No.

JAPAN INTERNATIONAL COOPERATION AGENCY

VICE MINISTRY OF ENERGY AND HYDROCARBONS
THE REPUBLIC OF BOLIVIA

THE STUDY ON RURAL ELECTRIFICATION IMPLEMENTATION PLAN BY RENEWABLE ENERGY IN THE REPUBLIC OF BOLIVIA

SUMMARY REPORT

SEPTEMBER 2001

KRI INTERNATIONAL CORP.
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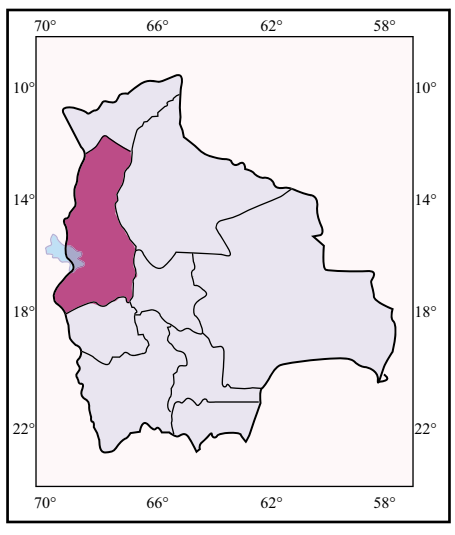
Location Map, La Paz

South America

REFERENCE

- Capital of Department
- Capital of Province
- Capital of Sección
- Cantón
- Major City/Town
- International Border
- Department Border
- Province Border



Bolivia

Scale. 1: 2,000.000

0 20 40 60 80 100 km

Location Map, Oruro

THE STUDY
ON
RURAL ELECTRIFICATION IMPLEMENTATION PLAN
BY
RENEWABLE ENERGY
IN
THE REPUBLIC OF BOLIVIA

SUMMARY

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CHAPTER 1 INTRODUCTION

Objectives of the study are to formulate the Rural Electrification Implementation Plan by Renewable Energy in La Paz and Oruro. The plan to be formulated covers the period of 2002-2011 and aims to promote the rural electrification keeping the balance between the power generation by renewable energy and extension of the grid line.

Transfer of technology to the counterpart staff of Bolivia is also another important objective of the study, which includes technology of renewable energy, their operation and management technology and planning technology.

The study was entrusted to KRI International Corp. in association with Nippon Koei Co., Ltd. in July 1999 and the study team (JICA Study Team) consisting of six experts was formulated for the succeeding field survey and study.

For the efficient implementation of the study, a Coordinating Group consisting of representatives of VMEH and, La Paz and Oruro prefectures was organized in Bolivia. In addition, a Working Group consisting of counterpart personnel from VMEH and related organizations was also formulated for conducting the study jointly and for effective technology transfer.

The JICA Study Team commenced the first field survey from August 1999 and continued the survey work up to September 2001.

CHAPTER 2 ELECTRIC INDUSTRY IN BOLIVIA

2.1 Legal Framework

Important legal framework for rural electrification in Bolivia consists of the Electricity Law, the Rural Electrification Rule, the Rural Electrification Information System and the Environmental Law. In addition, the rural electrification is to follow other related laws and regulations such as the Popular Participation Law and the Poverty Reduction Strategy Paper. Rural electrification projects are to be implemented within these legal framework.

2.2 Governing and Regulatory Bodies

The central government does not participate in the implementation of energy projects directly after enforcement of the new Electricity Law in 1994. The central governmental organizations related to rural electrification are the Vice Ministry of Energy and Hydrocarbons (VMEH), the Superintendence of Electricity (SE) and the National Committee of Electricity Supply (CNDC). The role of the central government is limited for promoting rural electrification.

(1) Vice Ministry of Energy and Hydrocarbons (VMEH)

The Vice Ministry of Energy and Hydrocarbons is the superior organization in energy sector under the Ministry of Economic Development in Bolivia. The VMEH, headed by the Vice Minister, consists of 12 units. The main unit related to rural electrification is the Energy Development Unit (EDU).

The EDU takes a leading role in rural electrification. The unit is composed of four staff including a chief, three technical engineers and the EFP team which has five experts for promoting the PRONER under the finance from UNDP.

(2) Superintendence of Electricity (SE)

The Superintendence of Electricity is an organization with national jurisdiction that regulates the activities of the electricity industry. Its activities began in 1996 following to the Electricity Law of 1994 under the Ministry of Economic Development.

(3) National Committee of Electricity Supply (CNDC)

The National Committee of Electricity Supply was created by Article 18 of the Electricity Law No. 1604 for coordinating generation, transmission and dispatching of electricity at the minimum cost within the National Interconnected System (SIN).

2.3 National Electric Supply System

(1) National System

The electric supply system in Bolivia consists of National Interconnected System (SIN), Isolated System (SA), other isolated systems and self producers.

The SIN is an interconnected power supply system comprising generation, transmission and distribution connected among themselves through the Interconnected Trunk System (STI). The SIN accounts for about 83% of the installed capacity, 89% of the generation and approximately 40% of the whole population in Bolivia.

The Isolated Systems are those electricity supply systems which do not belong to the SIN. Besides, there are isolated systems with the effective capacity of less than 1,000kW and independent self producers that generate electricity mainly to satisfy their own needs.

(2) Power Supply Structure

1) Power Generation System

There exist seven power generation companies within the SIN as of the end of 1999. They are Cobee, Corani S.A., Guaracachi S.A., Valle Hermoso S.A., Hidroelectrica Bolivia S.A., Rio Electrico S.A. and Synergia S.A. and Rio Electrico S.A. These generators must be connected to the STI (Interconnected Trunk System) and must comply with the regulations set by the CNDC and have to submit all the electricity to the Electricity Dispatching Center.

The next table shows the historical trend of electricity production by generation type.

Historical Trend of the Electricity Generation by Generation Type

(GWh)

	1995	1996	1997	1998	1999
Hydroelectric powe	1283	1460	1573	1513	1793
Share	42.7%	45.3%	45.5%	41.1%	46.0%
Growth rate	-5.0%	13.8%	7.7%	-3.8%	18.5%
Thermal power	1720	1760	1884	2172	2105
Share	57.3%	54.7%	54.5%	58.9%	54.0%
Growth rate	16.8%	2.3%	7.0%	15.3%	-3.1%
Total	3003	3,220	3,457	3,685	3,898
Growth rate	6.3%	7.2%	7.4%	6.6%	5.8%

Source: `Anuario Estadistico del Sector Electrico Boliviano 1999`,VMEH

2) Transmission System

The Empresa Transportadora de Electricidad (TDE) is engaged in the transmission business of the electricity as the only one transmission company in the country.

The STI is a part of the SIN and owns transmission lines and substations which are connected to generators and major domestic markets. The total length of the transmission lines connected to the STI is summarized below.

Voltages and Length of Transmission Lines Connected to SIN

Voltages Connected to SIN (kV)	230	115	69
Length of Lines Connected to SIN (km)	535.5	863.0	100.0

3) Distribution System

In the wholesale market of the SIN, there are 6 distribution companies. These are ELECTROPAZ in La Paz, ELFEO in Oruro, ELFEC in Cochabamba, CRE in Santa Cruz, CESSA in Sucre y SEPSA in Potosí. The voltages of the distribution lines in Bolivia are 44kV, 24.9kV and 6.6kV. The lower voltage is 230/115V in La Paz and 380/220V in the other areas.

CHAPTER 3 RURAL ELECTRIFICATION IN BOLIVIA

3.1 VMEH Policy

The government of Bolivia acknowledges that rural electrification is the base for rural development and considers the rural electrification as an important priority issue in the energy policies of the VMEH. Under these circumstances, the VMEH started a five-year program called PRONER 1998 in order to promote rural electrification. The ultimate goal of the PRONER is to help contribute to the improvement of living conditions and economic activities for the people living in the rural areas, thus assisting and promoting socio-economic development in the rural areas of the country. More specifically, the VMEH, through the PRONER, plans to double the rural electrification rate from 13.7% to 28% by 2002, offering electricity to 110,000 households, or 450,000 people.

The VMEH promotes use of environmentally friendly renewable energy sources such as PV, micro-hydro and wind power to save exportable energy sources and reduce carbon dioxide emissions. Involvement of the private sector for rural electrification is also encouraged especially through Three Models of PRONER, which provide incentives to the private sector.

Electricity cooperatives and committees formed by rural residents themselves become the promoter of rural electrification through identification and implementation of the electrification projects. The VMEH expects more active participation from the beneficiaries. It is anticipated that rural residents share the installation and equipment costs and take more responsibility for operation and maintenance of the systems in the future.

3.2 Progress of PRONER

The table below presents the progress of PRONER.

Rural Electrification Rate in Bolivia

	1997	1998	1999	2000
Total Rural HHs	866,714	882,113	892,809	885,454
HHs with Electricity	118,482	152,500	183,223	197,239
RE Rate	13.7%	17.3%	20.5%	22.3%

Source: VMEH
Note: The figures of 2000 are preliminary.

The presented PRONER is scheduled to be completed by August 2002. The government, however, considers rural electrification as a high priority issue and rural electrification will likely to be promoted even after 2002, as long as sufficient fund is made available.

3.3 Rural Electrification Investment

The table below summarizes public infrastructure investment including energy/rural electrification of Bolivia for the past 6 years.

Public Infrastructure Investment of Bolivia

(US$ 1,000)

	1995			1996			1997		
	Total	Internal	External	Total	Internal	External	Total	Internal	External
Energy	40,641	13,221	27,420	26,245	5,948	20,297	13,930	8,925	5,005
Generation of Electric Energy	26,815	5,168	21,647	18,953	2,121	16,832	75	75	0
Transmission of Electric Energy	10,714	5,264	5,450	5,601	2,396	3,205	5,879	1,593	4,286
Rural Electrification	2,435	2,435	0	1,157	1,155	2	7,105	6,993	112
Other Energy	677	354	323	534	276	258	871	264	607
Alternative Energy	-	-	-	-	-	-	-	-	-
Transportation	156,979	45,475	111,504	184,551	45,067	139,484	162,797	82,298	80,499
Communications	5,134	4,113	1,021	0	0	0	0	0	0
Hydraulic Resources	5,564	2,760	2,804	4,851	2,382	2,469	4,108	2,360	1,748
Total Infrastructure Investment	208,318	65,569	142,749	215,647	53,397	162,250	180,835	93,583	87,252
GDP	6,700,000			7,200,000			7,800,000		
Total Investment as % of GDP	3.1%			3.0%			2.3%		

	1998			1999			2000		
	Total	Internal	External	Total	Internal	External	Total	Internal	External
Energy	10,144	6,046	4,098	8,327	6,205	2,122	8,520	8,206	314
Generation of Electric Energy	370	370	0	-	-	-	107	107	0
Transmission of Electric Energy	2,397	809	1,588	2,018	2,018	0	954	954	0
Rural Electrification	6,379	4,486	1,893	4,634	3,925	709	7,262	7,005	257
Other Energy	998	381	617	873	69	804	112	112	0
Alternative Energy	-	-	-	802	193	609	85	28	57
Transportation	140,481	66,098	74,383	148,805	66,033	82,772	171,922	77,434	94,488
Communications	29	29	0	-	-	-	-	-	-
Hydraulic Resources	4,413	2,020	2,393	2,134	1,877	257	5,839	3,223	2,616
Total Infrastructure Investment	155,067	74,193	80,874	159,266	74,115	85,151	186,281	88,863	97,418
GDP	8,088,000			8,351,000			-		
Total Investment as % of GDP	1.9%			1.9%			-		

3.4 Organizations Related to Rural Electrification

(1) Local Government, Distribution Company and Supplier

Local government including prefecture and municipality plays an important role in rural electrification after legislation of the People Participation Law and the Decentralization Law in 1991. The rural electrification projects by renewable energy have been implemented under the leadership of local government through the people's participation in cooperation with the private sector including distribution companies and suppliers.

1) La Paz Prefecture and Oruro Prefecture

The energy unit under the Department of Infrastructure Development is in charge of rural electrification in La Paz prefecture. The unit has six staff including one chief, two electric engineers, two electric technicians and a secretary. In Oruro prefecture, the energy unit under the Infrastructure Division is responsible for rural electrification. The unit is composed of ten staff including a chief, five electric engineers, an electric technician, a topographical engineer and two drivers.

2) Municipality

After enforcing the Poverty Reduction Strategy Paper (PRSP), municipality is expected to play a more important role as an implementation organization of rural electrification project. However, substantial strengthening of the organization seems to be required as well as utilizing external manpower resources for efficient implementation of the rural electrification projects.

3) Distribution Company

There exist five distribution companies in La Paz and five in Oruro. The distribution companies purchase energy from power generation companies and distribute electricity to the consumers within their territories by using their own distribution lines or the distribution lines owned by department. The distribution companies have the license for grid extension provided by the Superintendence of Electricity and are responsible for rural electrification through the grid extension.

(2) Funding Organizations

Most of the national funds that come from foreign aids for rural development are through the Integrated Unit of National Funds (DUF) in accordance with the PRSP procedure. The DUF will be a major funding organization for a rural electrification project.

In addition, the following other domestic fund organizations are also expected to support rural electrification.

- Revolving Fund for UNDP project

- Bolivian Rural Electrification Fund (BREF)

3.5 Activities of International Organizations

International organizations have provided technical and financial support to local governments as well as central government to promote rural electrification through renewable energy as well as extension of grid lines. Active multilateral and organizations are The World Bank, UNDP and IDB. The Spanish Cooperation Agency, GTZ and KfW and Dutch Mission are providing assistance as bilateral organizations.

CHAPTER 4 RURAL ELECTRIFICATION IN LA PAZ AND ORURO

4.1 Trend of the Rural Electrification

The table below summarizes the trend of the rural electrification rates and investment amount of La Paz and Oruro departments. Though the figures of 2000 are still preliminary, the rural electrification rates increased to 25.5% in La Paz and 15.4% in Oruro.

Rural Electrification Rate in La Paz and Oruro

	1998	1999	2000
La Paz			
RE Rate (%)	18.6%	22.5%	25.5%
HHs with Electricity	45,237	54,906	59,515
Investment (US$1,000)	6,073	2,672	1,138
Oruro			
RE Rate (%)	10.3%	12.6%	15.4%
HHs with Electricity	6,437	7,894	9,634
Investment (US$1,000)	648	2,905	1,355

Source: VMEH

4.2 Present Situation of Rural Electrification

(1) Grid Extension

Figures 4.1 and 4.2 are the extension maps of transmission lines (69kV, 115kV and 230kV) and primary distribution lines (10kV, 14.4kV, 24.9kV and 34.5kV) in La Paz and Oruro departments in 2001.

(2) Renewable Energy Sources (MHP and PV)

At present, renewable energy sources are used in a limited way for rural electrification in the two departments. Only 2% of the total rural electrified households is being electrified by renewable energy in La Paz and 19% in Oruro.

1) Inventory of Micro-hydro Power

Total numbers of the existing micro-hydro power are 23 and 2 in La Paz and Oruro respectively. In La Paz, the total installed capacity is 1,084 kW with 7,161 households of beneficiaries, while in Oruro, the total installed capacity is only 200kW with 170 households of beneficiaries.

2) Inventory of PV System

The major system installed in La Paz and Oruro is solar home system for house lighting. No other type of PV system was identified except solar pumping system in La Paz and Oruro.

The solar home system installed both in La Paz and Oruro are 1,526 in total which amounts approximately to 80kW as of June 2001.

4.3 Target Households and Potential Demand for Rural Electrification

(1) Target Households for Rural Electrification

Numbers of target households for rural electrification and the numbers of not-electrified households in 2000 were estimated as presented below.

Target Households and Households without Electricity in Rural Areas in 2000

	La Paz	Oruro
Target Rural Households (Total No. of Rural Households)	233,202	62,566
No. of Rural HHs w/o Electricity	174,724	53,690

Source: VMEH

Note: These are adjusted figures based on the aggregate figures of each canton and are slightly different from the VMEH's official figures.

The numbers of target rural households were projected on the basis of the past trend as shown below.

Projected Total Number of Rural Households

	2002	2006	2011
La Paz	232,629	231,879	231,669
Oruro	61,981	60,846	59,473

Source: JICA Study Team

(2) Potential Demand for Electricity

The demand for electricity in the rural areas in La Paz and Oruro departments was estimated on the basis of the following assumptions and conditions:

1) Present power demand from the electrified households is estimated by applying the following unit to the number of households served;
   - Households electrified by the grid line, diesel and micro-hydro: 300kWh/year
   - Households electrified by PV: 65kWh/year
2) Power demand of the already electrified households as of the year 2000 will increase at annual growth rate of 2% after 2002;
3) Potential power demand from unelectrified households is estimated by applying 300 kWh to the number of the unelectrified households.
4) 60% of the unelectrified households are counted as effective demand
5) Total demand is the combined figure of the demand from the existing rural electrified households and effective demand.

The tables below are the summary of the electricity demand in rural areas in the two departments.

Demand for Electricity in Rural Areas (MWH/Year)

La Paz

	2000	2002	2006	2011
Total Number of Rural HHs	233,202	232,629	231,879	231,669
Existing No. of Electrified HHs	59,039	58,894	58,704	58,651
Demand from Exisiting Electrified HHs	16,972	16,930	18,267	20,150
Potential No. of Rural HHs to be Electrified	174,163	173,735	173,175	173,018
Effective Demand for Electricity	31,349	31,272	33,741	34,385
Total Demand for Electricity	48,321	48,202	52,008	54,534

Oruro

	2000	2002	2006	2011
Total Number of Rural HHs	62,566	61,981	60,846	59,473
Existing No. of Electrified HHs	8,887	8,804	8,643	8,448
Demand from Exisiting Electrified HHs	2,281	2,260	2,402	2,592
Potential No. of Rural HHs to be Electrified	53,679	53,177	52,203	51,025
Effective Demand for Electricity	9,662	9,572	10,171	10,140
Total Demand for Electricity	11,944	11,832	12,573	12,732

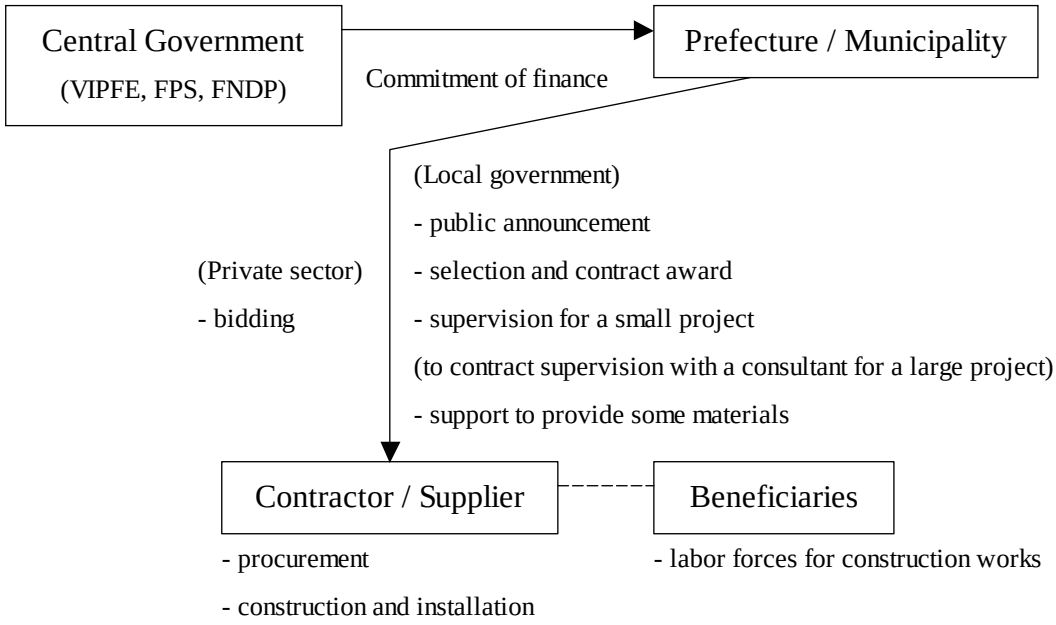
Source: JICA Study Team and VMEH

4.4 Implementing Organization and Organization for O&M

(1) Implementing Organization

Local government including prefecture and municipality is, in principle, an implementing organization for rural electrification under the promotion of local participation as the national development strategy. Users organize a rural electrification committee/cooperative and request prefecture a rural electrification project through municipality. Implementation of the project is being conducted with the following process.

Process of Project Implementation for Rural Electrification



(2) Organization for Operation and Maintenance

The following organizations are responsible for the operation and maintenance of rural electrification after transferring the responsibility for the operation and maintenance from local government.

Energy Source	Organization for Operation and Maintenance
Grid line	Distribution company, Electrification cooperative
Diesel power	Municipality, Electrification cooperative
Micro-hydro power	Electrification cooperative, Rural electrification committee
PV system	Electrification cooperative, Rural electrification committee, NGO and Users

CHAPTER 5 SUMMARY OF PV PILOT PROJECT

5.1 Survey and Study Conducted

The field survey commenced from August 7, 1999 and continued up to September 7, 2001 intermittently with the following survey and study.

- Collection for the existing PV data and information
- Site selection for PV pilot project sites
- Inspection for the installation of the PV systems
- Organizing operation and maintenance system and guidance for O&M
- Monitoring the pilot project/collection of data and analysis of the PV data
- Preparation of PV potential map and identification of priority sites for PV for rural electrification plan

5.2 Installation of PV Pilot Project

(1) Selection of Pilot Project Sites

Through the field investigation and discussion with the VMEH, and La Paz and Oruro prefectures, the sites for PV systems were finally selected as follows:

La Paz department

1) Calteca
2) Calacachi, Stgo. Llallagua, Canuma
3) Murchapi, Chiarumani & Chacoma, Catavi, Millo and Culli Culli Alto
4) Satgo. Hiruyo, Sanfrancisco Llallagua, Sipe Sipe

Oruro department

1) Paria Pampita
2) Laguna Ancocota
3) Milluni

(2) Components of PV System

The proposed PV system consists of PV module, controller, battery and three fluorescent lamps.

(3) Installation of PV System

Inspection schedule was prepared by the local supplier in consultation with JICA expert, based on which actual installation work continued from October to December 1999. In the second field survey conducted in January 2000, the installed PV systems in La Paz and Oruro were inspected by the JICA Study Team with Operators.

After the inspection, the local supplier started the improvement of the PV systems from February 2000 in reply to the resolution of the Coordinating Group and Management Unit. The supplier completed the re-installation in April 2000.

5.3 Operation and Maintenance System

(1) Organization for Operation and Maintenance

As an organization for operation and maintenance for the PV pilot project, a Management Unit was formulated, which consists of Rural Electrification Committee (REC) representing users, an Operator and prefecture. The REC was organized by users in each community. As Operators for the PV pilot project, a local distribution company, ELFA and an electricity cooperative, COSEP were selected in La Paz and Oruro, respectively. La Paz and Oruro prefectures participated into all the Management Unit.

The VMEH-prefecture-JICA Study Team formed a Coordination Organization and was responsible for overall management of the operation and maintenance of the pilot project.

(2) User Guide and Maintenance Manual

The JICA Study Team prepared a Users' Guide for the PV system and distributed it to the users for the purpose of introducing the basic idea and knowledge regarding the PV system for their daily use.

The Operators, ELFA in La Paz and COSEP in Oruro, are responsible for operating and maintaining the PV system. The JICA Study Team prepared a Maintenance Manual for the Operators.

5.4 Power Tariff

In order to share the installation cost of the PV system, payment of Bs 700 was requested to users as the initial payment. The initial payment is equivalent to 13% of the total system cost of Bs 5,300 (US$ 886).

For operation and maintenance of the PV system, monthly fee of Bs 30 was requested to users. The original payment scheme was modified later in due consideration of the actual payment situation of users.

5.5 Monitoring and Analysis

(1) Monitoring Operation and Maintenance

Monitoring was conducted to follow up the operation and maintenance of the installed PV system and the payment from users. The monitoring conducted during the study period consists of the following:

1) Monitoring on system use measured by data loggers
2) Monitoring on operation and maintenance by Operator
3) Monitoring on payment

For collecting data of PV function and the related meteorological information, data loggers were installed at three places: two in La Paz and one in Oruro. Analysis of the system use was also made based on the collected data from the data loggers. For monitoring operation and maintenance by Operators, monitoring sheets were prepared, on which monitoring results were recorded.

1) Monitoring on O&M by Operators

The results of the monitoring are presented in the following table.

Result of Monitoring on O&M

(August – October 2000)

(unit:household)

		Equipments				Number of Additional Loads	
Community	Household	Number Defective Lamp (1)	Blackish Bulb (2)	Noise on Radio (3)	Battery Water *(4)	Radio Cassette (5)	TV (6)
La Paz							
Calteca	10	1	2	3	3	8	-
Chiarumani	6	1	3	2	2	5	-
Muruchapi	22	2	5	20	8	20	-
Millo	30	4	8	25	12	27	-
Catavi	12	1	3	10	5	10	-
C.C. Alto	3	-	1	3	1	3	1
Hiruyo	19	2	2	15	6	18	-
Llallagua	14	1	4	13	9	14	-
Calacachi	32	-	-	2	-	32	3
VMEH	1	-	1	-	-	-	-
Oruro							
P.Pampita	16	3	2	13	5	15	1
Milluni	23	5	8	22	16	23	-
L.Ancocota	44	9	12	38	39	40	-
Minas	5	1	2	1	2	5	-
Total	238	35	53	167	108	220	5

*(4) Battery Water: numbers of refilling distilled water to batteries
Source:JICA Study Team

Although there were some problems as indicated above, the PV systems function in order. The performance of Operators for operation and maintenance were satisfactory in general.

2) Monitoring on Payment

The result of the payment in May 2000 was not satisfactory. Collection rates of the Initial Payment and Monthly Fee were 8.0% and 5.5%, respectively in La Paz, while those were 11.0% and 8.6%, respectively in Oruro.

To follow up the results, analysis was made on the delayed payment and the following actions were taken to improve the situation.

- Re-Orientation for User
  During the fourth field survey, the JICA Study Team and Operators visited

communities and conducted re-orientation to users for clarifying the misunderstanding and explaining the present PV system and its operation and maintenance.

- Modified Payment Schedule
  The Monthly Fee and Initial Payment were reduced.
- Modified User O&M (Appointment of technical assistant)
  For supplementing the function of Operators, a technical assistant was proposed to be selected in each community who carries out the following tasks:

Through the implementation of re-orientation and modified payment scheme the payment situation was improved as summarized below:

Collection Ratio (Paid amount / Full amount to collect)

(unit: %)

Month	La Paz		Oruro	
	Initial Payment	Monthly Fee	Initial Payment	Monthly Fee
May 2000	8.0	5.5	11.0	8.6
July 2000	16.9	28.5	19.6	25.9
Dec. 2000	38.7	56.2	47.7	46.3
Apr. 2001	42.4	67.2	51.1	41.4

Source: JICA Study Team

(2) Monitoring of Users

Users Survey

After installation of the PV pilot project, a monitoring survey was conducted. Main objectives of the survey were to monitor the following aspects.

- change of user's life after introduction of PV system,
- payment situation for initial payment and monthly fee, and
- situation of the operation and maintenance.

1) Change in Household Energy Situation

Average time using fluorescent lamps ranged from 2.5 hours in Calteca to 3.2 hours in Paria Pampita according to the third survey. The average time was not different between the first survey and the third survey.

The average time of listening radio recorded in the third survey ranged from 1.6 hours in Calteca to 2.5 hours in Paria Pampita. The average time in this survey was not so different from the former two surveys.

2) Change in Financial Source for Payment of User Charge

The main source of the initial payment and monthly fee was selling agricultural products and/or livestock products, the same as indicated in the initial benchmark survey. Around 42% of users in Muruchapi, 25% in Paria Pampita, and 16% in Calteca sold agricultural products such as potato, chuño, carrot and onion. About 58% of users in Paria Pampita, 42% in Muruchapi, and 33% in Calteca sold livestock such as sheep, llama, and cattle.

3) Change of Life

Users, 91% of interviewees in Paria Pamita, 87% in Muruchapi, 85% in Laguna Ancocota and 83% in Calteca, recognized that of their daily lives were improved after using the PV system. The main reason of the better life was improved conditions at night, while 18% of total interviews considered that their situation did not change.

4) Operation and Maintenance by Users

The water level of battery was kept well by all users. When the PV system had problems, users normally informed the chief of the Rural Electrification Committee. The chief communicated and requested the Operators to settle the problem.

5.6 Technical Evaluation of PV System

The JICA Study Team and Operators examined the PV systems installed through the operation and maintenance. The results of the surveys proved that the function of the system is satisfactory in general as follows:

- The PV panel of 55Wp generated sufficient power for charging 100Ah battery.
- The controller worked well for protecting the battery from over charging and over discharging.
- The battery had enough capacity for the normal use.

No specific major troubles occurred nor were there any accidents caused by lightning in the hilly area. The systems installed for the pilot project are, therefore, considered to be appropriate ones from the technical point of view.

Several minor problems and lessons learnt for the future project are as explained below.

(1) Technical Problems and Solutions

Through the monitoring of operation and maintenance the following technical problems of the PV system were identified:

- Blackish bulbs
- Lamp with defective ballasts
- Noise on radio

Blackish bulbs

Some users in La Paz and Oruro complained this problem. For improving this, the JICA Study Team advised Operators both in La Paz and Oruro to collect all the blackened bulbs and ordered to request the replacement to the supplier before the warranty expired. The replacement was completed in April 2001.

Lamps with defective ballasts

Some lamps were not functioning in Oruro and La Paz. The JICA Study Team recognized that the problem was caused by defective ballasts and proposed to replace all ballasts. New ballasts were procured and the replacement was completed by end of April 2001.

Noise on Radio

Noise on radio was another complaint from users, when they put the radio near the fluorescent lamp. To solve the problem of the radio noise, the JICA Study Team procured and installed a filter inside the lamp. The installation to the PV systems was completed at the end of April 2001. The problem of the noise was solved after the installation of the filter.

(2) Comment on the System Capacity

During the field surveys conducted for this pilot project, the PV system with large capacity was requested to be installed by the residents with the following objectives.

- Lighting for livestock
- TV, computer and video deck for school
- Water pumping system for drinking and irrigation

Their requests on the PV system capacity were for more income generation and productive use. On the other hand, many people are still on subsistence level who cannot afford the payment of monthly fee of US$3 in our pilot project.

Under this situation, if PV systems with different capacities were provided depending on the users' selection, users would be satisfied more with the system and payment of the tariff would improve.

5.7 Evaluation of O&M System

(1) Evaluation of the Performance

Through the monitoring of the pilot project, evaluation was made on their performance. Result of the evaluation is satisfactory, in general, but several problems were identified as explained below:

1) Maintenance service of the Operator was not fully implemented. This is partly due to the location of the pilot project (isolated and far from main road) and partly due to frequent absence of users during Operator's inspection.
2) Coordinating function of the Prefecture / VMEH was expected for efficient operation and maintenance. However, the expected function was not fully implemented due to the limited manpower available and difficulty in daily communication.
3) Payment of the tariff was delayed and the tariff payment rate was still around 50% though it was improved after modification and enforcement of the system. According to the result of an interview survey, reasons of the delay are:

- PV system was misunderstood as the donation from JICA
- no regular income and/or limited income opportunity
- higher expectation for PV versus limited installed capacity

(2) Proposed Improvement

For solving the problems of operation and maintenance mentioned above, the following improvements are proposed and partly implemented.

1) O&M system mainly conducted by User/REC
   Most of the tasks conducted by the Operator are to be transferred to users/REC. For this, technical assistants are selected in REC who coordinate major operation and maintenance after getting training from the Operator. In case of major problems of equipment including replacement, the Operator is to provide technical service under the agreement with Users/REC.

2) Participation of Municipality in O&M
   Instead of Prefecture or VMEH, a representative of the municipality is to be included for necessary coordination in operation and maintenance for the PV system. In view of the location of municipality and intimate relation with users, the participation of municipality seems more practical for improvement. However, further capacity building for the staff of municipality might be required.

3) Improved tariff system
   For easy payment, the monthly fee is to be set at the minimum that covers only cost of distilled water and manpower cost of technical assistants and is to be collected by the technical assistants monthly or bi-monthly. However, replacement is required for battery and controller every 5 years or so. Some users can arrange the fund for the replacement, but most of the users may not.

   In order to arrange such fund and the fund for initial payment, creation or arrangement for establishing micro credit seems required.

5.8 Disposal of Used Battery

Recycling of batteries is being conducted by another private company, COMMETAL, a sister company of BATEBOL. The company handles 40% of the used batteries in

Bolivia and is functioning as a recycling center of battery. The capacity of disposal is reported at over 400,000 units of batteries per year.

In the Implementation Plan for Rural Electrification formulated in this study, about 2,895 PV systems and 7,998 PV systems are planned to be installed during Phase I (2002-2006) and Phase II (2007-2011), respectively. Even if these batteries are added to the present consumption, the COMMETAL still has enough capacity for recycling.

CHAPTER 6 SUMMARY OF STUDY ON MICRO-HYDRO POWER

6.1 Survey and Study Conducted

Survey and study conducted during the above period are as follows:

- Study on inventory and identify sites for discharge observation
- Installation of staff gauges (2 in La Paz and 2 in Oruro)
- Daily water level observation on selected priority project sites
- Selection of high priority projects (1 in La Paz and 1 in Oruro) and their engineering survey
- Topographic survey and mapping on the selected two priority sites
- Pre-feasibility study on the selected priority projects including Initial Environmental Evaluation (IEE)

6.2 Selection of Proposed Projects for Pre-feasibility Study

Selection of the projects for pre-feasibility study was made based on the result of the ranking study and through discussion with VMEH and La Paz and Oruro prefectures. The selected projects for pre-feasibility study are the following two projects.

1) La Paz : Apolo Machariapu River MHP (Apolo, F.Tamayo province)
2) Oruro : Tambo Qumeado MHP (Turko, Sahjama province)

6.3 Pre-feasibility Study on Apolo Micro-hydro Power Project

(1) Location and Hydrology

The proposed site of Apolo is 382 km north from La Paz city and around 14 hours distance by vehicle. The Apolo municipality is located in the province of Franz Tamayo, the department of La Paz.

The rainfall pattern is characterized by distinct two seasons, rainy and dry seasons. The annual average precipitation in Apolo is 1,618 mm/year. The catchment area at the proposed intake site is 371.15km^2. The river flow of the Machariapu River was estimated using the daily water level data collected in the Turiapu River from October 1999 to April 2001.

(2) Socio-economic Conditions and Demand for Electricity

1) Socio-economic Conditions

The population of Apolo Municipality was 12,857 in 1992. Agriculture still plays a dominant role in the local economy. A diesel generator (222 kW) owned and managed by a cooperative is currently under operation in Apolo town. Electricity supply is restricted to three hours a day. The average monthly household income is low at Bs 500 to 800 in Apolo town and the expenditure on electricity is Bs.30 to 40 per month.

2) Demand for Electricity

The target area to be electrified by the proposed micro-hydro project is determined depending on the hydropower potential. As the Machariapu River is endowed with abundant discharge, the target area would encompass surrounding communities including Apolo town.

All other communities except Apolo town are not electrified yet. The target area for electrification is supposed to encompass cantons of Apolo and Santa Cruz del Valle Ameno where many communities remain non-electrified. The target area is divided into seven (7) blocks.

Projection of the demand for electricity in the target areas was mad by separating it into domestic demand and non-domestic demand. The target year of the demand projection was set at year 2005.

Both domestic and non-domestic demands were aggregated to estimate total power demand, which is summarized as presented in the following.

(kW)

Block	Urban Area			Rural Area			Total Peak Demand
	Evening	Midnight	Daytime	Evening	Midnight	Daytime	
A	267	30	95	0	0	0	270
B	267	30	95	75	17	41	340
C	0	0	0	92	23	42	90
D	0	0	0	70	16	41	70
E	0	0	0	92	22	42	90
F	0	0	0	68	15	40	70
G	0	0	0	31	3	38	40
Total (B~G)	270	30	100	430	100	240	700

Note: Numbers of total and peak demand are rounded.

(3) Formulation of the Optimum Development Scheme

The Apolo project endowed with abundant discharge guarantees electricity supply to an extensive service area. Several alternative cases were formulated by increasing the target area as presented below.

Case		Target Area
Case-1	:	Apolo central town serving for 587 HH
Case-2	:	Case-1 + Airport + surrounding villages on the route of transmission line from MHP P/S to Apolo town serving for 840 HH
Case-3	:	Case-2 + Block F (San Jose) serving for 1,056 HH
Case-4	:	Case-3 + Block D (St. Domingo) serving for 1,286 HH
Case-5	:	Case-4 + Block C (St.Cruz.D.V.Ameno) serving for 1,624 HH
Case-6	:	Case-5 + Block E (San Pedro) serving for 1,961 HH
Case-7	:	Case-6 + Block G (San Marcos) serving for 1,993 HH

Power demand for the alternative cases was estimated based on which cost estimate was conducted. The construction cost includes civil works, electrical-mechanical works and was preliminarily estimated by using standard costs. The operation and maintenance cost was estimated on the basis of the construction cost. The benefit was also estimated in terms of the cost saving of the alternative diesel power.

Based on the estimated cost and benefit, economic evaluation was made for selecting the optimum scale of the project. The results of the comparison are as summarized as follows.

Case No.	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	**Case 7**
P (kW)	270	340	410	480	570	660	**700**
EIRR (%)	12.4%	14.2%	13.6%	14.9%	15.3%	15.7%	**16.1%**
B–C (US$) *	257,164	496,836	485,726	718,560	878,442	1,040,111	**1,154,299**
B/C *	1.17	1.27	1.22	1.29	1.30	1.31	**1.33**

*: with the discount rate of 10% per year

From the above analysis, the case 7 with the installed capacity of 700 kW was selected as the optimum scale of the Apolo micro-hydro power project.

(4) Preliminary Design and Cost Estimate

Proposed layout plan and preliminary design of the Apolo micro-hydro power was prepared as presented in Figure 6.1. The estimated construction cost of the project is US$4.0 million as summarized below.

Construction Cost of Apolo MHP (Summary for Pre-F/S)

Financial Cost (with tax) Unit : US$.

Item	Pre-F/S Case (700kW)	Note
1. Preparation Works & Access, etc.	**625,300**	
1.1 Preparation Works	294,200	(2.+3.).*10%
1.2 Access Road	325,500	Gravel Paved, W=4m (Sta.Teresa - Site)
1.3 Mitigation for Environment	5,600	2.*0.01
2. Civil Works	**562,500**	
2.1 Intake Weir	19,300	
2.2 Intake	19,600	
2.3 Sand Settling Basin	0	
2.4 Headrace	195,200	
2.5 Head Tank	112,600	
2.6 Penstock	35,300	
2.7 Spillway	12,600	
2.8 Power House	153,700	
2.9 Tailrace	14,200	
2.10 Outlet	0	
3. Electric and Mechanical Woks	**2,379,600**	
3.1 Turbine/Generator	740,000	350kW x 2 set, include tax, transportation, installation
3.2 Transmission/Distribution Line	1,419,900	
3.3 Mechanical Works	219,700	
4. Transportation	**110,100**	(2.+3.2+3.3)*5% (La Paz - Apolo - Site)
5.Direct Cost Total	**3,677,500**	1.+2.+3.+4.
6. Administration and Engineering Service	**323,000**	{Admin.: (1.+2.+3.)*6%+D/D: US$20,000}*138%
Total Construction Cost	**4,000,500**	4. + 5.

Note: Access Road Cost = Mountain Area (Rock): 9.1km*30,000 US$/km + Flat Area (Standard): 3.5km*15,000US$/km

(5) Construction Schedule

In due consideration of the present situation in Apolo and required fund, two stage development was proposed. Assuming that required time for design including basic design is 6 months, total required period for completion of the project is around 4 years.

(6) Economic and Financial Justification

1) Economic Evaluation

The economic viability of the Apolo micro-hydro power project is examined by computing the Economic Internal Rate of Return (EIRR), on the basis of the economic cost and economic benefit.

The EIRR is calculated at 19.2%, which indicates that the proposed project is economically feasible.

2) Financial Evaluation

The financial viability of the Apolo micro-hydro power project is examined by computing the minimum power tariff to cover the investment and O&M costs of the project. This indicates that the proposed project has substantial financial viability.

The calculated monthly power tariff to cover the investment cost and O&M cost is $1.27 per household, which is less than half of the amount residents pay at present.

(7) Initial Environmental Evaluation

The study on Initial Environmental Evaluation (IEE) was conducted during the fifth field survey in May 2001. According to the results of survey, no serious impact is anticipated in implementing the Apolo micro-hydro power project.

6.4 Pre-feasibility Study on Tambo Quemado Micro-Hydro Power

(1) Location and Hydrology

Tambo Quemado is around 200 km west from Oruro city and around 5 hours distance by vehicle. Tambo Quemado is located in the municipality of Turco, the province of Sajama, the department of Oruro.

The annual average precipitation is 327 mm. About 97% of the annual precipitation concentrates during the period from October to March, while the remaining 3% on April to September. The daily discharge of the Tambo Quemado River was estimated using the collected data in the Jaruma River.

(2) Socio-economic Conditions and Demand for Electricity

1) Socio-economic Conditions

The number of households in the Tambo Quemado village is around 55 with the estimated population of 235. Services related to the customs are major economic activity in Tambo Quemado. Livestock breeding is another economic activity. The annual average income per household is Bs 600 (around US$100).

Electricity is available from a diesel generator with the installed capacity of 112 kW. The company called "FRONTERA" started the electricity supply in 1997. Main users of the electricity are private companies and the government offices. The average monthly power tariff is around Bs. 25 per household.

2) Demand for Electricity

Since the hydropower potential of the Tambo Quemado is quite limited, the target area for electrification is confined to the Tambo Quemado village.

For the estimate of the demand, users were classified into two groups, namely domestic demand and non-domestic demand. The domestic demand is the demand of households and the non-domestic demand is further divided into business and public.

The estimated demand for electricity in 2005 is 62 kW as summarized in the table below.

Category	Present (2001)		Future (2005)	
	Number of HH or Facilities	Peak Demand (kW)	Number of HH or Facilities	Peak Demand (kW)
Domestic	55	40.2	69	58.8
Business	20	1.6	34	2.8
Industry	0	0.0	2	0.0
Public	2	0.0	1	0.0
Total	77	41.8	106	61.6

(3) Formulation of the Optimum Development Scheme

From the hydrological analysis, the proposed micro-hydro power to be constructed guarantees the projected peak demand during only 22% of a day. To meet the peak

demand during the remaining 78% of a day, additional power by diesel and/or construction of storage pond for the micro-hydro are required.

Considering the above, the following three alternative development plans were formulated for comparison.

Case A	MHP 40kW ($Q_{100\%}$) plus Diesel (22kW)
Case B	MHP 50kW ($Q_{54\%}$) with storage pond plus Diesel (12kW)
Case C	MHP 62kW ($Q_{22\%}$) with storage pond plus (No Diesel)

For selecting the optimum scheme of the project, cost and benefit for three alternative plans were estimated. Construction costs of alternative plans were estimated as well as the operation and maintenance cost. The benefit was estimated by the cost of the alternative diesel power to be saved.

Economic comparison on the alternative cases was made as summarized below.

Case No.	Case A	Case B with Storage Pond	Case C with Storage Pond
P (kW) HMP	40 kW	50 kW	62 kW
P (kW) Diesel	22 kW	12 kW	0 kW
EIRR (%)	9.0%	8.7%	**16.2%**
B–C (US$) *	-10,721	-14,250	**88,408**
B/C *	0.964	0.953	**1.438**

*: with the discount rate of 10% per year

The results of comparison indicate that the installed capacity of 62 kW with storage pond (Case-C) is the optimum one. Case-C was finally selected as the optimum development plan.

(4) Preliminary Design and Cost Estimate

Proposed layout plan and preliminary design of the Tambo Quemado micro-hydro power was prepared as presented in Figure 6.2. The estimated construction cost of the project is 239,700US$ as summarized in the following table.

Estimated Construction Cost of Tambo Quemado MHP

Financial Cost (With Tax) (62kW) **Unit : US$.**

Item	Cost	Note
1. Preparation Works & Access, etc.	**2,224**	
1.1 Preparation Works	1,112	2.*0.01
1.2 Access Road	0	
1.3 Mitigation for Environment	1,112	2.*0.01
2. Civil Works	**111,195**	
2.1 Intake Weir	133	
2.2 Intake	113	
2.3 Sand Settling Basin	0	
2.4 Headrace	77,873	
2.5 Head Tank	29,717	
2.6 Penstock	943	
2.7 Spillway	450	
2.8 Power House	1,904	
2.9 Tailrace	62	
2.10 Outlet	0	
3. Electric and Mechanical Woks	**94,626**	
3.1 Turbine/Generator	38,700	
3.2 Transmission/Distribution Line	26,056	
3.3 Mechanical Works	29,870	
4. Transportation	**10,291**	(2.+3.)*5%
5.Direct Cost Total	**218,336**	1.+2.+3.+4.
6. Administration and Engineering Service	**21,366**	6. *9.8%
Total Construction Cost	**239,700**	4. + 5.

(5) Construction Schedule

Assuming that required time for design including basic design is 4 months, total required period for completion of the project is around 10 months.

(6) Economic and Financial Justification

1) Economic Evaluation

The economic viability of Tambo Quemado micro-hydro power project is examined by computing the Economic Internal Rate of Return (EIRR) on the basis of the economic cost and economic benefit.

The EIRR of the Tambo Quemado micro-hydro power project are computed to be 16.4%, using the economic cost and benefit stream shown above. It indicates that the proposed project is economically viable.

2) Financial Evaluation

The financial viability of the Tambo Quemado micro-hydro power project is examined by computing the minimum power tariff of the residential sector to cover the costs of the project.

The results of the calculation indicates that the estimated power tariff covering O&M cost and the investment cost is less than the current rate the residents pay.

(7) Initial Environmental Evaluation

During the fifth field survey in May 2001 the study on Initial Environmental Evaluation (IEE) was conducted. The Tambo Quemado micro-hydro power project will have no serious impacts in/around the project site according to the results of survey.

CHAPTER 7 SUMMARY OF STUDY ON WIND POWER PROJECTS

7.1 Survey and Study Conducted:

Survey and study conducted for the wind power development are as follows:

- Collection of the existing wind data and information.
- Site selection of the wind monitoring system.
- Procurement of equipment and contractor, and supervision of construction
- Monitoring of the wind monitoring system / collection of data and analysis of the wind data.
- Project formulation for wind power development.
- Selection of high priority projects for pre-feasibility study and economic/financial analysis of the projects.

7.2 Site Selection and Installation of Wind Monitoring System

Appropriate sites for installing the wind monitoring system were selected; five (5) sites in La Paz and five (5) sites in Oruro.

(1) La Paz

1)	Achiri,	Municipality: Caquiaviri
2)	Charaña,	Municipality: Charaña
3)	Ramon Gonzales	Municipality: G.J.J.Perez
4)	Isla Taquiri	Municipality: Manco Kapac
5)	Santiago de Llallagua	Municipality: Colquencha

(2) Oruro

1)	Comujo / Coipasa	Municipality: Coipasa
2)	Caripe	Municipality: C.de Carangas
3)	Chachacomani	Municipality: Turco
4)	Salinas de Garci Mendoza	Municipality: S.Garci Mendoza
5)	Sevaruyo	Municipality: S.de.Quillacas

The installation works of the wind monitoring systems began in January and were finished in February 2000. The installation works started later than originally scheduled due to the customs clearance of the monitoring equipment.

7.3 Selection of Proposed Projects for Pre-feasibility Study

Three potential sites for La Paz and Oruro are to be selected for further study based on the results of one-year wind monitoring and socio-economic data. As criteria for the selection, wind potential, canton population and development priority on prefectures were take into consideration.

On the basis of the above results, the following three cantons from, one in La Paz and two in Oruro were selected for pre-feasibility study.

La Paz	1	Charaña
Oruro	1	Chachacomani
	2	Caripe

7.4 Pre-feasibility Study on Wind Power Projects: Charaña, Caripe and Chachacomani

(1) Location and Socio-economic Condition

Charaña is a border town between Bolivia and Chile. The population of Charaña was 1,037 in 1992, which decreased to 1,016 in 2000. Main economic activities are custom services and the related activities in Charaña. Livestock breeding is another major economic activity. Electricity is being supplied by a diesel generator in Charaña. The installed capacity of the diesel generator is 135 kVA supplying electricity to 80 households. The diesel generator is operated by the canton.

Caripe is located north of Oruro department. The population of Caripe was 208 in 1992, which decreased to 206 in 2000. The main economic activity is livestock breeding in Caripe. Around 300 cattles are held per household on an average and people are relatively rich. The demand for electricity in Caripe is small due to the size of the population. There is no electricity supply service in Caripe at present.

Chachacomani is located north of Oruro department. The population of Chachacomani was 476 in 1992, which decreased to 470 in 2000. The main economic activity is livestock breeding in Chachacomani. Many residents of Chachacomani work in Tambo Quemado, the border town to the Chile. There is no electricity supply service in Chachacomani. People are using candle, kerosene lamp and gas lamp for lighting instead of electricity.

(2) Demand for Electricity

The demand for electricity was estimated on the basis of the results of the community interview survey. The demand was estimated for commercial activity, public service and household use, separately. The target year for the estimate of the demand was set at year 2005.

The estimated peak demand is around 26 kW in Charaña, 4.9 kW in Caripe and 9.7 kW in Chachacomani.

The monthly power demand was also calculated as presented in the following table. The total demand for electricity was estimated at 65,678 kWh in Charaña, 9,951kWh in Caripe and 20,440kWh in Chachacomani.

Monthly Power Demand

	Power Demand (kWh/Mo.)		
	Charana	Caripe	Chachacomani
Jan.	5,328	845	1,736
Feb	4,812	763	1,568
Mar	5,626	845	1,736
Apr	5,445	818	1,680
May	5,626	845	1,736
Jun	5,445	818	1,680
Jul	5,626	845	1,736
Aug	5,626	845	1,736
Sep	5,445	818	1,680
Oct	5,626	845	1,736
Nov	5,445	818	1,680
Dec	5,626	845	1,736
Total	65,678	9,951	20,440

Source: JICA Study Team

(3) Formulation of Optimum Development Scheme

Charaña

For the selection of the optimum development scheme of the Charaña wind power project, five alternative schemes were formulated for satisfying the project demand. Since, there exists no hydro power potential in Charaña, only wind –PV combination was studied. From the wind data analysis, the minimum installed capacity of PV guarantees 80% of the daytime demand. Economic investment cost for each alternative scheme was estimated and compared.

From this comparison, combination of wind with 80kW and PV with 16kWp was selected as the optimum scheme.

Caripe

For the selection of the optimum development scheme of the Caripe wind power project, two alternative schemes were formulated through the analysis of the wind data. Since, there exists no hydro power potential in Caripe, only wind –PV combination was studied and the minimum installed capacity of the PV was set at 2 kWp that guarantees 80% of the daytime demand. Investment cost for each alternative scheme was estimated and compared. From this comparison, the combination of wind with 10kW and PV with 4kWp was selected as the optimum scheme.

Chachacomani

In Chachacomani, two hybrid systems, namely, wind-microhydro and wind-PV were formulated because micro-hydro potential was identified.

The evaluated best combination of the two hybrid schemes are:

1) Hybrid of wind – microhydro: wind power of 20 kW and micro-hydro power of 3 kW
2) Hybrid of wind – PV system: wind power of 40 kW and PV system of 9kWp

Estimated cost for the wind–microhydro power and the wind–PV system are US$ 252,969 and US$ 347,066, respectively, that indicates the hybrid system with micro-hydro is preferable. Beside this, the capacity of battery is smaller in case of the wind – microhydro system and the maintenance cost is less than that of wind-PV system.

Through this analysis, the wind-microhydro hybrid system was finally selected as the optimum development scheme for the Chachacomani wind power project.

(4) Preliminary Design and Cost Estimate

1) Proposed Wind Power System

As explained earlier, the power generation system at Charaña and Caripe consist of wind turbine and PV system, the system at Chachacomani consists of wind turbine and micro-hydro. In case of Charaña, the existing diesel generator is planned to be used as a back up generator. According to the development policy of the VMEH, electrification by diesel generator is not recommended. However, for high demand town such as Charaña, back up generator is necessary during terminal maintenance and/or for unexpected increase of power demand. In Chachacomani, to reduce the investment cost of the hybrid scheme, the micro-hydro power is to be designed to produce steady power throughout a year. As the most optimum scheme, the installed capacity of the micro-hydro was designed to be 3.0 kW. Generation systems and layout plans of the Charaña, Caripe and Chachacomani are presented in Figure 7.1 to 7.6.

2) Cost Estimate

The estimated costs of the wind power development projects are US$ 817,798 for the Charaña, US$ 147,296 for the Caripe and US$ 294,674 for the Chachacomani as summarized below.

Project Cost Estimation (Financial cost)

(unit: US dollar)

Item	Charana	Caripe	Chachacomani
1. Wind generator, PV system, etc.	478,822	88,405	209,242
2. Distribution Line	35,885	11,040	15,000
3. Installation Works	144,000	21,000	30,000
4. Transportation	92,946	14,938	16,598
5.Direct Cost Total	751,653	135,382	270,840
6. Administration and Engineering Service.	66,145	11,914	23,834
Total Construction Cost	**817,798**	**147,296**	**294,674**

Source: JICA Study Team

(5) Economic and Financial Justification

1) Economic Evaluation

The economic viability of the three wind power projects is examined by computing the Economic Internal Rate of Return (EIRR) on the basis of the economic cost and economic benefit.

The EIRRs of the three projects on the basis of the above assumptions are computed as follows.

EIRR of the Wind Power Projects

Charaña	Caripe	Chachacomani
-2.6%	1.0%	-0.9%

The EIRRs of the two projects are negative. However, the costs of the wind turbine, inverter, converter and PV systems are expected to decline in the future. Should the demand for the wind power generation systems increases in the future, the unit price will likely to fall further and the wind power projects might be justified economically.

2) Financial Evaluation

The financial viability of the three wind power projects is examined by computing the power tariff to cover and O&M cost of the projects.

a) Charaña

The calculated monthly payment would be US$2.65, which is lower than the amount they pay at present. The wind power project in Charaña will be able to recover 100% O&M cost and a part of the investment cost through power tariff. Under such condition, the wind power project in Charaña would be financially sustainable.

b) Caripe

The calculated monthly payment would be US$3.15, which is lower than the amount they pay at present. The wind power project in Caripe will be able to recover 100% O&M cost and a part of the investment cost through power tariff.

Under such condition, the wind power project in Charaña would be financially sustainable.

c) Chachacomani

The calculated monthly payment would be US$4.73, which is slightly higher than the amount they pay at present. However, the service and the benefit they get from 24 hour-a-day operational wind power generation would be no comparison to that of using a kerosene lamp. It could well be said that the wind power project in Chachacomani is sustainable if O&M cost is to be covered by the power tariff.

(6) Initial Environmental Evaluation

The study on Initial Environmental Evaluation (IEE) was conducted during the fifth field survey in May 2001. The results of survey indicate no negative impact on the natural environment as well as social environment is foreseen in implementing the Charaña, Caripe and Chachacomani wind power projects.

Anticipated noise and obstacle of landscape will give a negligible impact on the social environment because the system plans to be built on the outskirts of the town.

CHAPTER 8 RURAL ELECTRIFICATION PLAN BY RENEWABLE ENERGY IN LA PAZ AND ORURO (2002-2011)

8.1 Renewable Energy Sources and Evaluation

(1) Target Renewable Energy Sources

The following three environmentally-friendly renewable energy sources are to be included for rural electrification planning in La Paz and Oruro departments.

1) Micro-hydro power (MHP)
2) Wind power
3) Photo-voltaic (PV)

Biomass is not included in this plan. The rural electrification plan of 2002-2011 was, thus, formulated using the renewable energy sources such as micro-hydro, wind power and PV in combination with the grid line extension.

(2) Potential Energy Resources

1) Micro-hydro Power

For identifying micro-hydro power projects, potential for hydropower in La Paz and Oruro was reviewed and studied.

The estimated potential maps of hydropower in the department La Paz and Oruro are as shown in Figures 8.1 and 8.2.

As indicated, high potential area of hydropower is located at northwest - southeast corridor along "Cordillera Oriental de Los Andes" mountains in La Paz, while the potential area is quite limited in Oruro.

2) Wind Power

Wind potential maps were prepared based on the collected wind data and available topographic data as presented in Figure 8.3 to 8.4. The map indicates that the wind potential area in Oruro is larger than that of La Paz. The wind potential is high especially in west side of Oruro and southwest part of La Paz.

3) PV Power

PV potential map was prepared based on the collected data from the PV and window monitoring sites being supplemented by the radiation data of GTZ as presented in Figures 8.5 and 8.6.

As indicated in the map, potential of PV power is very high in Bolivia and Oruro has much potentiality for PV than La Paz.

(3) Cost Comparison of Renewable Energy Sources

Costs of the renewable energies were estimated and compared with those of grid extension and diesel power.

The results of the analysis are summarized below.

Electricity Cost by Energy Source

(US$ per kWh)

	Grid		PV	MHP	Wind	Diesel
	Small	Large				
Economic Cost	0.15	0.17	1.60	0.16	0.58	0.18
Financial Cost	0.16	0.18	1.90	0.18	0.70	0.21

Source: JICA Study Team

8.2 Methodology of the Rural Electrification Plan

(1) VMEH's Policy

Although the VMEH promotes renewable energy-based generation in the potential areas, the majority of the rural electrification is still done by grid extension because of its cost advantage. Based on the VMEH's policy and the results of the cost comparison, it was assumed that rural electrification plan of La Paz and Oruro is to be prepared principally by the grid extension, and will be complemented by renewable energies.

As already discussed in Chapter 3.1, the VMEH expects more active participation on the part of the beneficiaries in identifying and implementing rural electrification projects. It is expected that rural residents share the installation and equipment costs and take more responsibility for operation and maintenance of the systems in the future.

(2) Rural Electrification Investment

As the total framework for the electrification, annual investment for rural electrification for 2002 both in La Paz and Oruro was estimated based on the average of the past four-year investment amounts and it is expected to increase by 3.6% per annum till 2011.

Estimate of Annual Investment for Rural Electrification in 2002

La Paz	:	US$2.7 million
Oruro	:	US$1.6 million

In La Paz, 65% of the total investment for rural electrification is expected to be allocated for grid extension during 2002-2006 and 60% during 2007-2011. In Oruro, 70% of the total investment for rural electrification is to be allocated for grid extension during 2002-2006 and 60% during 2007-2011.

(3) Plan Formulation of Renewable Energy Development and Grid Extension

1) Micro-hydro Power and Wind Power

Development of micro-hydro power and wind power is to be planned in the areas where the power potential exists. Formulation of development projects for micro-hydro and wind powers were carried out in the following process.

- Evaluation of potential areas and identification of candidate sites
- Exclusion of projects located in the areas where a grid line exists or is to be installed in the future
- Selection of priority projects through economic comparison with grid extension
- Prioritization of the selected projects for implementation

2) PV Power

Since the energy cost of the PV is the most expensive one among the renewable energies, installation of PV was planned only in the isolated areas where no other economical energy resources are available and outside of the grid extension plan in the future. Identification of candidate sites was made in the following manner.

- Evaluation of the potential area for PV
- Selection of the candidate sites for PV from the isolated areas where no grid line is extended in the future

Numbers of the PV projects were determined by the remaining amount of investment after the allocation to the micro-hydro and wind power.

3) Grid Extension

Future projection was made in the following process:

- Projection of extension during 2002-2006 on the basis of allocated budget and plans of the VMEH and two prefectures
- Projection of extension during 2007-2011 based on the priority analysis of related cantons and the projected grid extension map of 2006

8.3 Rural Electrification Plan (2002-2011)

(1) Micro-hydro Power Development Plan

1) Formulation of Candidate Projects

Identification of candidate micro-hydro power projects was made on the basis of a hydropower potential map, and available micro-hydro power inventory.

Since micro-hydro powers to be formulated for the rural electrification are basically for isolated power source, the projects which plan to supply electricity to the areas with the existing grid or grid line to be connected in the near future were excluded from the candidate list.

2) Selection of Priority Projects

For the selection of the priority projects for micro-hydro power, evaluation was made whether the cost of the candidate micro-hydro is competitive to that of the grid line (if connected) or not.

Only the hydropower projects which are more economical than that of grid extension are to be finally selected for the priority projects to be included in the rural electrification implementation plan up to year 2011.

Through this, priority projects of the micro-hydro power for the rural electrification were finally selected; 31 projects in La Paz and 3 projects in Oruro. The installed capacities of the priority projects are 2,316 kW in La Paz and 102 kW in Oruro.

3) Stage-wise Implementation of the Priority Projects

Based on the result of the ranking study on the priority projects, the micro-hydro power projects were divided into Phase-I to be implemented during 2002 - 2006 and Phase-II during 2007 - 2011 as summarized below.

Proposed Micro-Hydro Power Projects (La Paz)

Phase	Year	Beneficiary Household (HH)	Installed Capacity (kW)	Investment Cost (MHP) (US$)
Phase - I	2002 - 2006	4,240	1,096	3,496,000
Phase - II	2007 - 2011	3,490	1,220	3,541,000
TOTAL	(2002 - 2011)	7,730	2,316	7,037,000

Proposed Micro-hydro Power Projects (Oruro)

Phase	Year	Beneficiary Household (HH)	Installed Capacity (kW)	Investment Cost (MHP) (US$)
Phase - I	2002 - 2006	69	62	240,000
Phase - II	2007 - 2011	140	40	128,000
TOTAL	(2002 - 2011)	209	102	368,000

As indicated above, 30 micro-hydro power projects, 13 during phase-I and 17 during phase-II are planned to be implemented in La Paz, while only 3 micro-hydro power projects in Oruro.

(2) Wind Power Development Plan

1) Formulation of Candidate Projects

For identifying candidate projects for wind power development, review of the wind potential map was made together with the monitored wind data.

12 sites in La Paz and 5 sites in Oruro were selected as the candidate sites. For preparing wind power development plan for each site, demand for electricity

including for households, commercial and public use was firstly estimated. Then, the optimum hybrid scheme with PV or micro-hydro was determined after comparison of alternatives. Most of the formulated wind power development projects are hybrid system with PV except one with micro-hydro.

The formulated wind power projects were further evaluated by comparing their costs to the cost of grid extension. Only the projects which are competitive to the grid extension were finally selected as the priority projects for wind power development to be included in the Implementation Plan for Rural Electrification. In La Paz, 10 wind power projects were selected with the installed capacity of 386 kW, while only four wind power projects in Oruro with the installed capacity of 135 kW.

2) Priority of Project Implementation

Based on the result of the ranking study on the priority projects, all the wind power projects were planned to be implemented during the period of two different phases. During Phase I period (2002-2006), seven wind power projects, four in La Paz and three in Oruro were planned to be implemented with the installed capacity of 279 kW, while another seven wind power projects, six in La Paz and one in Oruro were planned with the installed capacity of 242 kW during Phase II (2007-2011).

Wind Power Development Plan (Phase I: 2002 — 2006)

	Canton	Objective HHs	Capacity (kW)	Investment Cost (US$)
La Paz	OKORURO	48	36	251,624
	CHARANA	150	96	678,437
	CHINOCABI	44	26	198,042
	RIO BLANCO	36	24	172,464
	(Sub Total)	278	182	1,300,567
Oruro	CARIPE	30	14	122,364
	COSAPA	146	60	432,575
	CHACHACOMANI	70	23	267,426
	(Sub-Total)	246	97	822,365
Total		524	279	2,122,932

Source: JICA Study Team

Wind Power Development Plan (Phase II: 2007 — 2011)

	Canton	Objective HHs	Capacity (kW)	Investment Cost (US$)
La Paz	E.ABARO	32	22	150,150
	GREAL. PEREZ	30	22	149,062
	LADISLAO CABRE	34	22	150,150
	CATACORA	74	56	363,140
	PAIRUMANI GRAN	46	36	250,536
	POJO PAJCHIRI	60	46	303,030
	(Sub-Total)	276	204	1,366,068
Oruro	LAGUNAS	62	38	273,938
Total		338	242	1,640,006

Source: JICA Study Team

(3) PV System Development Plan

1) Selection of PV Priority Areas

As indicated in the alternative cost comparison, the energy cost of the PV system is the most expensive among the renewable energy sources. Application of the PV system is, therefore, confined to the isolated areas, in principle, where no other renewable energy sources is available such as micro-hydro and wind power.

The priority sites for the PV system were selected using the priority map of grid extension prepared in the succeeding subsection. As indicated in Figures 8.9 to 8.10, cantons belong to C and D groups were selected as the priority sites for the PV system both in La Paz and Oruro. However, considering the situation that only a part of the canton is electrified even if the grid lines extend to the canton, isolated areas of the cantons belong to A and B groups were also considered as potential sites for the PV system.

2) PV Implementation Plan

According to the result of the economic comparison, higher priority for the electrification plan is to be given to micro-hydro and wind power among renewable energies. The implementation plan of the electrification by using PV was, therefore, formulated within the framework of allocated fund for the total renewable energy development (or using the fund after deducting investment for micro-hydro and wind power from the total allocated fund for the renewable energies) assuming that investment cost of PV is $800 per household.

The estimated implementation plan for PV system both in La Paz and Oruro is summarized below

PV Implementation Plan

(Unit: PV System)

Phase / Department	Phase 1 (2002-2006)	Phase 2 (2007-2011)	Total
La Paz	177	3,361	3,538
Oruro	2,235	4,637	6,872
Total	2,412	7,998	10,410

(4) Grid Line Extension Plan

1) Grid Line Extension Plan for 2002-2006

Grid line extension between 2002 and 2006 was projected on the basis of the grid line map of 2001 in due consideration of the future development projects of the VMEH and the two prefectures. The projected grid line extension plans by 2006 are as presented in Figure 8.7 and 8.8.

2) Grid Line Extension Plan for 2007-2011

The grid line extension between 2007 and 2011 was projected by prioritizing the non-electrified cantons in La Paz and Oruro using the criteria explained below.

The non-electrified cantons as of 2006 (184 in La Paz and 49 in Oruro) were evaluated and priority ranking for the electrification was made.

Three criteria to rank not-electrified cantons for prioritizing grid extension are 1) population density, 2) distance from the existing grid line and 3) Basic Needs. Scores are given to each not-electrified canton based on the three criteria mentioned above and they are categorized into four groups from A to D according to the total scores gained as follows. Those cantons in the group A have the highest priority for electrification by grid extension while those in the group D have the lowest priority.

The cantons with the priority A and B are planned to be connected by grid line extension by 2011 in principle.

Results of the above prioritization are presented in Figures 8.9 and 8.10 as well as the projected grid extension in 2011.

(5) Overall Projection of Rural Electrification

Projection of rural electrification in La Paz and Oruro departments during 2002-2011 was made based on the development plans proposed in the preceding sections and the following additional assumptions on new beneficiaries by the micro-hydro and wind power.

New Beneficiaries of MHP and Wind Power Projects

		2001	2002-2006	2007-2011
MHP	La Paz	779	4,240	3,490
	Oruro	0	45	140
Wind Power*	La Paz	0	278	276
	Oruro	0	246	62

*Wind power projects are hybrid-generation with PV or MHP.
Source: JICA Study Team

The results of the projection are summarized below.

1) Number of New Beneficiaries

The numbers of total new beneficiaries are 14,212 during 2002-2006 and 17,611 during 2007-2011 in La Paz while such numbers are 8,610 and 11,060 in Oruro.

2) Projected Rural Electrification Rates

The next table summarizes the projected rural electrification rates for La Paz and Oruro. It is expected that rural electrification rate will reach 36.4% (84,321 households) in 2006 and 43.9% (101,643 households) in 2011 in La Paz and 30.8% (18,746 households) and 50% (29,739 households) in respective years in Oruro.

Projected Rural Electrification Rate

La Paz

	2000	2002	2006	2011
Total No. of Rural Households	233,202	232,629	231,879	231,669
Existing No. of HHs with Electricity	54,906	70,673	81,436	97,916
New Benecifiary HHs with Electricity	4,323	2,724	2,969	3,771
Decrease in No. of Electrified HHs by Diesel	-190	-145	-85	-43
Total No. of Rural HHs with Electricity	59,039	73,252	84,321	101,643
Rural Electrification Rate (%)	25.3%	31.5%	36.4%	43.9%

Oruro

	2000	2002	2006	2011
Total No. of Rural Household	62,566	61,981	60,846	59,473
Existing No. of HHs with Electricity	7,908	10,268	16,955	27,303
New Beneciary HHs with Electricity	1,023	1,739	1,810	2,445
Decrease in No. of Electrified HHs by Diesel	-44	-34	-20	-10
Total No. of Rural HHs with Electricity	8,887	11,973	18,746	29,739
Rural Electrification Rate (%)	14.2%	19.3%	30.8%	50.0%

Source: VMEH and JICA Study Team

3) Total Beneficiaries and Breakdown by Energy Source

The tables below show the number of total beneficiaries and breakdown by energy source.

Total Beneficiaries and Breakdown by Energy Source

La Paz

		2000	2002	2006	2011
PV	Total	693	916	1,070	4,431
	Share	1.2%	1.2%	1.3%	4.4%
Micro-hydro	Total	516	2,195	5,535	9,025
	Share	0.9%	3.0%	6.6%	8.9%
Wind	Total	0	30	278	554
	Share	0.0%	0.0%	0.3%	0.5%
Total Renewable Energy	Total	1,209	3,141	6,883	14,010
	Share	2.0%	4.3%	8.2%	13.8%
Grid Extension	Total	56,510	69,102	76,848	87,332
	Share	95.7%	94.3%	91.1%	85.9%
Diesel	Total	1,320	1,010	591	302
	Share	2.2%	1.4%	0.7%	0.3%
Total	Total	59,039	73,252	84,321	101,643
	Share	100%	100%	100%	100%

Oruro

		2000	2002	2006	2011
PV	Total	1,352	2,355	3,984	8,621
	Share	15.2%	19.7%	21.3%	29.0%
Micro-hydro	Total	365	365	410	550
	Share	4.1%	3.0%	2.2%	1.8%
Wind	Total	0	0	246	308
	Share	0.0%	0.0%	1.3%	1.0%
Total Renewable Energy	Total	1,717	2,720	4,640	9,479
	Share	19.3%	22.7%	24.8%	31.9%
Grid Extension	Total	6,860	9,016	13,968	20,189
	Share	77.2%	75.3%	74.5%	67.9%
Diesel	Total	310	237	138	71
	Share	3.5%	2.0%	0.7%	0.2%
Total	Total	8,887	11,973	18,746	29,739
	Share	100%	100%	100%	100%

Source: JICA Study Team

In La Paz, the ratio of total households electrified by the grid line is expected to go down from 95.7% in 2000 to 85.9% in 2011. It is mainly replaced by the micro-hydro, whose ratio to total is expected to increase from 0.9% to 8.9% during the same period. The ratio of total renewable energies to the total will expand from 2% in 2000, 8.2% in 2006 and 13.8% in 2011.

In Oruro, total households electrified by the grid are expected to go down from 77.2% of the total in 2000 to 67.9% in 2011. Those electrified by PV are projected to expand significantly from 15.2% of the total in 2000 up to 29% in 2011. The ratio of total renewable energies to the total will increase from 19.3% in 2000, 25.0% in 2006 and 32.0% in 2011.

4) Estimated Electricity Consumption

On the basis of the projected electrification during 2002-2011, electricity consumption was estimated. In La Paz, electricity consumption is expected to increase from 21,377MWh in 2002, 26,608MWh in 2006 and then to 34,558MWh in 2011. In Oruro, it is expected to expand from 2,874MWh in 2002, 4,835MWh in 2006 and then to 7,951MWh in 2011.

5) Comparison with the Projected Power Demand

The proposed rural electrification plan is to meet the following percentage of the potential demand estimated in the preceding chapter.

Proportion of the Demand to be Satisfied by the Plan

	2002	2006	2011
La Paz	44.4%	51.2%	63.4%
Oruro	24.3%	38.5%	62.4%

8.4 Implementation Structure

(1) Implementation Organization

Under the PRSP, municipality plays an important role as an implementing organization. Municipality is expected to be the implementing organization for this development plan since foreign aid organizations are going to strengthen human resources of municipality in line with the trend of PRSP. However, the human resources of municipality is limited both in quality and in quantity, municipality is to have a capacity of commitment and management to the private companies and NGOs at least.

After taking the trainings of renewable energy development such as the PROPER (Extension and Transfer Technology with Renewable Energy Program) assisted by the GTZ, the private companies and NGOs conducted the projects committed foreign aid organizations and play an important role as an implementing and supporting organization. Thus, the existing private companies and NGOs have a potential to conduct the implementation of this plan. There is no experience of wind power project in Bolivia. Experienced foreign consultants are to be employed in the initial stage due to the quite limited knowledge and experience in the wind power project.

Public-oriented

The public-oriented is that municipality as an implementing organization utilizes the DUF fund mainly and conducts a rural electrification project. Target area is poor area where rural electrification by renewable energy is difficult to expand without governmental financial support. Under the PRSP, Figure 8.11 presents proposed organization for a project implementation.

Private-oriented

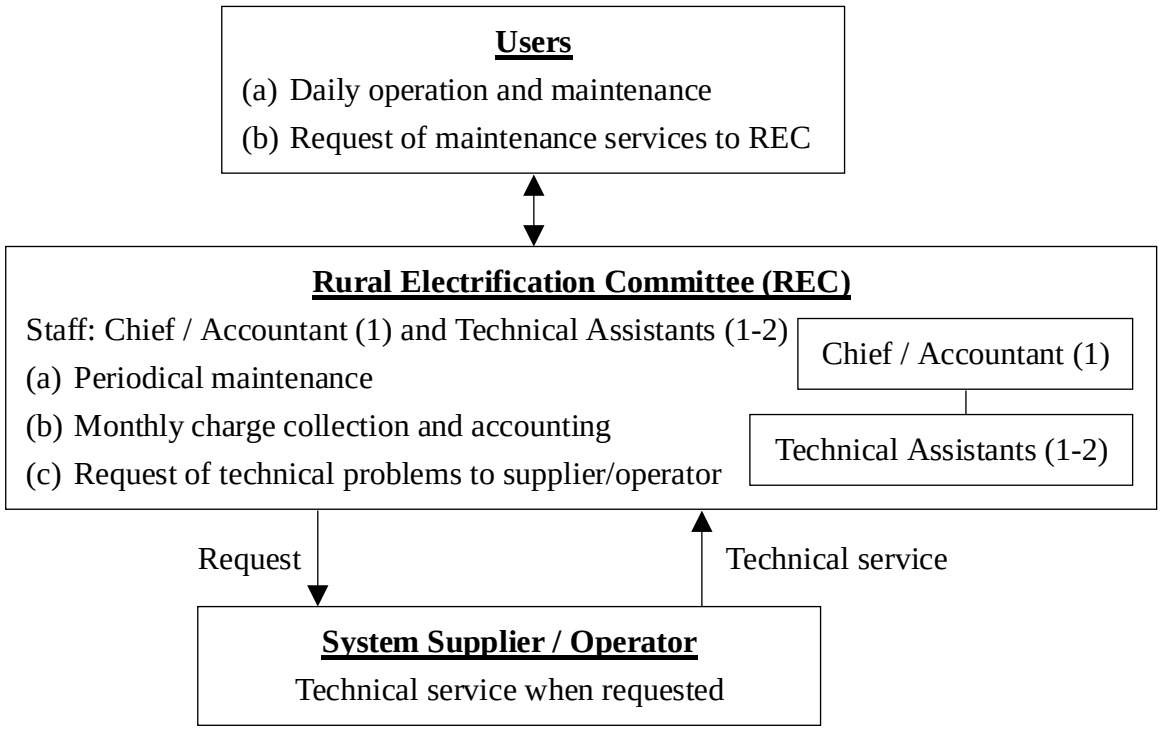
The private-oriented is that the PV system suppliers work for procurement of equipment, installation, training of daily operation and maintenance for local users and technical service when users require. This system is, thus, applied for relatively rich local people who have a capacity to pay for the PV equipment. Under implementing the PRSP, as private businesses, private companies such as a system supplier promote and implement PV projects.

(2) Operation and Maintenance System

1) PV System

Through the experience of the PV pilot project, users and a rural electrification committee (REC) are to carry out ordinary operation and maintenance of PV system. In this sense, initial training to users and technical assistants of the REC is very important for sustainable operation and maintenance.

The training is to be conducted by the system supplier or operator during the project implementation. Proposed operation and maintenance system of PV is as summarized below

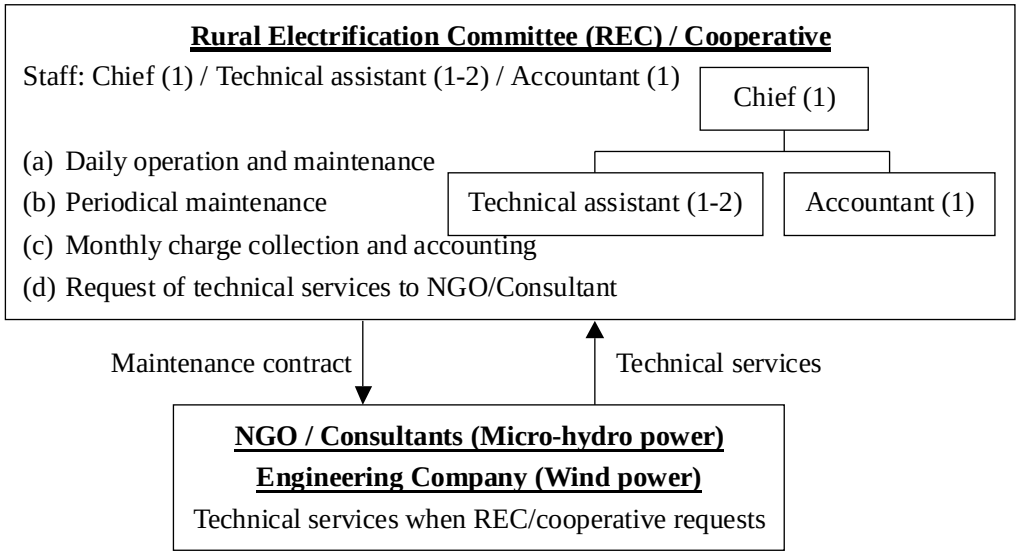


2) Micro-hydro Power and Wind Power

A well-organized system has already been established through cooperation with experienced NGOs and consultants for the operation and maintenance of micro-hydro power projects. A rural electrification committee (REC) or cooperative trained by NGO or consultants manages the daily operation and maintenance. NGO/consultants carry out special maintenance services if REC or cooperative requests.

There is no experience of wind power project in Bolivia. The job of the local consultants/engineering company is to get the technology transfer of the operation and maintenance through experienced foreign consultants and to accumulate the know-how for continuous operation and maintenance of the wind power projects.

The technical assistants of REC/cooperative are to be trained on the operation and maintenance by the consultants/NGO and the engineering company who are in charge of the installation during the project implementation. Proposed operation and maintenance to be conducted by REC/cooperative is through the following system.



8.5 Fund Arrangement for Rural Electrification

(1) Fund Arrangement Plan

The required fund for implementing the proposed electrification plan was estimated as presented below. Financial viability of the rural electrification plan was checked by verifying whether the two prefectures would be able to arrange these funds for the Phase I.

Required Fund for Rural Electrification

(US$1,000)

	Phase I (2002-2006)	Share
Public Investment	14,594	62.5%
External Source	7,297	(50%)
Internal Source	7,297	(50%)
Private Investment	8,739	37.5%
Total	23,333	100%

* Estimated figure on the basis of the past trend of VIPFE

1) Fund from External Source

As presented in the above table, the estimated public fund to be arranged by the external source is approximately US$7.3 million during the Phase I.

During the period of 1996-2001, Bolivia spent US$70 million for energy sector. Assuming that 33% of the total amount was allocated to La Paz and Oruro, and

44% was spent for rural electrification out of total energy sector, the amount of US$10.2 million would have been spent for rural electrification in La Paz and Oruro.

Meanwhile, the country has been negotiating with various external sources and at this stage expects external funds of US$23 million[1] for the energy sector between 2002 and 2005. It is estimated that US$3.3 million may be available for the plan for the two prefectures during the Phase I.

In addition, IBRD has a plan to finance approximately US$20 million, of which about two thirds is said to be earmarked for rural electrification. It is estimated that US$4.4 million may be available for the plan in the Phase I.

Thus, approximately US$7.7 million (US$3.3 million + US$4.4 million) would be available for the rural electrification of the two departments during the Phase I, which is sufficient to cover the required amount of US$7.3 million for the proposed plan.

2) Internal Source Fund

The requirement from the internal public source (mainly tax revenues) for the plan during the Phase I is US$7.3 million. According to the statistics the combined rural electrification investment during the past five years (1996 - 2000) was US$23.6 million, of which approximately US$7.8 million would have been spent for the rural electrification in La Paz and Oruro departments. The amount is larger than the estimated internal fund of US$ 7.3 million.

3) Private Sector Fund

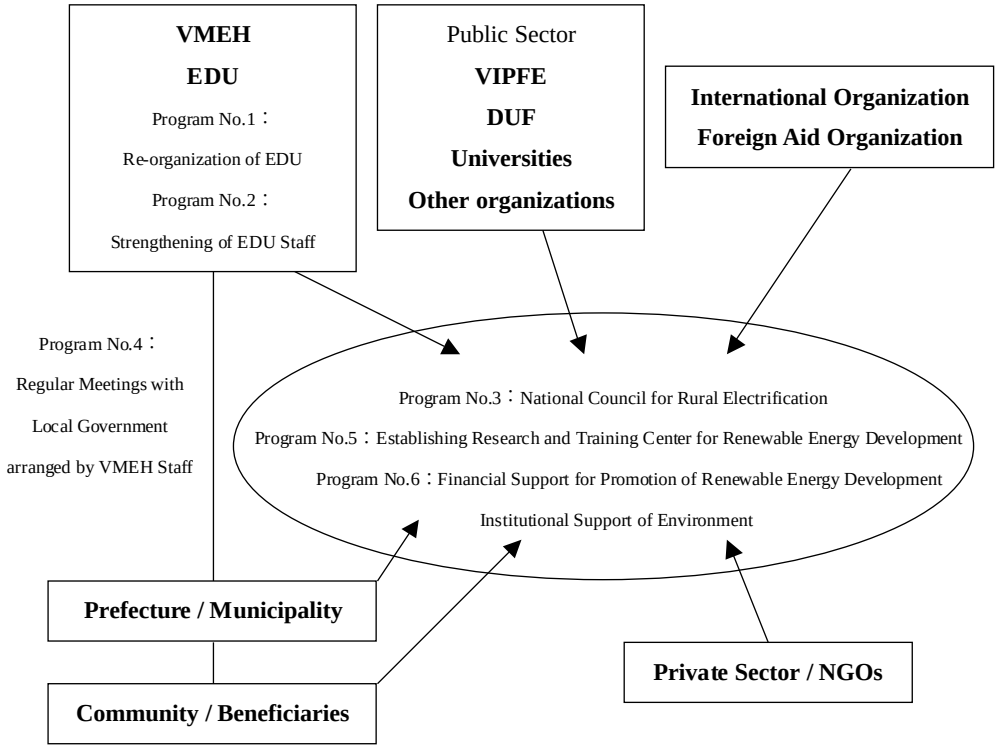
Approximately US$8.8 million is required from the private sector for the plan during the Phase I. It is expected that Bolivian Rural Electrification Fund is scheduled to be set up in the middle of 2001 with some contribution from the private sector. Private enterprises, on their part, will continue to put in their own money for the profitable part of the investment. Considering these factors, required fund from the private sector may be achieved.

[1] Spain (US$19 million) and Germany (US$4 million)

The above analysis indicates that the proposed rural electrification plan can be implemented without serious financial difficulties.

CHAPTER 9 INSTITUTIONAL SUPPORT FOR PROMOTING RURAL ELECTRIFICATION USING RENEWABLE ENERGY

The following institutional strengthening and improvement are required for further promotion of rural electrification using renewable energy.



9.1 Planning Capacity Improvement

The Energy Development Unit (EDU) of the VMEH is in charge of the overall planning of the rural electrification in Bolivia. In view of the required function, the current organizational structure of the VMEH, particularly for the EDU seems quite weak and is to be strengthened further.

(1) Program No. 1: Re-organization of EDU

The EDU is to be re-organized under the Director General of Energy, VMEH and number of staff be increased. The proposed organization of the EDU has the five sub-sections with the increased number of staff and functions as presented in Figure 9.1.

(2) Program No. 2: Strengthening of EDU staff

Planning capacity of the EDU staff is to be strengthened by getting technical assistance from foreign experts of rural electrification. Through and after this program, the EDU staff is to train the energy units of prefecture for rural electrification plan using renewable energy.

The experts will be arranged by international organizations and/or foreign aids.

9.2 Improved Coordination with Local Government and Private Sector

More close coordination is required for promoting rural electrification between the VMEH and the local government. Necessity of further coordination with local government as well as other public organization has been increased by the progress of local participation in the rural development including rural electrification. Cooperation with private sector is also very important for the VMEH because rural electrification is practically implemented through grid extension by private sector.

(1) Program No. 3: Setting up National Council for Rural Electrification

VMEH as a leader of rural electrification is to set up a national rural electrification council for improving coordination/cooperation among organizations related to rural electrification. Meeting of the national council is to be held twice a year.

The expected participants are from the VMEH, public organizations such as VIPFE, DUF, prefectures, international aid organizations and private sector related to rural electrification.

(2) Program No. 4: Regular Meetings with Local Government arranged by VMEH Staff

At present, occasion of the meetings between the VMEH and local government including prefecture and municipality are limited. For close coordination, more frequent visits of the VMEH staff to prefectures are required.

The EDU staff including rural electrification experts are to visit all the prefectures every three months and have meetings for discussing progress of rural electrification and the related problems. Representatives of the municipalities are also to be invited in the meetings.

9.3 Research and Training

No integrated research system for renewable energy exists in Bolivia. At present, the research on micro-hydro power is being conducted in universities (like UMSA) and by consultants/NGO, while the technology on PV system is accumulated in system suppliers.

For facilitating rural electrification using renewable energies, research and training functions are to be strengthened under the auspice of the VMEH. The research on the renewable energies and training for rural electrification committees (REC)/cooperatives as well as public and private sectors are essential to realize sustainable development.

(1) Program No. 5: Establishing Research and Training Center for Renewable Energy Development

The Research and Training Center for renewable energy development is to be established by the VMEH in close cooperation with experienced universities and consultants/NGOs related to renewable energy development.

The objectives of the program are as follows:

- to conduct an integrated research on renewable energies
- to demonstrate the results to the public
- to train the operation and maintenance skills for local users and rural electrification committees/cooperative as well as private sector

Basic plan for establishing the Research and Training Center for renewable energy development is to be prepared by the VMEH in collaboration with the related universities and consultants.

9.4 Financial Support

Available fund is limited, particularly, no specific fund is available under the control of the VMEH. Lack of their own fund of the VMEH would make it difficult to support the private sector and NGOs for promoting renewable energy development.

Reducing tax of equipment and facilities for renewable energy and providing credit and subsidy using a revolving fund will be quite effective for easier procurement.

(1) Program No. 6: Financial Support for Promotion of Renewable Energy Development

1) Reducing tax of equipment for renewable energy

For further promotion of rural electrification using renewable energy, the VMEH is to take leadership to reduce tax and duties to be imposed on the equipment and facilities as presented below.

Tax	Current Tax Rate	Proposed Rate
Import Tax	- PV: 10%, - Micro-hydro power over 10,000 kW: 0% - Micro-hydro power less than 10,000 kW: 5% - Wind power: 5%	0% for all products related to renewable energy

2) VMEH Revolving Fund for Rural Electrification Project

A revolving fund is to be organized for promotion of rural electrification project under the control of the VMEH. This fund will be applied for the rural electrification using renewable energy in local communities. The fund source is contribution from users for the rural electrification project granted from international organizations.

9.5 Environmental Impact

(1) Methodology of Calculating Environmental Impact

Environmental impact of implementing the proposed rural electrification plan for 2002-2011 was studied by comparing the emission of carbon (CO_2) between the case of the proposed plan and the case of an alternative plan. As the alternative plan, electrification by grid line extension using natural gas was selected. The renewable energy-based electricity generation using energy sources such as micro-hydro, wind power and PV emit no CO_2 during the operation. Therefore, the estimated emission of CO_2 by the alternative plan is taken as the saving of the CO_2 emission.

(2) Estimate of Reduction Amount of CO2

Applying the electricity consumption of the proposed renewable energy-based generation to the formula equation, the emission of CO_2 by the alternative plan, or saving of CO_2 by implementing the proposed plan was calculated at 5,390 tons during Phase I and 12,552 tons during Phase II as presented below.

Reduction of CO_2 by the Proposed Plan

La Paz

(ton/5 years)

	Phase I (2002-2006)	Phase II (2007-2011)
PV	232	781
Micro-hydro	3,739	8,631
Wind	132	488
Total	4,104	9,900

Oruro

(ton/5 years)

	Phase I (2002-2006)	Phase II (2007-2011)
PV	743	1,692
Micro-hydro	431	598
Wind	95	347
Total	1,269	2,637

Source: JICA Study Team

CHAPTER 10 RECOMMENDATION

For continuous study on the renewable energy development and sustainable implementation of the rural electrification plan proposed in this study, it is recommended that the following actions be taken by the VMEH, La Paz and Oruro prefectures and other organizations related.

10.1 Recommendation on Technical Matters

(PV System)

1) The VMEH and La Paz/Oruro prefectures are to follow up operation and management of the PV systems installed in La Paz and Oruro, particularly through:
   - conducting additional training for users and technical assistants (by Operators), and
   - strict management of the Initial Payment.

(Micro-hydro Power)

2) The La Paz and Oruro prefectures are to carry out continuous measurement of water level and discharge for the selected two priority project sites.

(Wind Power)

3) The La Paz and Oruro prefectures are to continue the monitoring and wind data collection, particularly from the four monitoring sites newly installed.
4) The VMEH is to assist the private sector for the technology development and promotion of wind power.

10.2 Recommendation on Institutional Strengthening

1) The function of EDU of the VMEH is to be strengthened further by reorganization and capacity building.

2) The coordination between the VMEH and prefectures/municipalities is to be enhanced through establishing the National Council of Rural Electrification and more frequent visits of EDU staff to prefectures.

3) Research and training function is to be strengthened by establishing the Research and Training Center of Renewable Energy Development, basic plan for which is to be prepared by the VMEH.

4) Financial supporting function of the VMEH is to be strengthened through establishing revolving fund for rural electrification and arrangement for credit and subsidy system.

5) The VMEH and La Paz and Oruro prefectures are to coordinate the cooperation between DUF and municipality and to conduct continuous supports for municipality under the PRSP.