
6.3	Socio Economic Survey	A6 - 7
6.3.1	Selection Criteria for 10 Villages.....	A6 - 7
6.3.2	Surveyed Method.....	A6 - 8
6.3.3	Socio-Economic Status.....	A6 - 9
6.4	Socio-Economic Survey for Participants in the Dissemination Project	A6 - 25
	Appendix Document 6	AD6 - 1

Appendix 7 Selection of the Target Villages for PV Electrification

7.1	Least-cost Options for Rural Electrification.....	A7 - 1
7.1.1	Rural Household Electricity Consumption.....	A7 - 1
7.1.2	Cost Comparison of SHS Versus the Grid-based Electrification	A7 - 2
7.1.3	Comparison of Cost Recovery of SHS Versus the Grid.....	A7 - 4
7.1.4	Cost Comparison of SHS with PV Mini-grid Electrification	A7 - 4
7.1.5	Cost Comparison of SHS with Diesel Mini-grid Electrification	A7 - 6
7.2	Current Electrification Status of Villages and Localities	A7 - 33
7.3	Priority of PV Electrification to Selected Villages and Localities	A7 - 33
	Appendix Document 7	AD7 - 1

Appendix 8 PV System Design and Environmental Measures

8.1	PV Systems Technology.....	A8 - 1
8.1.1	Consideration of Botswana Standard BOS 2-1:1999 “Code of Practice for PV Energy Systems Design and Installation – Part1: Buildings”	A8 - 1
8.1.2	Technical Evaluation of Local Suppliers (Equipment)	A8 - 3

8.1.3	Consideration of System Installation Work for Quality Assurance	A8 - 6
8.2	Environment and Health Protection	A8 - 9
8.2.1	Environmental Benefits of Solar Home Systems	A8 - 9
8.2.2	Negative Environmental Impact.....	A8 - 10
8.2.3	Recycling Required by Environmental Law	A8 - 11
8.3	Results of Technical Monitoring of Dissemination Project	A8 - 13
8.3.1	Battery Charging Station (BCS).....	A8 - 14
8.3.2	System 50Wp Lorolwana	A8 - 29
8.3.3	System 200Wp Kudumatse	A8 - 34

Appendix 13 PV Rural Electrification Project Planning Model and Financial/ Economic Analysis

Appendix 14 Evaluation of RCS

Appendix 15 Dissemination Project

15.1	Objectives of PV Dissemination Project	A15 - 1
15.2	Selection Criteria for Candidate Villages and the Results.....	A15 - 3
15.2.1	Selection Criteria	A15 - 3
15.2.2	Evaluation and Recommendation.....	A15 - 3
15.3	PV Applications and System Specifications	A15 - 7
15.4	Project Basis	A15 - 12
15.5	Contractor Selection and System Installation.....	A15 - 12
15.5.1	Tender Procedure.....	A15 - 12
15.5.2	Tender Progress	A15 - 18
15.5.3	Installation Works	A15 - 19
15.6	Operation Structure for the Dissemination Project.....	A15 - 27
15.6.1	Outline	A15 - 27
15.6.2	Fee and Prepaid Card.....	A15 - 30
15.6.3	Budget Arrangement for BPC	A15 - 30
15.7	Lesson from the Dissemination Project.....	A15 - 32
15.8	Benefits Derived from PV Electrification	A15 - 37
15.8.1	Number of Samples and Surveyed Method.....	A15 - 37

15.8.2	Surveyed Items	A15 - 38
15.8.3	Result.....	A15 - 38
15.9	Monitoring Results of Operation.....	A15 - 40
15.9.1	BPC's Operation Management.....	A15 - 40
15.9.2	Services Rendered by Contractor (SIB)	A15 - 40
15.9.3	Operation Status in the Three Villages.....	A15 - 40
15.9.4	Status of Revenue Collection	A15 - 41
15.9.5	Countermeasures for Revenue Collection Improvement and Smooth Operation of the Project.....	A15 - 42
	Appendix Document 15	AD15 - 1

【Reference List】

Chapter 1 Introduction

Chapter 1 Introduction

1.1 Background and Objective of the Study

In Botswana, electrification of rural villages has been rapidly promoted by means of extension of the existing power transmission lines. However, due to a relatively high cost for grid connection - which is not affordable for many village households, the electrification rate in the rural sector remains much lower than that in the urban sector, i.e., 4% vs. 26% (Energy Master Plan 1996), not to mention a large difference between regions.

To accelerate rural electrification, the government emphasizes the use of decentralized energy sources in addition to the continued efforts to expand the grid coverage and reduce the connection charge and payment conditions.

Botswana enjoys one of the best solar energy regimes in the world. Various studies have concluded that solar energy applications have potential for widespread use in Botswana.

The Botswana Energy Master Plan Summary Report (1993) concluded that “Solar energy is the only renewable energy source which has the potential to make large scale, strategic impact on the country’s future energy supply”. The SADC Study on PV Market (1992) indicated a substantial market potential for PV in the region, Botswana included. These studies suggest a lot of potential for PV application.

Both the first and second phases of Botswana Energy Master Plan (BEMP) recommended the use of solar energy for both electricity generation and water heating. The BEMP Final Phase among others recommended:

- Integration of PV electrification into the national electrification program**
- Allocation of PV electrification to a suitable organization**

Based on the recommendations, the government has supported the use of renewable energy, solar energy in particular, through the successive Development Plans. During the 7th National Development Plan (NDP 7) the focus was placed on technology development and dissemination with an emphasis to meet the energy needs of the rural

areas. The private sector was encouraged to develop some of the solar energy products and components.

During NDP 8 the main policy objective is to promote photovoltaic electrification in an orderly way with adequate coordination, institutional support, financing and technical standards.

Parallel to the policy pronouncements the government has also initiated a number of programs to promote solar energy. In 1991 the Energy Affairs Division of the Ministry of Minerals, Energy and Water Resources initiated a pilot project to install, monitor and evaluate solar energy technologies in Manyana Village. The objective was to assess the socio-economic viability of solar energy technologies in a village environment, with a view to replicate them in other parts of the country should they prove viable.

Following the positive outcome of the pilot project the National PV Rural Electrification Program (NPV-REP) was initiated in 1997. This program was implemented by Rural Industries Innovation Center (RIIC) and offers loans to individual households and small businesses to purchase PV home systems repayable over a period of 4 years. Although the program was expected to install about 237 systems per year, only 300 were installed over a period of 4 years.

Reasons cited for the low uptake of the systems include lack of clear strategies to achieve the preset targets, poor record management and the project having to cover too many areas with limited resources. The program also faced a high defaulting rate due to the lack of follow-ups and failure to take appropriate action e.g. repossession of systems.

Japan International Cooperation Agency (JICA) undertook a project formation study work during 1997 and 1998. As a result of field study and discussions with the competent parties in Botswana, JICA concluded that the feasibility and level of expected effects of implementation of a photovoltaic electrification project in Botswana were high. Thereafter, the Botswana Government submitted an official request to the Government of Japan for a development study. Subsequently, JICA dispatched a preliminary mission to Botswana in December 1999 and in February 2000 the Scope of Work (S/W) was signed and exchanged between the two countries.

1.2 Objective of the Study

The study is designed to formulate a master plan for promotion of rural electrification in Botswana by using photovoltaic electrification over the ten year period, starting in 2003.

1.3 Study Area

The study covers villages and small settlements, called localities, throughout the country.

1.4 Implementation Phases

The study was conducted in the following three phases.

(1) Phase I: Preliminary study (September 2000 – end of March 2001)

- Data collection, socioeconomic surveys of selected villages and localities, and development of policy recommendations for PV rural electrification

(2) Phase II: Field verification of the PV promotion project (April 2001 – end of March 2002)

- To evaluate adequateness and viability of programs recommended in Phase I, a PV promotion and dissemination project (Dissemination Project) was conducted in three villages, and data and information was collected through the monitoring of the project to form the basis of modifying the original project plan.

(3) Phase III: Formulation of the master plan (April 2002 – end of March 2003)

- Based on the results obtained in the above two phases, a Master Plan for PV Rural Electrification was formulated and proposed.

1.5 General Outline of the Report

The Master Plan for PV Rural Electrification was developed according to the process described in Chapter 4. To ensure that major elements of the Master Plan are developed and implemented in the sequence envisaged in the process, the report sets

forth discussions and recommendations accordingly. A general outline of each chapter is as follows.

- Chapter 1 “Introduction” discusses the background and the primary objective of the Master Plan and its inception.
- Chapter 2 “Overview of Botswana, Energy and Power Sector” outlines the country’s political, social and economic conditions and raises the issues to be addressed in the development of the Master Plan for PV Rural Electrification, such as energy and electricity supply conditions, particularly the history of PV use.
- Chapter 3 “Goals and Objectives of PV Rural Electrification Master Plan” defines the significance and objective of PV Rural Electrification in the country in the context of ongoing national policies and programs.
- Chapter 4 “Development Process for the Master Plan for PV Rural Electrification” designs and proposes the formal process of developing the Master Plan for PV Rural Electrification.
- Chapter 5 “Institutional Framework for Promotion of PV Rural Electrification” describes an institutional setup required for the central government and its relevant departments to implement the Master Plan for PV Rural Electrification and proposes candidate organizations for implementation of PV electrification projects.
- Chapter 6 “Socio-Economic Situations and PV Potential in Botswana Rural Areas” analyzes a future outlook for the Master Plan, including the estimates of PV electrification demand in the rural villages to be covered by the Master Plan and the ability to pay the charge, on the basis of the results of the socioeconomic surveys and the Dissemination Project. It then proposes the potential scope of PV Rural Electrification.
- Chapter 7 “Selection of the Target Villages for PV Electrification” selects villages to be PV-electrified and sets the target electrification rate for such villages. Also, potential electricity demand by public facilities in the villages is estimated. Selection criteria for the villages to be

PV-electrified are proposed. Prioritizing the selected villages for PV electrification is proposed.

- Chapter 8 “PV System Design and Environmental Protection Measures” outlines PV system design requirements and specifications (SHS, battery charging station, PV system for public facilities) proposed for the target villages, and proposes environmental protection measures to be considered in the PV electrification project.
- Chapter 9 “Operation and Management of the PV Electrification System and Service” proposes a system and organization for operation and management of the PV electrification project, including the service provision system, the rate structure, the organization of the implementation body, the institutional setup for overall project implementation, the field fee collection system, the maintenance organization, and user contract administration.
- Chapter 10 “Manpower Development” discusses the current state of the technical education and training system for PV and proposes programs to be implemented to improve education and training.
- Chapter 11 “Financial Planning” proposes a financial plan for the PV rural electrification project in consideration of the country’s financial condition and the project’s feasibility outlook.
- Chapter 12 “PV Rural Electrification Project Planning and Implementation Procedures” proposes the project planning and implementation procedures as well as a preliminary schedule for implementation of the Master Plan.
- Chapter 13 “PV Rural Electrification Project Planning Model and Financial/Economic Analysis” formulates a detailed project plan including an annual budget for the entire project period by taking into account the issues identified and discussed in the previous chapters. Key issues are then addressed through financial and economic analyses of the project on the basis of assumptions made in the project plan, and solutions are proposed to make the project viable.

Chapter 14 “Implementation Strategies for PV Rural Electrification” proposes a set of strategies to be taken to achieve the goals and objectives defined in Chapter 3 and address the issues raised in the subsequent chapters.

Appendix 1 to 14

Various data used to support the discussions and proposals in the above chapters and the results of evaluation and analysis are presented in Appendices 1 through 14.

Appendix 15 The details of the Dissemination Project are described.