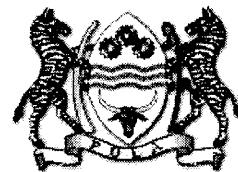


JAPAN INTERNATIONAL COOPERATION AGENCY

**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
(SUMMARY)**

FEBRUARY, 2003

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

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	Exchange Rate \$1 = P6.5 1/100 P R1 = ¢ 100
P	Pula	
Th	Thebe	
R	Rand (RSA)	
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	$1\text{ kWh} = 3.6 \times 10^6 \text{ J}$

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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 low.

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.

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.

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.

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.

Chapter 2 Overview of Botswana, Energy and Power Sector

Chapter 2 Overview of Botswana, Energy and Power Sector

2.1 Overview of the Country of Botswana

2.1.1 Economic Situation

At the time of Independence in 1966, Botswana was one of the poorest countries in Africa. An overwhelmingly rural population depended mainly on agriculture for a livelihood.

The 30 years since 1966 have seen a remarkable economic transformation.

GDP growth has averaged around 6% per annum in real terms over the entire post Independence period. The altered structure of the economy is dominated by the emergence of the mineral sector.

The National Development Plan 8 (NDP 8), covering the six-year period from April 1997 to March 2003 has the theme of *Sustainable Economic Diversification*, to be achieved primarily through accelerated growth of the non-mining sectors of the economy, especially manufacturing, tourism and financial services.

The commencement of NDP 8 in 1997 followed the *Framework for a Long Term Vision* for Botswana in September 1996. The long-term Vision (Vision 2016) runs to the 2016, when Botswana will have been independent nation for 50 years. It sets some goals for the nation for the year 2016, identifies major challenges in achieving them, proposes a set of strategies to meet those challenges.

(1) The most critical issues

a. HIV/AIDS

The HIV/AIDS epidemic continues to pose a threat to the social and economic development of Botswana. The disease is not only a health problem but is also a social and economic problem, cutting across all groups in society and all sectors of the economy. On the economic front, it poses a threat to development by depleting the country's supply of labor, lowering productivity and increasing the dependency ratio.

b. Unemployment

Another major problem facing the nation is unemployment. The 1998 Demographic Survey estimated unemployment at 19.6% of the labor force.

However, 19.6% rate of unemployment is still very high and unacceptable, and continues a major socio-economic problem for the country.

c. Poverty

The other major challenge facing the country is poverty. According to the 1997 Study of Poverty and Poverty Alleviation in Botswana, a higher proportion, 50% of female-headed households were living in poverty compared to 44% of male-headed households. Furthermore, it was estimated that 62% of poor or very poor Botswana were living in rural areas, 24% in urban villages and 14% in urban areas.

d. Economic Diversification

Economic growth in Botswana over the last three decades has been driven chiefly by the growth of the mining sector, the mining of diamonds. The call for sustainable economic diversification in both NDP 8 and Vision 2016 came out of the realization that high and stable growth of the economy in the long run, along with approaches towards full employment and eradication of absolute poverty, can only come through sustained growth and development of the other, i.e., non-mining and non-Government, sectors of the economy.

e. Public Sector Reform

Public sector reform is an encompassing term, which includes, among others: changes in the public procurement system, cost control and cost recovery, right-sizing of Government, productivity increases, privatization, improvement of implementation capacity in Government, etc.

f. Citizen Economic Empowerment

Citizen economic empowerment has recently become a topical issue.

2.2 Overview of Energy Sector

2.2.1 Overview of Botswana Energy Sector

Botswana is endowed with large reserves of coal and high level of solar insulation, but has no gas or oil and has, in general low rainfall over the country which limit

hydro potential. Large reserves of coal have not been exploited yet, due to the lack of sufficient demand.

The major sources of energy supplied were fuel wood and coal. For the past years, these sources were the most predominant. Although solar energy is becoming increasingly popular, especially in the field of water heating and lighting, its contribution to PES is still 0.034% and other renewable energy sources contributes only 0.002%.

2.2.2 Energy Policy

Energy policy is an extension of national policy. Presently Botswana energy sector is governed under the following hierarchy of national policy.

(1) Long Term Vision in Context with Energy Policy and Rural Development

The Botswana Government set forth “Long Term Vision 2016” and shaped the vision and strategies.

In order to accomplish such vision, the following strategies, among others, are raised:

- * The improvement of all level of schooling by the proper equipping of primary and secondary schools with electricity, especially in remote areas.
- * Economic growth in rural areas creating employment with the full utilization of solar power abundant in Botswana.

(2) National Development Plan in Context with Energy Policy and Rural Development

The main theme of the Eighth National Development Plan (NDP8) is sustainable economic diversification. In NDP8, energy sector policy and strategy are raised.

(3) Energy Master Plan

The Ministry of Minerals, Energy and Water Resources (MMEWR) has been responsible to coordinate development and operational activities in the energy, water and minerals sector. According to Botswana Energy Master Plan drafted under the Energy Affairs Division (EAD) of MMEWR in June 1996,

Botswana has an explicit commitment to equalizing the distribution of economic benefits between all parts of Botswana society.

According to the basic policy above mentioned, Energy Master Plan dictates access to electricity, both connected to the national grid, off-grid and photovoltaic (PV) to all those households where it makes economic and social sense, and improving the affordability of electricity to households.

As for policies relating to the PV, Energy Master Plan sets forth the policy to include electrification using PV systems in national electrification planning. Planning of PV electrification needs to take cognizance of grid expansion plans, and should be funded under the same principle that justifies grid rural electrification.

2.2.3 Overview of the Power Sector in Botswana

(1) The Structure of the Power Sector

Botswana Power Corporation (BPC), which is a wholly government owned public power corporation, has an overall power generating capacity of 132 MW at Morupule, and produced approximately 48.5% of Botswana's total power and 51.5% was imported through Southern African Power Pool (SAPP).

In addition to power generation, BPC also has a monopoly on power transmission and distribution. BPC has continued high growth in the demand for power supplies. BPC's sales increased by 11.1% from the previous year. Although domestic sales growth stayed low by 1997/98, high increase of sales has been attained in recent years.

Department of Electrical and Mechanical Services (DEMS) of Ministry of Works, Transport and Communications (MWTC) has constructed diesel power plants for the governmental and public facilities in the area where grid is not extended and has supplied surplus electricity to households in the vicinity of the facilities.

Photovoltaic electricity generation has been significantly developed in various fields such as in telecommunication, water pumping, lighting of public

facilities, railway signals. Non-grid rural electrification started from the pilot project in Manyana Village in 1991.

(4) Tariffs

BPC customers are categorized into six classes based on the use and size of supply taken. The tariffs for domestic customer are P7/m for fixed charge and P0.2523/kWh for energy charge. Customers pay a security deposit of P200. For remote area customers such as those of 72 villages grid extension project, P7/m of fixed charge is exempted.

A tariff increase of 5% was effected in February 1999. This was the first increase since October 1993. Accumulated inflation for the period March 1994 to March 1999 was 53%, versus the accumulated increase in tariff over the same period of 2%.

2.2.4 Overview of Grid and Diesel Mini-grid Rural Electrification

(1) Extension of Transmission and Distribution Lines by BPC

BPC's power supply had been continuously expanded to rural villages, approximately at the pace of 15 villages every year in accordance with NDP7 and NDP8. Then, 72 villages electrification project started in 2000 and BPC completed it in September 2001.

Although the grid has been extended rapidly, the number of households connected to the extended grid has not increased as a satisfactory rate, due to the policy of recovering the costs for connections from the end-users. Botswana Power Corporation (BPC) has planned a long-term loan program, the Rural Electrification Collective Scheme (RCS), to alleviate the burden of users' connection fees. However, the down payment and monthly payment were not in the affordable range for average rural households, according to the evaluation of RCS made by EAD in 1999. Following the evaluation, since April 2000, measures to decrease by half the amount required as down payment, and to lengthen the term for payment to 15 years from 10 years were adopted. Since then, the increase in the rate of connection has picked up steeply.

Number of connections increased by about 600 in one month from August to September, 2000. In case this increase remains, about 7,200 consumers will be newly grid-electrified in the rural villages in a year.

As a result of revision of the RCS, 49,170 households in urban area (43.3% of urban households 113,619) and about 50,000 households in rural villages (17.1% of rural village households) have been connected to the grid. Of all households in Botswana (rural villages and urban cities and towns excluding the localities) 24.5% were electrified in September 2000.

The grid was extended to 195 villages by the end of 2001. Total number of households in these villages is estimated as 191,800. Therefore, average electrification rate in the grid-connected villages reaches to 26% in 2002, taking 50,000 households into account as grid-connected. BPC's target grid-connection rate is 12% increase per year to the previous year. If such target is accomplished, average electrification rate in the grid-connected villages exceeds 80% after 10 years.

According to the post-revision of RCS, the average monthly payment for the connection fee is P38/m and the total monthly payment including BPC's tariff for electric consumption for average rural households is estimated to be average P47 to P50/m. The rural households who can afford the monthly payment of more than P50/m account for to about 40% of total households in the rural villages, utilizing Figure 6.2-4 which is derived from the ability to pay for SHS application as discussed in Chapter 6.

The willingness and ability to pay for grid-connection will be higher than shown in Figure 6.2-4, taking into consideration more merits in case of grid-connected users. The electrification rate will be more than 40%. Judging from the above mentioned discussion, the average grid-connection rate in the villages where the grid is extended is projected to reach about 60% within 10 years.

2.2.5 Overview of PV Rural Electrification

Since the National Development Plan 7 (NDP 7) the government has initiated Programs to promote the use of renewable energy sources. In 1991 the Energy

Affairs Division (EAD) of the Ministry of Minerals, Energy and Water Resources (MMEWR) initiated a pilot project to install, monitor and evaluate solar energy technologies in Manyana Village.

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 offered loans to individual households and small businesses to purchase PV home systems repayable over a period of 4 years. Despite the existence of financing mechanism for PV dissemination the uptake remained low with only 300 systems disseminated over a period of 4 years.

The Department of Water Resources, which is responsible for water supply development in rural areas, promotes PV water pumping and has installed about 35 PV pumps in rural areas.

District Councils, which fall under the Ministry of Local Government, provide PV electricity to remote schools, clinics and health Centers in areas without access to grid-based electricity. The Ministry of Education provides PV in remote areas for their village reading rooms. The rooms are intended for reading purposes at night by students and the community. This is part of government efforts to improve literacy in rural areas.

The Botswana Telecommunication Corporation and the Botswana Police have installed substantial capacity for powering their communication equipment. Botswana Railways has also installed PV equipment for powering traffic signaling equipment.

These individual efforts have been going on for some time without an overall guiding framework.

PV Rural electrification projects in Botswana are as follows:

(1) Manyana PV Pilot Project

The project was started in 1992 as the first pilot project in Botswana to determine social economic viability, to test PV performance and to enquire data to formulate policy. The project was shifted into commercial phase and

operated from 1995 to 1997 by RIIC. Scheme of payment was to purchase system with 2 years loan. Concerning recovery of loans, almost all households (total 42 SHS) paid within two years and it was evaluated that users were satisfactory with the results.

(2) National PV Rural Electrification Program (NPV-REP)

Following the satisfactory results obtained in Manyana pilot project, NPV-REP was planned by EAD to disseminate SHS nationwide and implementation was entrusted to RIIC. The objective of the project was to make PV affordable through financing mechanism. The project scheme was to purchase with loan, 15% down payment and 4 years repayment at prime rate of interest.

In case of 50Wp user, down payment was P600 and repayment was P100/m. The project has been implemented since 1997 and by the end of 2001 only about 300 clients were gotten, despite the initial target was 237 households per year.

(3) Centralized PV system by BoTeC

The centralized PV system with capacity of 5.5kW(DC) started commercial operation in August 1998 in Motshegaletau Village. In June 1999, an inauguration ceremony was held in the presence of the President of Botswana. The system has two inverters and the AC output is 4.5 kW. It is the mini independent system which supplies electricity to 14 customers through the 240 V distribution line of about 2 km. Most electricity is supplied to a school, a clinic, Kgotla and households. Two TVs, which are donated by a firm, are installed in the school and the clinic. The rest of energy is supplied to streetlights.

Chapter 3 Goals and Objectives of PV Rural Electrification Master Plan

Chapter 3 Goals and Objectives of PV Rural Electrification Master Plan

The Government of Botswana has established its development vision and strategy toward 2016 (50th anniversary), entitled “Long Term Vision 2016 and Strategy for Next 20 Years (Vision 2016).” The PV rural electrification master plan should be formulated and implemented as an extension of the above national policies, particularly regional development policy and national energy policy. The goals and objectives for PV rural electrification are discussed in relation to the Vision 2016 and NDP8.

The terminology herein used is as follows:

- * The term “goal” is used in the sense of the end toward which effort is directed - the terminal point.
- * The term “objectives” is used in the sense of steps toward the goal, - i.e., sub-goals.

3.1 Role of PV Electrification

Botswana has been rapidly expanding grid electrification which already serves 195 (having total 191,800 households) out of 462 villages (having 228,500 households), and 267 villages (having 36,700 households) remains unserved in the end of 2001.

In addition to villages, there are large number of small settlements called localities. As of 2001, there are approximately 5,660 localities, with 282,000 population and 63,000 households.

As grid electrification progresses further under NDP9, additional 10 to 15 villages per year will be electrified in the next ten years. However, most of remaining villages/localities will not be able to benefit from grid electrification in the near future.

To achieve the national policy to promote social equity, PV electrification is considered to be a feasible solution alternative to grid electrification for the following reasons.

- 1) The cost for grid extension to most of the localities and remaining villages is much higher due to a long distance from the existing grid and a low density of electricity users.

- 2) Thus, off-grid electrification shows a clear cost advantage over grid electrification.
- 3) Among various off-grid electrification methods, PV electrification offers major advantages, i.e., use of environmental friendly technology and low costs in the long run.

In overall consideration of relevant factors, PV electrification is considered to be the most effective means to improve social equity at the minimum cost to the national economy.

3.2 Goals for PV Rural Electrification Master Plan

In consideration of national policies in context with energy policy and rural development, described in Chapter 2, the PV rural electrification master plan should pursue the following key goals and sub-goals. Refer to Figure 3.3-1

Goal - 1 PV rural electrification should be implemented as part of efforts to improve social equity

Electricity is a fundamental energy service required for long-term development of the country's society and economy and its supply constitutes a critical element of improving social equity. The PV rural electrification project is therefore highly desirable to meet such demand. However, it cannot be financially viable on a commercial basis as judged from the current conditions of rural areas in the country (e.g., household income and purchasing power). Sustainable supply of electricity using the PV system is not feasible without government support.

Goal - 2 PV rural electrification should contribute to local economic development

The PV rural electrification project alone can make moderate contribution to economic development in rural regions. Its effectiveness can be maximized in combination with development of other infrastructure facilities that are not available in most rural areas. The synergetic effect of PV rural electrification and infrastructure projects will stimulate local economies,

which growth will then increase income of local people and make the PV project viable and sustainable in the long run.

3.3 Objectives for PV Rural Electrification Master Plan

In order to accomplish the goals, 4 objectives are set forth.

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

Objective-2 : To implement the PV rural electrification project at the least practicable cost and in a financially feasible and sustainable manner

Objective-3 : Integration with infrastructure projects required for a specific region or area

Objective-4 : Expansion of environmentally friendly energy use

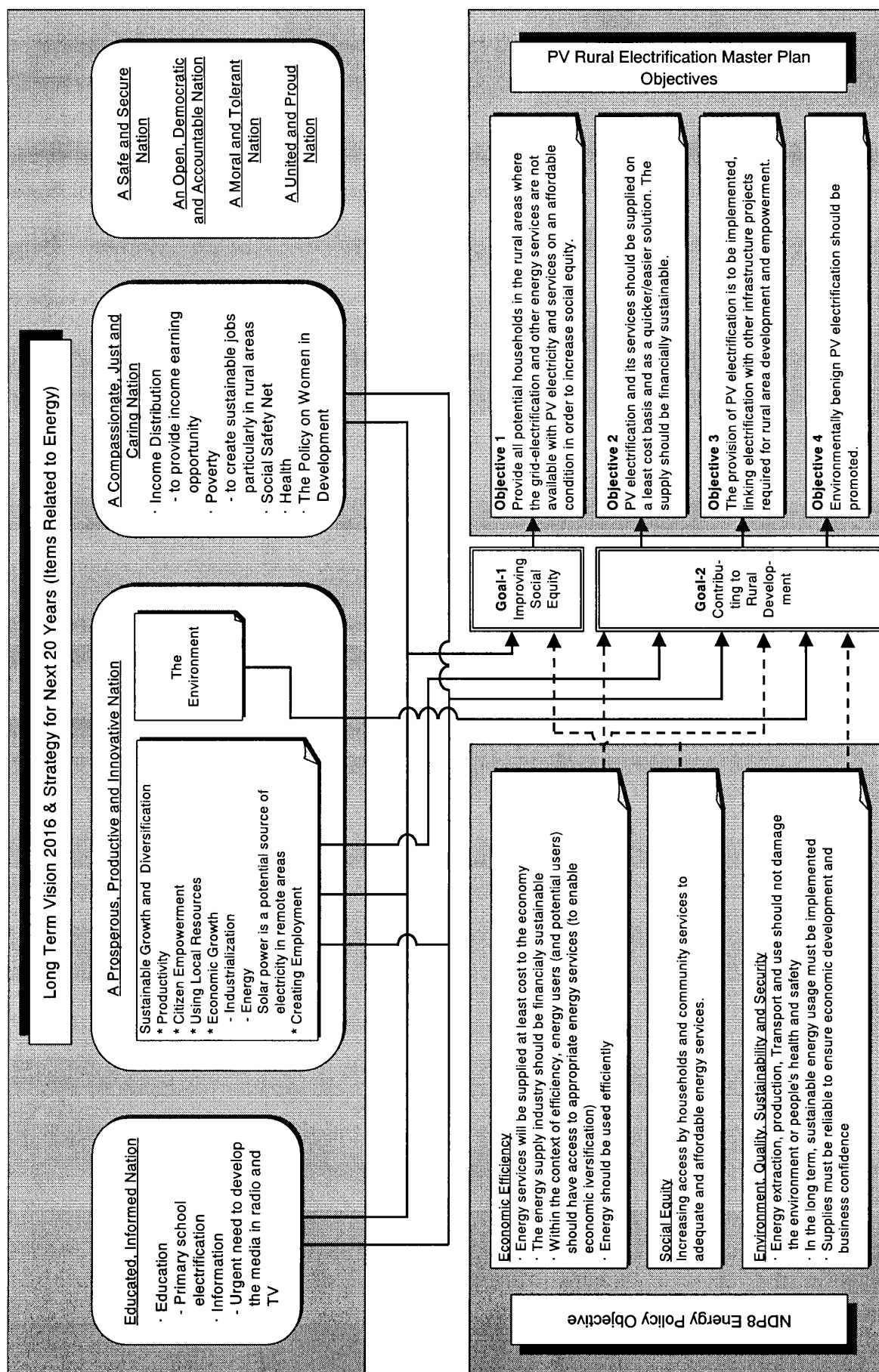


Figure 3.3-1 Objectives of PV Rural Electrification Master Plan

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

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

The formal process to develop the Master Plan for PV Rural Electrification is illustrated in Figure 4.1-1.

The Master Plan is intended to be used directly as the basis of developing a business plan of the PV rural electrification project that is readily executable. Essentially, the Master Plan analyzes various problems that were encountered in PV projects that had been conducted in the country, and on the basis of the lessons learned therefrom, it recommends, among other things, a new institutional homework to promote PV rural electrification, an optimal PV electrification system, and project operation and management methodology. It has also established selection criteria for villages to be covered by the PV electrification project in order to ensure that the selection is made on the basis of the minimum cost principle. The key planning parameters, such as the target electrification rate and the user charge system, are established by taking into account the results of the socioeconomic surveys of the selected (ten) villages as well as the results of the Dissemination Project conducted in the three villages – designed to check effectiveness of the programs recommended in the Master Plan. Finally, a preliminary business plan of the PV rural electrification project is formulated to incorporate all the necessary elements and its feasibility is evaluated through the financial and economic analyses. Then, necessary government support is identified to allow the project to be operated on a sustainable basis.

Validity of the parameters and other planning elements has been examined through the Dissemination Project which operation was thoroughly monitored by the study team, and the results are reflected in the master plan.

It is therefore important to follow the planning process when the Master Plan is implemented and reviewed in the future.

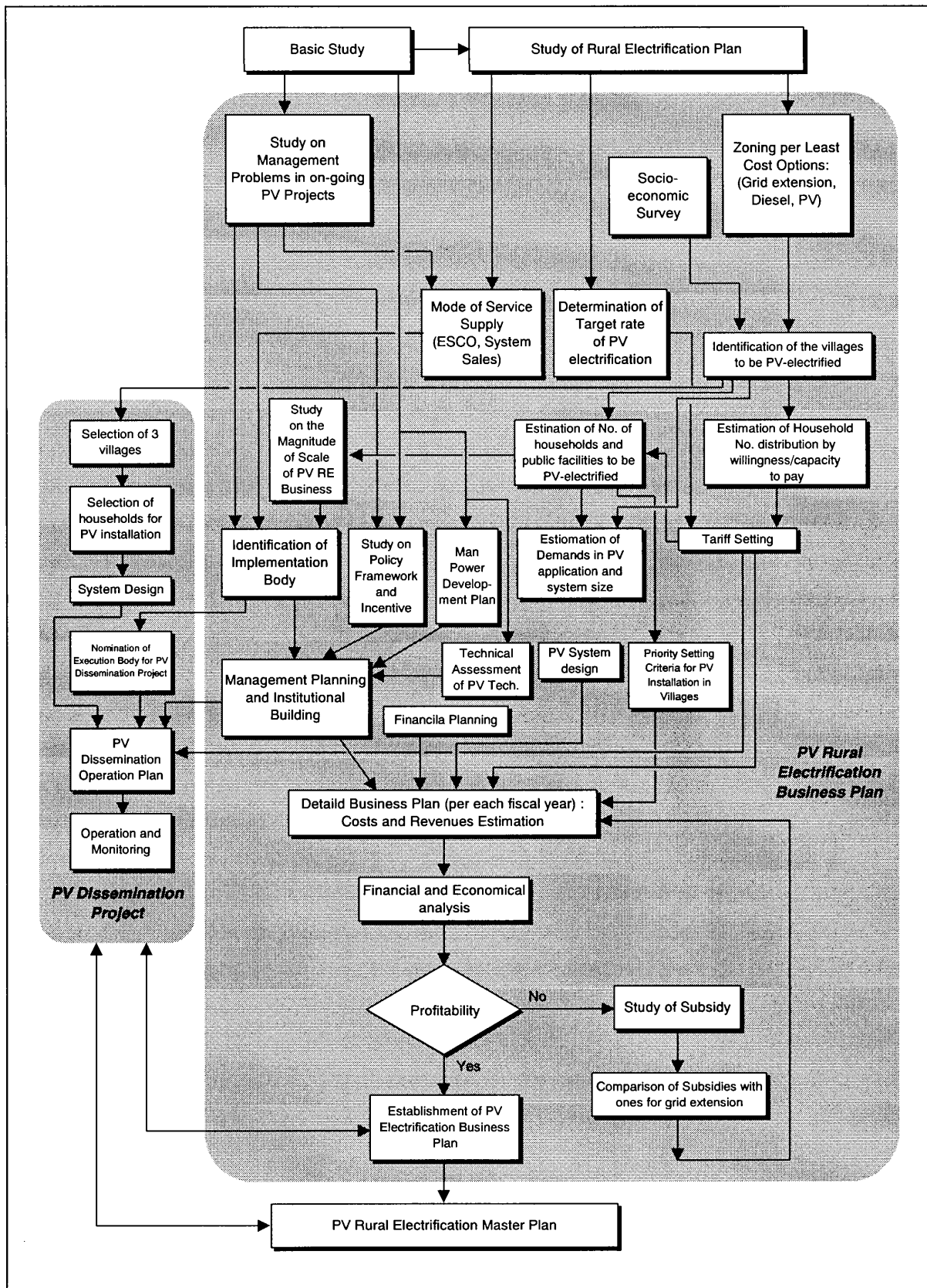


Figure 4.1-1 Process of PV Rural Electrification Master Plan Study