CHAPTER 1 INTRODUCTION

1.1 Background of the Study

The overall electrification rate of Bolivia was 45.8% in 1997. The rate of rural electrification was low at of 13.7%, which is at the lowest level even among developing countries.

Facing this problem, the Vice Ministry of Energy and Hydrocarbons (VMEH), a national government organization responsible for establishing energy policy and its strategy of Bolivia, prepared a national program of electrification (PRONER) in 1998 and launched the implementation for facilitating rural electrification. The PRONER in their first phase envisages to electrify an additional 110,000 households by the year 2002 through the investment of $103 million and plans to increase the rate of rural electrification up to 28%. In the plan, use of renewable energy sources is also recommended, which include solar energy, micro-hydro power and wind power.

It was under this circumstance that the Government of Bolivia officially requested technical assistance to the Japanese Government for conducting the study on rural electrification implementation plan by renewable energy. In response to the request, the Japanese Government dispatched a study team for project formulation in October 1998, in which the needs for the development study was confirmed. In succession, a preliminary survey team visited Bolivia for discussing details of the study in January 1999 and agreed on the scope of the work for the study with the Government of Bolivia. As the target study area, La Paz and Oruro Departments were selected in the discussing since both departments had a high potentiality for renewable energies including solar energy, micro-hydro power and wind power, being located in the poorest rural areas in Bolivia.

1.2 Objectives of the Study

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. In the study, conditions for realizing this plan are to be clarified as well as the proposed implementing system.

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 and planning technology. The technology transfer is expected to promote exploitation of rural electrification by renewable energy in Bolivia after completion of the JICA study.

1.3 Necessity and Importance of Rural Electrification and Target Study Area

Objectives of rural electrification are not only to supply local people with electricity but also to play an important role in implementing an integrated rural development to tackle poverty reduction in rural area. Promotion of rural electrification should contribute to improving basic human needs such as jobs, food, health services, education, housing, clean water and sanitation both in quality and in quantity.

For the selection of the target study area, La Paz and Oruro department, the following characteristics were taken into account.

- Both departments have a high potentiality for renewable energies including solar energy, micro-hydro power and wind power.
- Most of unelectrified area in both departments are located in one of the poorest areas called 'Alti-plano', the mountains and the Amazon jungle area.
- Accessibility from La Paz city, capital of Bolivia

1.4 Study Organization, Survey and Study Conducted

1.4.1 Study Organization

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 field survey and study. The member list of the study team is presented in Attachment 1.

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 the related organizations was also formulated for conducting the study jointly and for effective technology transfer. Member lists of the Coordinating Group and the Working Group are shown in Attachment 1.

1.4.2 Field Survey and Study Conducted

(1) First Field Survey

The JICA Study Team commenced the first field survey from August 7, 1999 and continued the survey work up to September 20, 1999. Presentation of Inception Report and its explanation was made to VMEH and other agencies related to the study. Main items of the first field survey related to renewable energy development are:

1) PV System
   - selection of PV pilot project sites
   - socio-economic survey in the pilot project sites

2) Micro-hydro Power
   - discharge observation and installation of staff gauges

3) Wind Power
   - site selection for wind monitoring system

(2) Second Field Survey

The second field survey was conducted during the period of January 5 to February 12, 2000. In this survey, the first seminar was held in La Paz inviting representatives from VMEH, La Paz and Oruro prefectures, and other public and private agencies related to the study.

Main aspects of the second field survey on renewable energy development were:

1) PV System
   - installation of PV systems in La Paz and Oruro

- guidance for operation and maintenance
- formulation of organization for operation and maintenance

2) Micro-hydro Power
    - observation of water level and discharge

3) Wind Power
    - installation of 10 wind monitoring systems
    - monitoring and data collection

After the second field survey, the Progress Report(1) was prepared in Tokyo summarizing the progress of the survey and study so far conducted.

(3) Third Field Survey

The third field survey started from May 15, 2000 and continued up to July 14, 2000. Presentation of the Progress Report(1) was made to the VMEH and La Paz and Oruro prefectures in this survey period. Beside this, the second seminar was held in Oruro inviting representatives from VMEH, La Paz and Oruro prefectures, and other related public and private organizations.

Main items of the third field survey related to renewable energy were:

1) PV System
    - review of operation and maintenance system
    - monitoring PV systems and PV users

2) Micro-hydro Power
    - field investigation on candidate sites
    - selection of priority sites (2) for pre-feasibility study

3) Wind Power
    - replacement of SIM cards
    - monitoring and collection of wind data

During the third field survey, early implementation of topographic survey on the proposed micro-hydro power sites was suggested by VMEH. A JICA expert was dispatched to the proposed sites in September 2000 for supervising the subcontracted topographic survey. After the third field survey, Progress Report (2) was prepared compiling the data and information additionally collected in Tokyo, which was brought to Bolivia in the fourth field survey for presentation.

(4) Fourth Field Survey

The fourth field survey commenced from January 5, 2001 and continued until February 15, 2001. Main items of the fourth field survey related to renewable energy were:

1) PV System
   - continuous monitoring of pilot project

2) Micro-hydro Power
   - review of topographic survey result
   - engineering survey on the proposed 2 sites

3) Wind Power
   - continuous monitoring of wind monitoring systems
   - selection of priority sites (3 each in La Paz and Oruro)

All the results of the fourth field survey and the study as well as the results of the previous studies were compiled into the Interim Report in Tokyo.

(5) Fifth Field Survey

The fifth field survey started from May 10, 2001 and continued up to June 8, 2001. Presentation of the Interim Report was made to VMEH and La Paz and Oruro prefectures at the initial part of the survey period.

Main items of the fifth field survey related to renewable energy were:

1) PV Systems
   - monitoring and evaluation of PV pilot project
   - preparation for equipment transfer and management of pilot project

2) Micro-hydro Power
   - selection of priority projects
   - additional survey and data collection for the selected 2 projects
   - IEE on the proposed 2 projects

3) Wind
   - selection of priority projects
   - replacement of wind monitoring systems
   - IEE on the proposed 3 projects

Incorporating all the results of the previous field surveys and study, Draft Final Report was prepared in Tokyo to be brought to Bolivia for explanation and discussion.

(6) Sixth Field Survey

The sixth field survey will be conducted from August 27 until September 7, 2001. Presentation of the Draft Final Report will be made to VMEH and La Paz and Oruro prefectures. In addition, a seminar (third Seminar) will be held inviting all the public and private organizations related to rural electrification including multilateral and bilateral aid organizations.

All the comments on the Draft Final Report raised in the presentation as well as in the seminar will be incorporated in the Final Report.

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 Regulation and the Rural Electrification Information System. In addition, the rural electrification developments must follow other related laws, policies and regulations such as the Popular Participation Law, Decentralized Law, the Environmental Law, the Poverty Reduction Strategy Paper and the National Public Investments System. Rural electrification projects are to be implemented within these legal frameworks.

(1) The Electricity Law

The Electricity Law (Law No. 1604) was promulgated on December 21, 1994. The main purpose of the law is to transfer activities of power sector to the private sector and to vertical disintegrate the sector into generation, transmission and distribution of electricity. Reform of the Bolivian electricity sector is being carried out under precepts of the law.

(2) The Rural Electrification Rule

The Rural Electrification Rule (Supreme Decree 24772), promulgated on July 31, 1997, lays down the implementation framework by issuing instructions and guidelines for project implementation of rural electrification through people's participation policy.

(3) The Rural Electrification Information System

The Decree on the Rural Electrification Information System (Supreme Rule 213357) was issued on May 12, 1998. The main objective is to collect and utilize important information for smooth implementation of rural electrification under VMEH's facility and prefectures and private sector execution.

(4) The Environmental Law

The Environmental Law (Law No. 1333) was issued in 1990. The law regulates that an environmental impact in sectorial studies to be carried out under supervision of the Authorized Sectorial Body and the Vice-Ministry of

Environment, Natural Resources and Forestry Development (VMARNDF) in case of negative impact on the environment anticipated in a rural electrification project, the Environmental Unit of VMEH and the VMASRND will be in charge of supervising the fulfillment of the law.

(5) The Popular Participation Law

The Popular Participation Law established in 1994 promotes people's participation in the implementation of rural development. Municipality is an executing agency who can carries out a rural electrification project under the sectorial and National Public Investments System norms.

(6) Poverty Reduction Strategy Paper (PRSP)

The Poverty Reduction Strategy Paper (PRSP) is the guideline of policies for action on poverty alleviation in Bolivia. It's objectives are as follows:

- Expansion of job opportunity and income generation for the poor
- Capacity building for the poor
- Establishment of safety-net for the poor
- Increase of the people's participation and social integration

Most of the rural electrification projects will be carried out following the strategy of the PRSP. Rural electrification is one of the top priority issues for poverty alleviation in the PRSP. According to the PRSP scheme, municipality would implement rural electrification projects in their territories.

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 to promoting rural electrification. Present structure and functions of the related organizations are briefly summarized below.

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

The Vice Ministry of Energy and Hydrocarbons is the governing organization in energy sector under the Ministry of Economic Development in Bolivia. Main roles of VMEH are as follows:

- to establish national energy policies and strategies,
- to propose standards and regulations,
- to promote domestic and foreign private investments,
- to coordinate and negotiate domestic and foreign finances, and
- to coordinate with the Superintendence of Electricity (SE) on the framework of the Sectorial Regulatory System.

The VMEH, headed by the Vice Minister, consists of 12 units as presented in Figure 2.1. Functions of the units related to rural electrification are as follows:

1) Energy Development Unit

The Energy Development Unit (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. The major functions are as follows:

- to establish national policies and norms for rural electrification,
- to promote rural electrification projects through technical assistance for project formulation and financial arrangement,
- to support implementation of rural electrification projects under the PRONER with the EFP team,
- to coordinate and implement rural electrification projects in cooperation with prefectures and municipalities, and
- to support the Energy Sector Management Assistance Program (ESMAP) of World Bank for rural electrification by renewable energy.

2) Evaluation and Norms Unit

- to evaluate and to prepare norm for the electrical industry and activities
- to supervise the project implementation in accordance with energy development policies,
- to coordinate with private companies in power market,
- to prepare strategies for power export to the neighboring countries,
- to provide timely and reliable statistical data, and
- to monitor electricity cooperatives and private companies.

3) Environmental Unit

- to preserve and control natural and social environment for sustainable development of hydrocarbons and energy sector.

4) Investment Promotion Unit

- to promote domestic and foreign investment for state projects, and
- to provide information for private investors.

(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.

The main functions related to rural electrification are as follows:

- to evaluate and give concessions and licenses for rural electrification projects,
- to approve and control the maximum applicable tariff of the electric industry,
- to supervise the quality of energy supply to rural area, and
- to assure activities of electricity industry and provide the necessary services for further 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 SIN.

CNDC has the following responsibilities.

- to plan the integrated operation of the National Interconnected system, with the objective of satisfying the demand by means of a safe, reliable and minimum cost operation;
- to perform the Load Dispatch based in real time at minimum cost;
- to determine the effective power of the generation units in the National Interconnected System;
- to calculate Node prices in the National Interconnected System, according to the provisions of the present law and present them to the Superintendency of Electricity for its approval;
- to establish the valued balance of the electricity movement which results of the integrated operation, according to regulations;
- to deliver to the superintendency of Electricity the technical information, mathematical models, computer programs and any other information required by the Superintendency.

2.3 National Electric Supply System

2.3.1 National System

The electricity system in Bolivia consists of the following four systems.

(1) National Interconnected System (SIN)

The SIN is the interconnected electric system, which supplies electricity in the Departments of La Paz, Cochabamba, Santa Cruz, Oruro, Chuquisaca and Potosí, and the Electric Systems interconnected to it in the future.

The electricity demand within the SIN is divided almost equally into La Paz, Santa Cruz and the rest (Cochabamba, Oruro, Chuquisaca and Potosi). Approximately 50% of the generation is from hydroelectric power and 50% from natural gas thermal power generation in 1999. In the SIN system, a company can engage itself in only one activity of the electric supply business.

(2) Isolated Systems (SA)

The Isolated Systems are those electricity supply systems not connected to the SIN. They cover the city of Tarija, other urban centers in Tarija department, Riberalta in the Beni department and the city of Cobija in the Pando department. The SA covers about 5% of the installed capacity, 5% of generation and 5% of the population of Bolivia.

(3) Other Minor Isolated Systems (OSA)

These are the isolated systems with the effective capacity of less than 1,000kW. They operate only for 4 to 8 hours a day. In most cases, they are operated by small electric cooperatives in small towns with less than 2,000 households. The OSA covers about 3% of the installed capacity, 1% of generation and 1% of the population of Bolivia in 1999.

(4) Self Producers

In addition to the above systems, there are independent self producers that generate electricity mainly to satisfy their own needs by hydroelectric and thermal generation using natural gas and biomas. In most cases, they are large factories and mines. They cover about 8.5% of the installed capacity and 5% of electricity generation of Bolivia. Some self producers sell surplus electricity to SIN.

The SA and the OSA are allowed to have a vertical integration of the three activities of the electric supply (generation, transmission and distribution). Diesel generators are the principal sources of energy for SA and OSA.

2.3.2 Power Supply Structure

(1) Power Generation System

There are seven power generation companies within the SIN as end of 1999. They are COBEE (Compania Boliviana de Energia Electrica), Corani S.A., Guaracachi

S.A., Valle Hermoso S.A., Hidroelectrica Bolivia S.A., Rio Electrico S.A., Synergia S.A. and Rio Electrico S.A. These generators are connected to the STI (Interconnected Trunk System) and must comply with the regulations set by the CNDC.

In the Isolated Systems, there are many cooperatives which also operate as generators. The CRE (Cooperativa Rural de Electrificacion), for example, supplies electricity in Santa Cruz. Moreover, distributors are allowed to have generation as long as capacity is less than 15% of the peak demand by renewable energies.
The new Electricity Law prohibits any one generator from having the capacity over 35% of the total capacity of the SIN.

1) Installed Capacity

Total installed capacity as of 1999 is 1,266MW, of which 872.5MW (68.9%) is by the thermal power generation and 393.1MW (31.1%) by the hydroelectric power generation, the former being supplied by a combination of gas turbines and diesel engines. The average annual growth rate of the installed capacity between 1995 and 1999 is 11.2%.

Historical Trend of the Installed Capacity by Generation Type

(MW)

	1995	1996	1997	1998	1999
Hydroelectric power	306.4	318.4	336.4	341.9	393.1
Share	37.0%	31.6%	32.9%	32.8%	31.1%
Growth rate	6.0%	3.9%	5.7%	1.6%	15.0%
Thermal power	521.5	688.9	687.3	700.9	872.5
Share	63.0%	68.4%	67.1%	67.2%	68.9%
Growth rate	4.8%	32.1%	-0.2%	2.0%	24.5%
Total	827.9	1,007	1,024	1,043	1,266
Growth rate	5.2%	21.7%	1.6%	1.9%	21.4%

Source: Anuario Estadistico del Sector Electrico Boliviano 1999,VMEH

2) Electricity Generation:

Total electricity generation was 3,898GWh in 1999. The table below shows the historical trend of electricity production by generation type. Thermal power generation surpassed that of the hydroelectric power production in 1994 in Bolivia.

The average annual growth rate of overall electricity production was 6.7% between 1995 and 1999.

Historical Trend of the Electricity Generation by Generation Type

(GWh)

	1995	1996	1997	1998	1999
Hydroelectric power	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) bought the STI (Interconnected Trunk System), the main trunk system of Bolivia in July 1997 and 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 STI connects substations such as Kenko, Vinto, Catavi, Valle Hermoso, Corani, Guaracachi, Potosi and Sucre. The voltages of the transmission lines connected to the SIN are 230kV, 115kV, 69kV with the frequency of 50Hz. The total length of the transmission lines connected to the STI (230kV, 115kV and 69kV) is 1,498.5km. The length of the lines is 535.5km for 230kV, 863.0km for 115kV and 100km for 69kV. The total capacity of substations connected to the SIN is 1,218MVA. The TDE also owns and operates 21 substations, 17 of which form a part of the STI.

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

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

The transmission of the STI is limited towards the eastern part of the country (Santa Cruz). In the Carrasco-Guaracachi line, because of the limited transformation capacity of the substation of Guaracachi, the flow is limited to 70MW. However, the transmission system was able to cover all the requirements of the wholesale market.

As it is the monopoly in Bolivia, activity of the TDE is totally regulated. The CNDC is responsible for adjustment of electricity transmission and monitors the operation of the TDE monthly. The transmission charge paid by the users (generators and distributors) is determined by the Superintendence of Electricity.

(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 and SEPSA in Potosí. Electricity distribution is a monopoly in the permitted areas of operation. In addition, there are small-scale cooperatives engaged in electricity supply in the rural areas.

The voltages of the distribution lines in Bolivia are 34.4kV, 24.9kV, 14.4kV, 10kV and 6.6kV. The lower voltage is 230/115V in La Paz and 380/220V in the other areas.

2.3.3 Power Cost, Tariff and Consumption

(1) Power Cost

In the SIN, there is a competitive wholesale market (spot market and fixed-term contract market) between generators and distributors. The wholesale market in the SIN is comprised of the entities such as generators, transmission companies, distributors and large-scale consumers. In the wholesale market of the SIN, business will be determined by negotiations among participants based on the demand and supply of the electricity in the near future. At present, three generators except for Cobee offer exactly the same tariff. The CNDC (Comite Nacional de Despacho de Carga) is responsible for the coordination of the operation and administration of the transactions.

To determine the price of the energy, each generating company offers the generation cost of each generator. The CNDC calculates the prices at the junctures and establishes the most efficient production programs in order to meet the demand.

Average Power Purchasing Price at the Spot Market

	Energy Charges ($/MWh)	Power Charges ($/kW-month)	Transmission Charge (kW-month)	Total ($/MWh)
CRE	19.2	7.5	0.3	36.8
ELECTROPAZ	22.0	9.2	2.9	51.2
ELFEC	19.1	7.7	1.9	41.8
ELFEO	19.9	8.2	4.4	54.0
SEPSA	19.4	8.6	1.7	43.8
CESSA	19.8	8.9	1.1	43.5

(Exchange Rate: 1US$ = 5.82Bs in 1999)
Source: `Informe de Actividades Gestion 1999`, Comite Nacional de Despacho de Carga

(2) Electricity Tariff

Each distributor charges different tariff for each category of customers. The tariff of the residential customers is being subsidized.

The table below shows the tariff structure of different distributors for residential category as of August 1999.

Tariff Structure for Residential Category (US$/Month)

1) ELECTROPAZ (August 1999)

Urban Area

	kWh	US$
Minimum Charge	0-50	3.58
	51-300	0.05
Cost per Additional kWh	301-500	0.06
	501-	0.06

Rural Area

PALCA

	kWh	US$
Minimum Charge	0-50	4.16
Cost per Additional kWh	51-	0.09

RIO ABAJO - LURIBAY

	kWh	US$
Minimum Charge	0-50	6.05
Cost per Additional kWh	51-	0.09

2) ELFEO (August 1999)

	kWh	US$
Minimum Charge	0-50	3.87
Cost per Additional kWh	51-120	0.06
	121-	0.08

3) ELFA (July 1999)

	kWh	US$
Minimum Charge	0-40	3.81
Cost per Additional kWh	41-	0.09

4) EMPRELPAZ

	kWh	US$
Fixed Charge		1.96
Cost per Additional kWh	0-25	0.02
	26-	0.02

Exchange Rate: 1US$=5.88Bs
Sources: Each Distribution Company, `Anuario Estadistico del Sector Electrico Boliviano 1999`,VMEH

Historical trend of the residential tariff by distributors is presented below.

Historical Trend of Residential Tariff (US$/kWh)

	1995	1996	1997	1998	1999
ELECTROPAZ	0.056	0.058	0.061	0.065	0.069
CRE	0.056	0.063	0.066	0.066	0.064
ELFEC	0.067	0.062	0.073	0.076	0.076
ELFEO	0.060	0.063	0.074	0.080	0.079
CESSA	0.054	0.059	0.064	0.068	0.052
SEPSA	0.074	0.077	0.081	0.086	0.083

Source: Anuario Estadistico del Sector Electrico Boliviano 1999, VMEH

(3) Electricity Consumption

Total electricity consumption in Bolivia was 3,176.5 GWh in 1999. The average growth rate of electricity consumption between 1995 and 1999 was 7.9%. The largest category is residential (40.7%), followed by industrial (24.3%), general (17.1%), mines (8.5%) and public lights (4.8%) in 1999.

Historical Trend of Electricity Consumption by Category

(GWh)

	1995	1996	1997	1998	1999
Residential	996	1,065	1,139	1,207	1,292
General	375	408	459	499	542
Industrial	514	549	680	744	771
Mines	197	199	229	245	269
Public Lights	107	117	127	137	153
Others	156	152	131	158	149
Total	2,345	2,491	2,766	2,991	3,176

Source: Anuario Estadistico del Sector Electrico Boliviano 1999,VMEH

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 one of the priority issues in the energy policies of VMEH. Under these circumstances, the VMEH started a five-year program called PRONER (Programa Nacional de Electrification Rural) in 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. Projected total investment for the PRONER is US$103 million for five years. In order to achieve these goals, the VMEH sets policies, arrange funds and provides necessary technical assistance and coordination for successful implementation of rural electrification projects in collaboration with prefectures and municipals.

The VMEH promotes use of environmentally friendly renewable energy sources such as PV, micro-hydro and wind power to save exhaustible energy sources and reduce carbon dioxide emissions. The use of renewable natural energy sources available in each locality is considered to be important to achieve sustainable electricity supply in the region.

Involvement of the private sector for rural electrification is also encouraged by the Government through the VMEH with incentives and co-finance by public and private sector to implement PV projects and micro-hydro power in rural areas. The involvement of the private sector, however, has not been as active as expected. The VMEH needs to consider how to provide further incentives to the private sector through adequate financial schemes.

There are cases that electricity cooperatives and committees formed by rural residents themselves become the promoter of rural electrification through identification and implementation of the projects. The VMEH expects more active participation from the beneficiaries. It is also expected that the users 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 development of PRONER requires both public and private funding sources based on the co-financing policy of the Rural Energy Strategy. Public funds are used to cover low profitability projects in order to give incentives to the private sector to channel their funds to projects with higher profitability.

The VMEH made review on the progress of rural electrification. The table below presents the trend of rural electrification of Bolivia. Rural electrification had a coverage of 22.3% at the end of 2000 according to the data. The goal for rural electrification coverage of 28.0% by 2002 may be achieved if enough funds are provided to be channeled into rural electrification.

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

The first stage of the PRONER is scheduled to be completed by December 2002. The government, however, considers the rural electrification as a priority issue and will likely to be promoted even after 2002.

3.3 Rural Electrification Investment

During the past six years, public infrastructure investment of Bolivia ranged between US$155 million to US$ 215 million per annum. It amounted to US$186 million in 2000. Investment for the energy sector started to decrease in 1997, possibly due to public sector didn't release investments for the privatization process of the sector. The investment was realized by the private sector. Investment for rural electrification, however, remains at a relatively level and recorded US$7.3 million in 2000.

The table below presents public infrastructure investment 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%			-		

Source: VIPFE and World Bank

3.4 Organizations Related to Rural Electrification

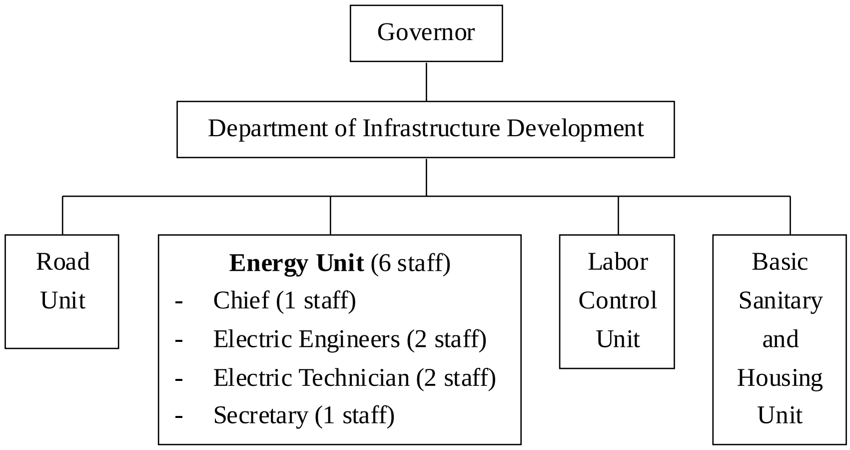
3.4.1 Local Government, Distribution Company and Supplier

Local government including prefectures and municipalities plays an important role in rural electrification after legislation of the Popular Participation Law and the Decentralization Law in 1995. The rural electrification projects have been implemented under the leadership of public sector and in some cases has the participation of the private sector.

(1) La Paz and Oruro Prefectures

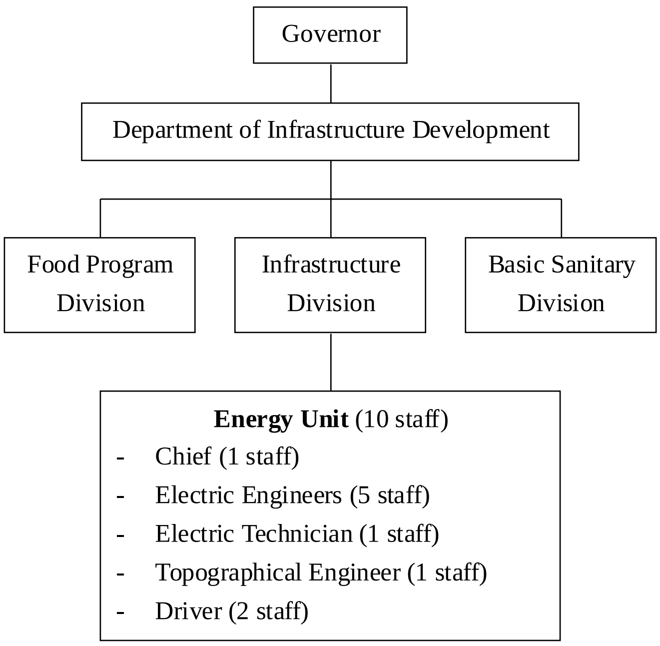
The energy unit under the Department of Infrastructure Development is in charge of rural electrification in La Paz Prefecture. The unit has six staff including one chief, two electric engineers, two electric technicians and a secretary as presented below.

Organization Chart of Energy Unit in La Paz Prefecture



In Oruro Prefecture, the energy unit under the Infrastructure Division is responsible for rural electrification as presented in the next figure. The unit is composed of ten staff including a chief, five electric engineers, an electric technician, a topographical engineer and two drivers.

Organization Chart of Energy Unit in Oruro Prefecture



Functions of the energy units both in La Paz and Oruro are summarized below.

- to identify needs of electrification in rural area,
- to prepare an electrification plan of the department,
- to formulate, evaluate and finance rural electrification projects,
- to supervise the project implementation, and
- to coordinate among municipalities, operators and users.

(2) Municipality

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

(3) Distribution Company

There are five distribution companies in La Paz and five in Oruro. The names of those distribution companies are as follows:

In La Paz

1. ELFA
2. Electropaz
3. Emprelpaz
4. CEYSA
5. EDEL

In Oruro

1. ELFEO
2. E.E.Caracollo
3. 5 de Agosto
4. COSEP Ltda.
5. COOPSEL.

The main 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 prefectures.

The main distribution companies have the license for public service provided by the Superintendence of Electricity.

(4) PV System Supplier

At present, the following five private companies operate as PV system suppliers in Bolivia and provide for procurement of equipment, installation, training of daily operation and maintenance for local users and technical service when users require.

Name of company	PV panel handling
HANSA	SIEMENS (Germany, USA)
ESAND	ATERSA (Spain)
SERCOIN	ISOFOTON (Spain)
ENERSOL	KYOCERA (Japan, USA)
ALKE	SHELL (UK, Holland)

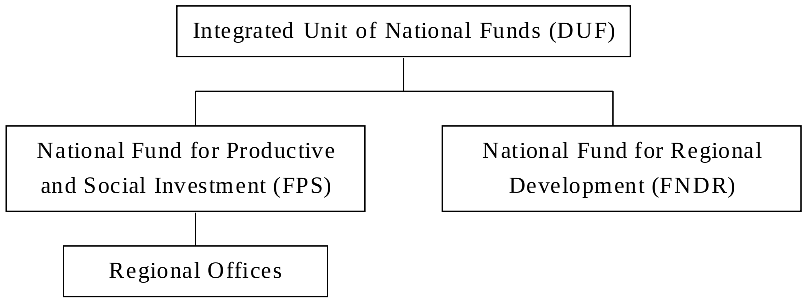
3.4.2 Funding Organizations

Most of the funds that come from foreign aid for rural development are channeled through the Integrated Unit of National Funds (DUF) in accordance with the new national compensation policy. The DUF will be a major funding organization for rural electrification projects for the municipalities. In addition, other domestic fund organizations are also expected to support rural electrification.

(1) Integrated Unit of National Funds (DUF)

The DUF is a national funding institution designed to tackle poverty alleviation including rural electrification at the municipality level under the direct control of the Ministry of Presidency. The DUF has two funding agencies ; one is the National Fund for Regional Development (FNDR) which provides credits to prefectures and municipalities and the other is the National Fund for Productive and Social Investment (FPS) which provides grants to municipalities. The DUF has established regional offices in each department. Rural electrification is regarded as one of the top priority sectors for the FPS fund. Total available amount for funding in the first fiscal year is expected to be US$ 50 million.

Organization Chart of DUF



(2) Revolving Fund for UNDP project

This fund is developed by FNDR for the support of UNDP/GEF electrification projects with renewable energy technologies. Total amount of this fund will be US$ two million, one million each from the Government and UNDP/GEF. This fund is planned to be used as a revolving fund to help financing rural electrification.

(3) Bolivian Rural Electrification Fund (BREF)

The Bolivian Rural Electrification Fund (BREF) will be financed by public and private initiatives for financing electrification projects in rural areas. The BREF will provide financing for the following projects: grid and transmission extensions, electrical interconnection, change of generation sources by small mergers and acquisitions aiming to consolidate rural electricity sector. Total amount of the fund is expected to reach US$ 30 million.

3.5 Activities of International Organizations

International organizations have provided technical and financial support to local governments as well as the central government to promote rural electrification through renewable energy as well as extension of grid lines.

3.5.1 Multilateral Aids

(1) World Bank

The World Bank provides funds and supports rural electrification initiatives under the framework of the Energy Sector Management Assistance Program (ESMAP) in cooperation with UNDP. Main activities for rural electrification are as follows:

- Support of energy sector reforms and energy strategy in rural areas,
- ESMAP energy plan program, and
- Renewable energy program for rural electrification.

The World Bank has two rural electrification schemes. One is credit scheme for PV project through the Global Environment Facility (GEF). The project will start in the middle of 2001 and be completed within 12 months. In this scheme, the credit will be provided to PV users for five years. The other is the rural electrification and telecommunication project with about US$ 60 million of credit which is under negotiation with the World Bank.

(2) United Nations Development Program (UNDP)

The Program had 22 rural electrification projects using renewable energy that are part of a global fund of US$ 8.2 million financed by GEF and local resources (FNDR, Government, Municipalities, etc.) in line with PRONER. Implementation of grid extensions and changes of socioeconomic conditions in the target project areas, prevented the projects from being implemented. New projects are planned to be combined with the UNDP/GEF projects.

(3) Inter-American Development Bank (IDB)

The IDB does not assist any rural electrification project implementation at present. It policy includes power development but power projects have not been included in the projects proposed by the Bolivian government to this organization for the past several years, with exception of the pre-investment studies through the VIPFE. The last power project was a transmission project with the ENDE started several years ago and completed in 1998.

3.5.2 Bilateral Aids

Rural electrification with renewable energy has been promoted by bilateral aid organizations such as the Spanish International Cooperation Agency (AECI), the German Technical Cooperation Agency (GTZ) and the Dutch Mission. After enforcing the EBRP, bilateral aid will continue supporting rural electrification projects under the EBRP scheme.

(1) Spanish Cooperation Agency (AECI)

The AECI carried out the first electrification program using PV system for 1,500 households in the Andean rural area from 1988 to 1993. From 1998 to 2002, 3,000 PV systems are planned to be installed for water supply, school and cottage industries as well as households in collaboration with local organizations. The cost of a PV system under this scheme is approximately US$ 850. The beneficiary pays 8% of the total cost (US$150 in advance) and AECI provides grants for the remaining.

(2) German Technical Cooperation Agency and German Financial Cooperation

The German Technical Cooperation Agency (GTZ) assisted the Extension and Transfer Technology with Renewable Energy Program (PROPER) from 1991 to 1997. The program put emphasis on the transfer of technology for manufacturing techniques with renewable energy including biomass, solar energy and wind energy to local entrepreneurs and NGOs. CINER, a Bolivian NGO for rural electrification, collaborated with GTZ after the PROPER's close and now works for a rural electrification program in the country.

The German Financial Cooperation Organization (KfW) committed ten million Deutsche Marks for rural electrification (PV and micro-hydro power) for which an agreement for studies with renewable energies was signed in 2001.

(3) Dutch Mission

The Dutch Mission has provided assistance for rural electrification under the Energy and Environment Program (PEMA) since 1992 in Cochabamba, Chuquisaca, Potosi, Tarija and Santa Cruz.

In the case of Santa Cruz, about 4,000 PV systems have been installed against a target of 10,000 systems as of September 1999. The Rural Electrification Cooperative (CRE) is in charge of operation and management of the PV system. The beneficiary pays US$ 320 (40% of total cost) in installations and US$ 8 per month for operation and maintenance.

In the case of Cochabamba, about 300 PV systems have been installed since 1998 against the target of 800 systems. The NGO (Energetica) employed by the Mission provides assistance for the sustainable operation of these systems.

CHAPTER 4 RURAL ELECTRIFICATION IN LA PAZ AND ORURO

4.1 Socio-economic Indicators

(1) Land Area and Population

The department of La Paz has a land area of 133,985 km^2 and Oruro 53,588 km^2. Total population in 1997 was 2,213,411 in La Paz and 366,829 in Oruro. The population density is very sparse, 16.5/km^2 in La Paz and 6.8/km^2 in Oruro. Population growth rate during 1992-1997 was high in La Paz (2.0%) and relatively low in Oruro (0.9%) compared to the national average of 2.3%.

Population Indicators

	La Paz		Oruro		Bolivia	
Year	1992	1997	1992	1997	1992	1997
Land area (km^2)	133,985		53,588		1,098,581	
Population	1,900,786	2,213,411	340,114	366,829	6,420,792	7,607,692
Households	545,566	602,421	120,027	121,719	1,692,566	1,914,793
Population density ('97)	16.5/km^2		6.8/km^2		6.9/km^2	
Population growth rate	2.0%		0.9%		2.3%	

Source: INE

(2) RGDP and Economic Structure/Employment

Regional GDP (RGDP) was Bs. 8,869 million (27.2% of the national GDP) in La Paz and Bs. 1,943.7 million (5.9%) in Oruro in 1996. Per capita RGDP was US$785 of La Paz and US$1,007 of Oruro. RGDP growth rates during 1992-1997 are 3.0% in La Paz and 1.7% in Oruro both of which are lower than the national average of 4.1%.

GDP Indicators (1996)

	La Paz	Oruro	Bolivia
GDP (Million Bs.)	8,869.0	1,943.7	32,510.9
GDP per capita (US$)	785	1,007	843
GDP growth rate (%)	3.0	1.7	4.1

Source: INE

The economy of La Paz relies on the services sector (21.9%), manufacture sector (17.7%) and public administrations services (15.1%), while Oruro largely depends on the mining sector (29.2%). The shares of the agriculture sector including forestry and fishery in GDP both in La Paz (8.0%) and Oruro (5.1%) were lower than that of the national average (14.2%).

Structure of Economic Sector (1996)

(%)

	La Paz	Oruro	Bolivia
Agriculture, Forestry, Fishery	8.0	5.1	14.2
Petroleum, Natural gas	-	-	1.3
Mining	5.2	29.2	4.6
Manufacture	17.7	16.2	16.4
Construction	4.6	3.4	2.6
Electricity, Gas, Water	2.7	2.7	3.0
Transportation, Communication	13.8	7.7	10.4
Commerce	10.9	8.3	8.1
Services	21.9	16.6	15.0
Public administration services	15.1	10.7	10.9
Total	100%	100%	100%

Source: INE

Agriculture sector including livestock raising provides large employment opportunity in La Paz (39.1% of total employment) and Oruro (42.9%). Unemployment rate was high in La Paz (2.3%) compared to 1.7% in Oruro.

Employment Indicators (1997)

(%)

	La Paz	Oruro	Bolivia
Rate of people who work in agriculture, forestry, fishery sector of total employment people	39.1	42.9	43.2
Unemployment rate	2.3	1.7	2.0

Source: INE

(3) Poverty Rate, Household Income and Expenditure

More than 70% of total households are poor both in La Paz (70.8%) and Oruro (70.6%). Poverty rates in rural areas are quite high, 95.5% in La Paz and 93.2% in Oruro.

Poverty Indicators

(%)

	La Paz	Oruro	Bolivia
Poverty rate of household (1992)	70.8	70.6	70.2
Poverty rate of urban household (1993)	56.0	55.3	51.1
Poverty rate of rural household (1993)	95.5	93.2	94.0

Note: The definition of poverty is the same as the Bolivian Poverty Map.
Source: INE 1998 and Mapa de Pobreza 1993

According to our survey conducted during the first field survey in 1999, average monthly household income of PV target communities was Bs.253.3 in La Paz and Bs.183.8 in Oruro. While, the monthly expenditure was Bs.252.8 in La Paz and Bs.177.1 in Oruro. The monthly expenses for energy was relatively high of Bs.24.9 (9.8% of total expenditure) in La Paz and Bs.21.4 (12.1%) in Oruro.

Household Income & Expenditure (1999)

(Bs.)

	PV target communities in La Paz	PV target communities in Oruro
Average monthly income	253.3	183.8
Monthly expenditure	252.8	177.1
Monthly expenses for energy	24.9	21.4

Source: JICA Study Team

4.2 Trend of the Rural Electrification and Investment

The table below summarizes the trend of rural electrification rates and investment amounts for the departments of La Paz and Oruro announced by the VMEH. Thanks to the participation of the public sector and the vegetative growth, rural electrification rates have increased significantly in both departments. It is reported that rural electrification rates have risen to 25.5% in La Paz and in 15.4% in Oruro respectively in 2000.

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

4.3 Present Situation of Rural Electrification

4.3.1 Grid Extension

As there is no updated grid line map available in either department, maps were prepared using the latest data collected from the VMEH, with information of the two prefectures and electricity distribution companies. Figures 4.1 and 4.2 are the extension maps of transmission lines (69 kV, 115 kV and 230 kV) and primary distribution lines (10 kV, 14.4 kV, 24.9 kV and 34.5 kV) in the departments of La Paz and Oruro for the year 2000.

In the department of La Paz, the main transmission lines of 115 kV run from the city of La Paz towards the northeast to Caranavi province and from La Paz down to southeast to the provinces of Aroma and Loayza. The primary distribution lines used are the 14.4 kV, 24.9 kV and 34.5 kV, which are installed in the wide area from the northwest of the department towards the south of the city of La Paz . Southwest, east and north of La Paz department as well as the north of La Paz City is relatively intact by the grid extension lines.

In the department of Oruro, only the areas near city of Oruro, i.e, northeast of the department, have 115 kV transmission lines. The primary distribution lines are of 24.9 kV , which are installed from city of Oruro towards southwest to the provinces of Litoral and to the south from city of Oruro to province Avaroa. The rest of the department, i.e., the west and south of the department, has no grid lines for 2000.

4.3.2 Use of Renewable Energy

At present, use of the renewable energy is limited to micro-hydro and PV systems in La Paz and Oruro. There is no experience in power development using biomass in La Paz. The department of La Paz has substantial resources for this type of generation. In this subsection, the present situation of existing micro-hydro power plants and PV systems is explained.

(1) Inventory of Micro-hydro Power Plants

Hydropower resource has been well developed in La Paz. There are 23 micro-hydro power stations under operation with the installed capacity of 1,084 kW and 7,161 beneficiaries household. In Oruro, however, only two micro-hydro power stations are providing electricity for 170 households with an installed capacity of 200 kW.

The inventory of the micro-hydro power in La Paz and Oruro is summarized in Table 4.1.

Besides the above, several micro-hydro projects are under planning with a installed capacity of 3,800 kW in La Paz and 650 kW in Oruro.

(2) Inventory of PV Systems

The systems installed in La Paz and Oruro are basically for solar home systems for house lighting. No other type of PV system was identified except solar systems for water pumping in La Paz and Oruro.

The inventory of the PV system in La Paz and Oruro is summarized in the following table. USAID has installed 480 systems in Oruro. The Spanish Financial Program installed 246 for households systems in La Paz and 500 systems in Oruro. In addition, 200 systems in La Paz and 100 systems in Oruro were installed through this pilot project by JICA.

Inventory of PV System (as of June 2001)

(Unit: number of PV system)

Department / Organization	La Paz	Oruro
USAID		480
Spanish Program	246	500
JICA	200	100
Total	446	1,080

＊ System capacity: 50Wp~55Wp
Source : JICA Study team

The solar home systems installed both in La Paz and Oruro are 1,526 in total witch amounts approximately to 80kW for June 2001.

4.4 Target Households and Electricity Demand for Rural Electrification

4.4.1 Target Households for Rural Electrification

Those communities with less than 2000 inhabitants by the 1992 census are defined as 'rural' while those with more than 2000 inhabitants are called 'urban' according to the definition given by INE. (A community is the administrative unit next smaller in a canton.) Target households in the rural areas (total number of households in rural areas) for La Paz and Oruro are estimated by subtracting those households in urban areas from the total number of households for each canton. The following table shows the numbers of target households and the numbers of non-electrified rural households in 2000, which are used as the base data for the future rural electrification plan. The list of target households, which includes rural population, total rural households as well as households with and without electricity of every canton in La Paz and Oruro departments at the end of year 2000 is presented in Appendix Report. Until the end of year 2000, there were 436 and 160 rural cantons in La Paz and Oruro respectively.

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 number of rural households of each canton is projected on the basis of past trend. Total numbers of rural households are projected to decrease slightly both in La Paz and Oruro as shown in the table below. This is mainly due to emigration to urban areas and low population growth rates in rural areas.

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

4.4.2 Demand for Electricity

The demand for electricity in the rural areas of the departments of La Paz and Oruro is estimated on the basis of the projected number of rural households with the following assumptions and conditions:

1) The base year is the year 2000.

2) Present power demand from the electrified households is estimated by applying the following consumption's average to the number of households served;
   - HHs electrified by the grid line, diesel and micro-hydro: 300 kWh/year
   - HHs electrified by PV: 65 kWh/year

3) Power demand of the already electrified households as of the year 2000 will increase at an annual growth rate of 2% after 2002;

4) Potential power demand from unelectrified households was estimated by applying 300 kWh of consumption's average to the number of the unelectrified households.

5) 60% of the unelectrified households are counted as effective demand.

6) 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 energy demand in rural areas in both departments. In La Paz, total demand for electricity is estimated at 48,321 MWh in 2000 and is expected to increase to 52,009 MWh in 2006 and 54,534 MWh in 2011. In Oruro, it is 11,944 MWh in 2002 and is expected to be increased to 12,573 MWh in 2006 and 12,732 MWh in 2011.

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

4.5 Implementing Organization and Organization for O&M

4.5.1 Implementing Organization

Local government including prefectures and municipalities are, in principle, an implementing organization for rural electrification under the actual norms and rural development strategy. Users organize a rural electrification committee/cooperative and request the prefecture for the support of a rural electrification project executed through the municipality. Implementation of the project is being conducted with the following process after financial arrangement.

(a) Central government such as VIPFE, FPS and FNDR commits a project fund to local government.

(b) Local government makes public announcement for the competitive bidding of a project implementation.

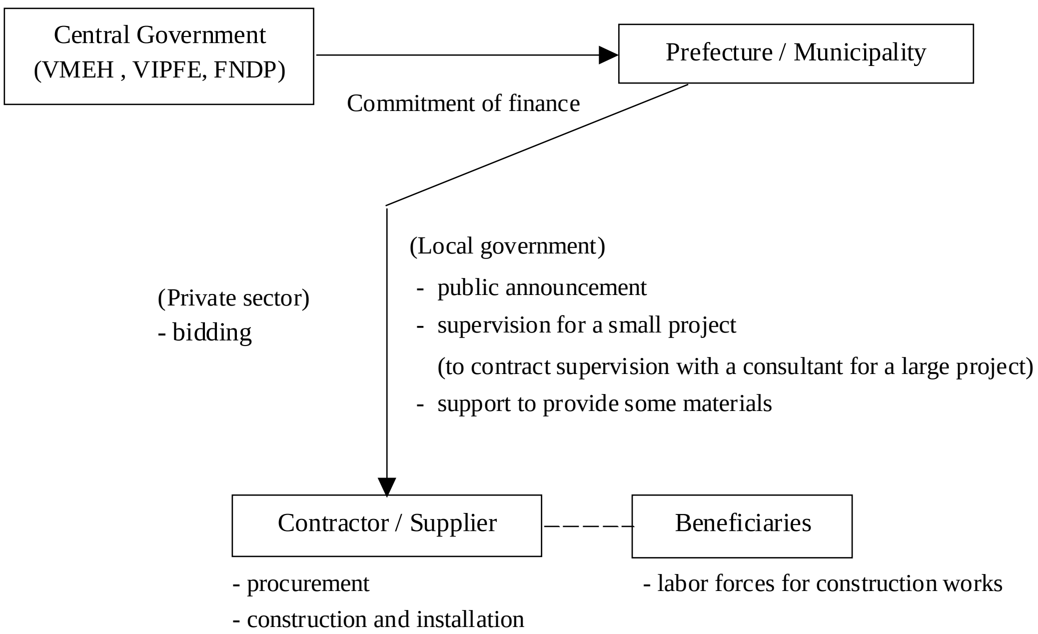
(c) A contractor or supplier participates in bidding.

(d) Local government selects a contractor or supplier and awards a contract.

(e) Local government supervises the construction and installation.

(f) Beneficiaries provide their labor force for construction works in case of projects such as micro-hydro power.

Process of Project Implementation for Rural Electrification



4.5.2 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

A small electrification cooperative and a rural electrification committee have limited technical skills for operation and maintenance and would request technical assistance to a consultant/NGO or supplier when major repairs are required.

(1) Case of O&M by Municipality

Municipalities may carry out the operation and maintenance of rural electrification projects, as seen in Municipality of Charaña in La Paz and Municipality of Salinas in Oruro.

In case of Charaña, cost of the diesel generation project was financed by the municipality. The daily operation and maintenance is being managed by an operator employed by the municipality. A mechanical engineer is called for maintenance when problems occur.

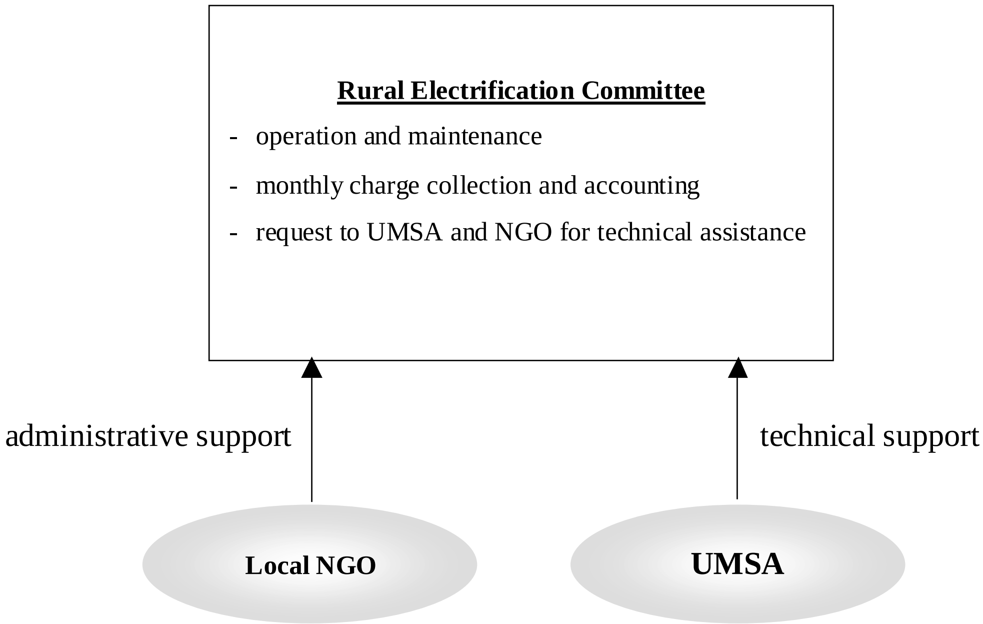
The financial situation for the operation and maintenance is very tight because of the high price of diesel oil. About 60% of the total operation and maintenance costs for the system is covered by the municipality budget.

(2) Case of O&M by Rural Electrification Committee

Micro-hydro power projects in Yungas, area of La Paz, are being managed by rural electrification committees (REC) already established, which are organizations for operation and maintenance as well as an implementing agents, with technical and administrative supports of UMSA and a local NGO.

A local technician of REC trained by UMSA and local NGO plays a key role in the operation and maintenance for the system. Continuous technical and administrative support is being given by UMSA and local NGO.

Organization Chart of O&M for Micro-hydro Power System



CHAPTER 5 SUMMARY OF PV PILOT PROJECT

5.1 Survey and Study Conducted

The study on the PV system focused on the following objectives:

- to identify appropriate sites and install three hundred PV systems as a pilot project in La Paz and Oruro;
- to evaluate the PV system and applied operation and maintenance system; and
- to identify priority sites for PV and incorporate PV development plan into the rural electrification plan.

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 OM
- 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

5.2.1 Selection of Pilot Project Sites

It was planned that 300 PV systems would be installed in La Paz and Oruro prefectures. The process of the selection of the PV sites is explained below.

(1) Criteria for Site Selection

For the selection and the confirmation of the candidate sites, the following criteria were set up and applied prior to the actual field investigation.

1) Sites outside future grid extension plan

2) Sites within less than two-hour driving distance from major city

3) Sites with minimum of 50 households

4) Sites within the territories of Operators

5) Sites where communities have capacity to pay

(2) Selected 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

5.2.2 Components of PV System

Proposed PV system consists of PV module, controller, battery and three fluorescent lamps with the following specifications:

(1) PV Module: Imported from U.S.

- Configuration : 12 V
- Cell numbers in series : 36
- Rated power : 55 W
- Minimum power : 50 W
- Voltage at load : 17.4 V
- Current at load : 3.15 A

(2) Loads: Local made

- Fluorescent lamp : 15 W x 3

(3) Controller: Imported from U.S.

- Over charge protection
  Charge termination : 14.3V +/- 0.2
  Charge resumption : 13.5V +/- 0.3
- Over discharge protection
  Load disconnect : 11.5V +/- 0.2
  Load reconnect : 13.0V +/- 0.3
- Reveres leakage protection with blocking diode

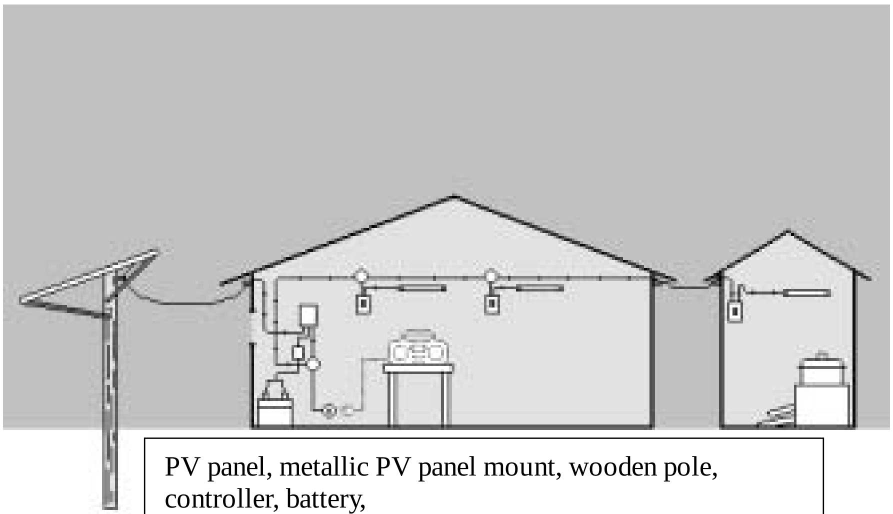
(4) Battery: Local made

- Solar type
- Nominal capacity : 99.12 Ah
- Nominal voltage : 12 V
- Final charge voltage : 14.8 V

(5) Voltage dropper DC/DC: Local made

- 12V $\rightarrow$ 3, 4.5, 6, 9 V

Image of the installed solar home system is as presented below.



PV panel, metallic PV panel mount, wooden pole,
controller, battery,

DC loads : 3-fluorescent lamps
DC TV and DC radio are user's option.

5.2.3 Installation of PV System

During the first field survey in August and September 1999, the first step for the installation work was conducted by checking the materials and the components of the PV system procured by JICA Bolivia office. The JICA Study Team recommended that some equipment and materials were to be changed as follows:

- Batteries : from 150 Ah to 100 Ah
- Controllers : from the one with single protection of over charge to the one with protection both of over charge / over discharge.
- Fluorescent lamps : from 20 W to 15 W

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.

After discussing with VMEH and two prefectures, the JICA Study Team installed 270 PV systems and kept the 30 PV systems (10% of total 300 PV systems) as spare parts. La Paz prefecture kept 20 PV systems and Oruro prefecture kept 10 PV systems as spare parts.

Necessary numbers of spare parts were adjusted later on the basis of the experience through the pilot project.

5.3 Operation and Maintenance System

5.3.1 Organization for Operation and Maintenance

As an organization for sustainable 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 prefecture participated into all the Management Unit in La Paz, while Oruro prefecture into all the Management Unit in Oruro.

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.

5.3.2 User Guide and Training

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 orientation for the user guide was conducted in La Paz and Oruro in January 2000. Several staffs in charge of the project including staff from prefectures and Operators also attended the orientations in La Paz and Oruro.

Users' attitude towards the PV system is the most important factor for the sustainability of the PV system. Considering importance of the battery, the JICA Study Team focused on use of battery and requested for careful consumption.

5.3.3 Maintenance Manual and Training

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

The JICA Study Team organized several training courses to explain and instruct the technical staff of the Operators and the staff of the Management Units.

The following aspects were emphasized in the Operation and Maintenance which was presented at the seminar and training for Operators.

- Maintenance schedule
- Careful maintenance required for batteries
- Maintenance for the panel
- Maintenance for wiring, fixtures and loads

The training of Operators was conducted both in La Paz and Oruro in September 1999, January 2000 and in May 2000.

Besides the above training in communities, the training was conducted in the seminars held in January 2000 and May 2000.

5.4 Power Tariff

5.4.1 Original Scheme

It was planned that the beneficiaries have to pay initial payment for the PV installation and a monthly power charge covering operation and maintenance costs. For determining the charges, power charges using grid line were reviewed in due consideration of the capacity to pay of the residents.

(1) Initial Payment

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) and covers the cost of the following items.

- 3 Fluorescent lamps
- Junction boxes
- Switches
- Interior cables & fixtures

The collected initial payment was planned to be used for future rural electrification using PV as a revolving fund.

(2) Monthly Fee

For operation and maintenance of the PV system, monthly fee of Bs 30 was requested to users.

5.4.2 Modified Payment Scheme

The original payment scheme was modified later in due consideration of the actual payment situation of users.

<u>Monthly Fee</u>
Monthly Fee was reduced from Bs. 30 to Bs. 22 for users. However, the original Monthly Fee (Bs.30) was maintained for the users in three communities with grid extension who were exempted from the Initial Payment.

<u>Initial Payment</u>
Two options for payment of the Initial Payment were offered to users. When the social problem happened in late 2000 in Bolivia, the Initial Payment was reduced from Bs.700 to Bs.600.

5.5 Monitoring and Analysis

5.5.1 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 of system use measured by data loggers

(2) Monitoring of operation and maintenance by Operator

(3) Monitoring of 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.

The result of the monitoring of system use is explained in more detail in the succeeding section and the results of the monitoring of operation and maintenance are explained below.

(1) Monitoring of OM by Operators

Although the Operators' visit for inspection was originally scheduled once every two months, actual inspection conducted was once every three or four months. This is because of the social problem in 2000 and long rainy days from December 2000 to February 2001.

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

Result of Monitoring on OM

(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

1) Defective Lamp

35 lamps, 4.9% of the total lamps installed, were found with defective performance. The JICA Study Team requested Operators to replace them.

2) Blackish Bulb

53 lamps, 7.4% of the total lamps installed, were found with blackened ends. The JICA Study Team decided to replace the ballasts.

3) Noise on Radio

167 users complained noise problem on radio when used near the fluorescent lamp. The JICA Study Team discussed the solution and decided to fix filters in the lamps.

4) Battery Water

Interval of the refilling water to battery was originally set at once every two months. However, the interval of every three months was practically satisfactory.

5) Radio Cassette and (6) TV

As shown in the above, 92% of the total users use radios or radio cassettes. Since possible sites for TV are limited in Altiplano, only 5 users have TV so far.

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

(2) Monitoring on Payment

After the completion of the installation, the monitoring on payment commenced from April 2000. The results of the payment in May 2000 were 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 following action was taken to improve the situation.

1) Re-Orientation for User

During the fourth field survey, the JICA Study Team and Operators visited three communities and conducted re-orientation to users for clarifying the misunderstanding and explaining the present PV system and its operation and maintenance.

2) Modified Payment Schedule

The Monthly Fee and Initial Payment were reduced.

3) Modified User OM (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:

- To coordinate with Operator
- To inspect cable and wiring connections and tighten or re-connect cable and wires
- To fill the distilled water to batteries
- To make regular report to Operator

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: %)

	La Paz		Oruro	
Month	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

5.5.2 Monitoring of Users

(1) 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 for formulating sustainable implementation plan for rural electrification by a PV system through this pilot project.

- 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.

The methods of key informant survey and household survey were applied to the survey. The interview survey using the Rapid Rural Appraisal (RRA) method was carried out for the users of the PV pilot project sites in La Paz and Oruro.

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. Besides, a kerosene lamp, about one or two liter(s) of kerosene per month, was still being used even after the PV installation.

The average time of radio listening 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. However, users would use radio more after solving the noise problem. A cassette recorder was rarely used. The average time of watching TV for three users in Paria Pampita was 2.4 hours per day.

2) Change in Financial Source for Payment of User Charge

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.

Some of the users were small-scale farmers who could not afford to sell agricultural products and livestock. For the payment, 25% of users in Paria Pampita, 16% in Calteca, and 14% in Muruchapi worked temporarily in the informal sector in the neighbor communities or cities.

3) Change of Living Environment

Users, 91% of interviewees in Paria Pamita, 87% in Muruchapi, 85% in Laguna Ancocota and 83% in Calteca, recognized that 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.

The capacity of the PV system is not sufficient. According to the comments of the users, installation of a larger power system was requested to implement an integrated rural development.

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. Communication between the users and the Operator was, however, limited by the following reasons:

- Users were not at home and worked outside in the daytime when the operators visited the user's houses for the maintenance and the fee collection, and
- Some of the representatives of the Rural Electrification Committee did not always stay in his community, but in the city where his family lived.

(2) System Use Monitored by Data Logger

Monitoring was conducted mainly for investigating power generation and the corresponding consumption using the data loggers installed at VMEH office and at community chief's houses in Calteca of La Paz and in Paria Pampita of Oruro.

The monitoring of the system use was made for the three different types of users, optimum user, light user and heavy user. The results of the monitoring are summarized below.

1) Optimum User

Total daily use of the PV system was regulated within 105Wh which is equivalent to 7 hours use of three 15 W fluorescent lamps. With respect to the unit of Ampere hour (Ah), the daily limit is 8.75 Ah which is taken as a benchmark in the pilot project.

The daily use of the lamps was fixed at the level indicated above, using a timer as follows:

- Lamp 1 : 3 hours
- Lamp 2 : 2.5 hours
- Lamp 3 : 1.5 hours total 7 hours

The level of the consumption is within the power generated, because the daily consumption was limited up to 8.75Ah. The battery charge balance is very stable, which enables the life of the battery to be maintained longer.

2) Light User

The load use (daily average) was:

- Lamp 1: 0.76 hours
- Lamp 2: 1.02 hours
- Lamp 3: 1.74 hours
- Radio : 0.84 hours

The daily average use was 4.36 hours for the month. This is equivalent to 62% of the benchmark level.

3) Heavy User

The load use (daily average) was:

- Lamp 1: 4.47 hours
- Lamp 2: 2.81 hours
- Lamp 3: 3.41 hours

The daily average use was 10.69 hours. This is equivalent to 152% of the benchmark level. The heavy consumption may affect the lifetime of the battery to be shorter.

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 generates sufficient power for charging 100Ah battery.
- The controller works well for protecting the battery from over charging and over discharging.
- The battery has enough capacity for the normal use.

No specific major problems occurred nor were there are accidents caused by lightning. 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.

5.6.1 Technical Problems and Solutions

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

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

(1) Blackish bulbs

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

(2) 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 the end of April 2001.

(3) 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 in the end of April 2001. The problem of the noise was almost solved after the installation of the filter.

5.6.2 Comment on the System Capacity

During the field surveys conducted for this pilot project, a PV system with a 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 the PV system 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.

The PV system with different capacities are:

- Small Size PV: 30Wp Battery: 40Ah
- Middle Size PV: 50Wp Battery: 100Ah
- Large Size PV: 100Wp Battery: 200Ah

5.7 Evaluation of OM System

5.7.1 Evaluation of the Performance

The proposed structure and function for the operation and maintenance consisting of Users/REC, Operator and Prefecture were originally formulated taking into account the following situation of the pilot project sites.

1) Level of users' technology

PV systems have been installed several areas in La Paz and Oruro. However, use of batteries in the rural areas seems quite limited compared to other developing countries. This fact leads to the proposed operation system that Operator plays main role in OM, while users take less responsibility.

2) Level of income

For sustainable maintenance of the PV system, replacement cost of battery and controller is to be secured every 5 years or so. However, income level of the households in the Altiplano area is very low. The proposed tariff was, therefore, set covering such replacement cost and more expensive than that for simple maintenance.

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 the 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 interview survey on 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

As indicated above, the current monthly fee of Bs. 22 is recognized expensive one for users.

5.7.2 Proposed Improvement

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

1) OM 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 Operator. In case of major problems of equipment including replacement, Operator is to provide technical service under the agreement with Users/REC.

2) Participation of Municipality in OM

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. This involvement becomes more important now since municipality is to be an executing agency for the rural development including rural electrification after PRSP enforcement. 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. Through this kind of institutional support, the fund collected from the initial payment can be used as the revolving fund for rural electrification.

5.8 Disposal of Used Battery

The number of batteries consumed in Bolivia is around 250,000 - 300,000 units per year including imported and recycled ones. There exists one private firm, BATEBOL which produces about 30% of the local consumption. The BATEBOL produced around 1,700 batteries for PV, which is less than 2% of the company's total production.

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 has still enough capacity for recycling.

Taking into account the situation above, disposal system for the PV battery is proposed as follows.

1) Used batteries are collected by Technical assistant of REC.

2) Agent/staff of BATEBOL(collectors) collects used batteries from REC and transports to COMMETAL for recycling.

   Collectors divide materials into recycle parts and non recycle parts as follows:

   - Non recycle parts : Electrolyte, Metal fittings etc.
   - Recycle parts : Electrode, Separator, Container

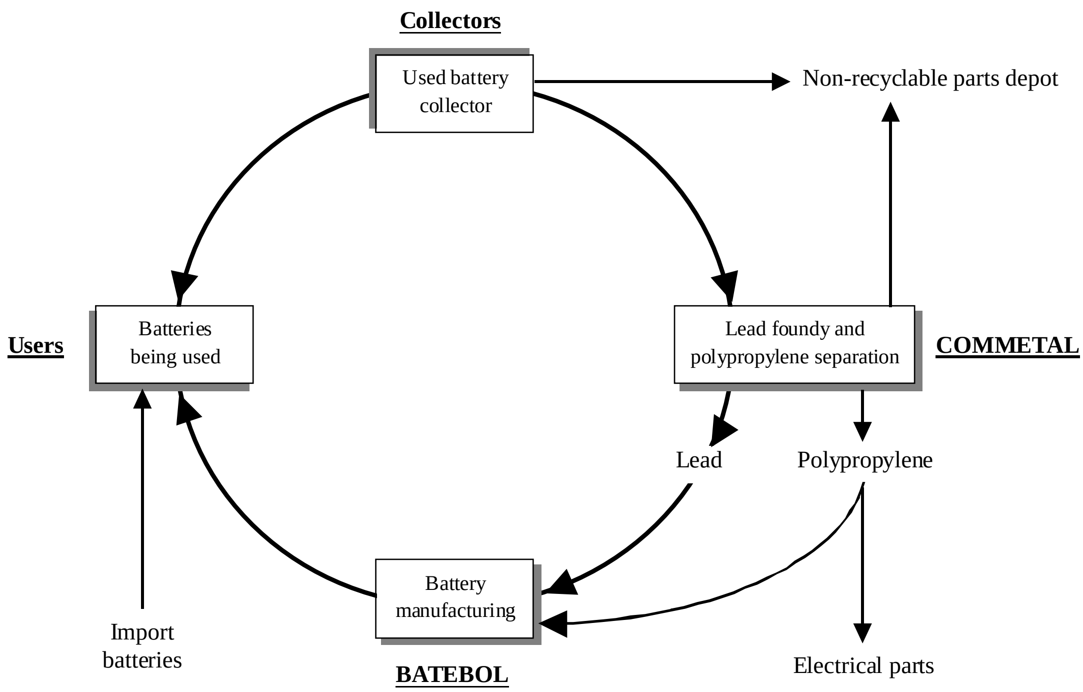
Non-recyclable materials are transferred to dealers which dispose them before transport to COMMETAL.

3) Through the recycling system, COMMETAL recovers lead and polypropylene. COMMETAL disposes residue from recycled materials and sells white type propylene as electrical parts.

4) Reuse the recycled material:

- refined lead to be supplied to BATEBOL for reuse
- recovered polypropylene to be supplied to BATEBOL for reuse

The process of the disposal and recycle of used batteries is presented below.



Source: JICA Study Team

CHAPTER 6 SUMMARY OF STUDY ON MICRO-HYDRO POWER

6.1 Survey and Study Conducted

The field survey on the micro-hydro power was conducted from August 1999 to September 2001 intermittently. The study on the micro-hydro power focused on the following objectives:

- to review the inventory and identify potential of micro-hydro power;
- to identify priority sites for micro-hydro power and evaluate cost competitiveness. The identified projects are to be included in the Rural Electrification Implementation Plan; and
- to select high priority projects (2 projects) for pre-feasibility study and to conduct pre-feasibility study.

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

- Study on inventory and identify sites for discharge observation
- Installation of staff gauges
- Daily water level observation on selected priority project sites
- Selection of high priority projects (one in La Paz and one in Oruro) and their engineering survey
- Topographic survey and mapping on the selected 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

As explained in subchapter 8.3, 30 micro-hydro power projects were selected as the priority project in La Paz, while three (3) projects were selected in Oruro.

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 MHP (Machariapu River, Apolo municipality, F. Tamayo province)

2) Oruro : Tambo Quemado MHP (Tambo Quemado River, Turco municipality, Sajama province)

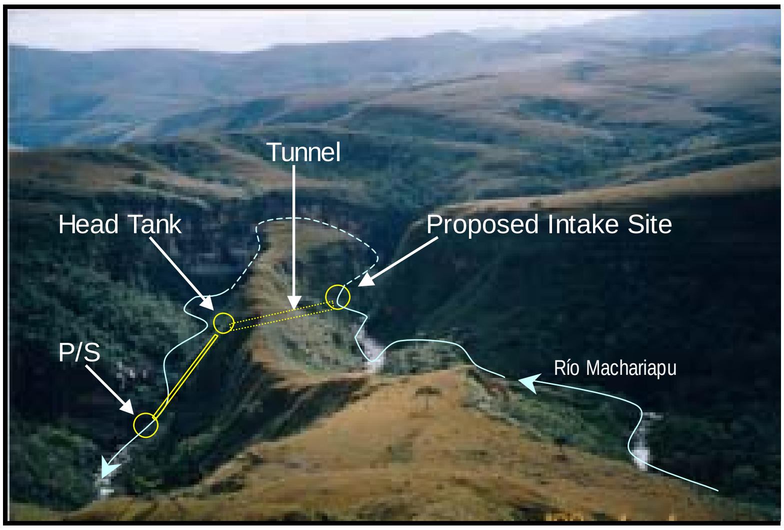
6.3 Pre-feasibility Study on Apolo Micro-hydro Power Project in La Paz

6.3.1 Location, Topography, Meteorology and Hydrology

(1) Location and Topography

The proposed site of Apolo is located at 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 topography of the surrounding area of Apolo town is characterized by undulatory plain. The project site is located at latitude 14° 36' S and longitude 68° 23' W. The proposed site for intake and power station is in the deep valley of the Machariapu River. Between the proposed intake site and outlet site there exists a steep ridge.



Overview of Proposed Project Site (Apolo,/F.Tamayo/La Paz)

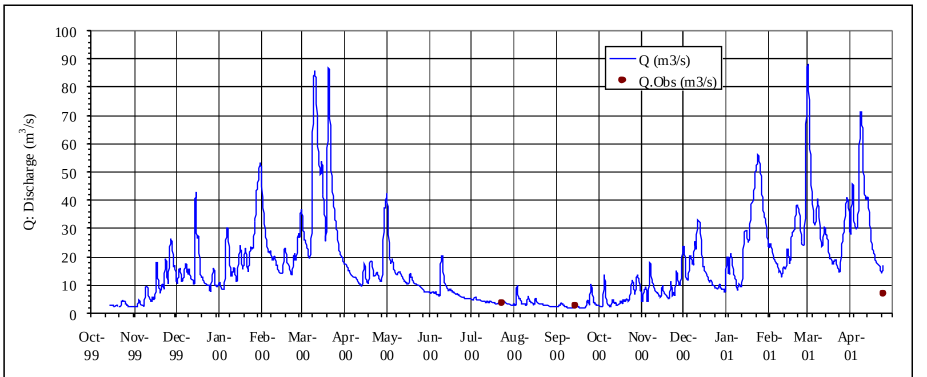
The location of the proposed intake site of the Apolo micro-hydro power project is shown in Figure 6.1.

(2) Meteorology and Hydrology

The rainfall pattern is characterized by the distinct two seasons, rainy and dry seasons. According to the data from the National Meteorology and Hydrology Service in Bolivia (SENAMHI) the annual average precipitation in Apolo is 1,618 mm/year. About 76% of the annual precipitation concentrates in a period from October to March. The maximum monthly precipitation is 242 mm in January, while the minimum is 33 mm in July.

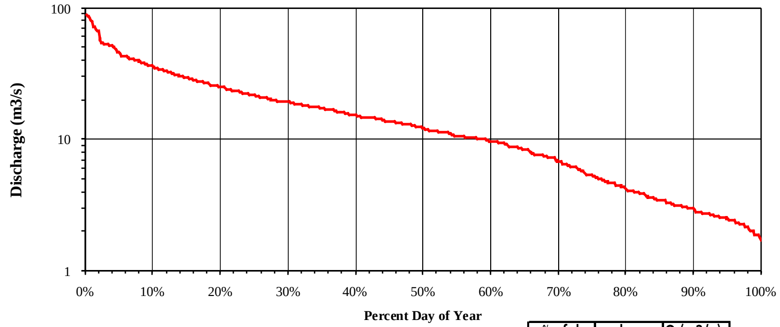
The catchment area at the proposed intake site of the Apolo micro-hydro power project was estimated at 371.15 km^2.

The river flow at the proposed intake site of the Machariapu River was estimated using the daily water level data during October 1999 to April 2001 at the Turiapu River. The estimated hydrograph of daily discharge at the proposed intake site is shown below:



Estimated Daily Discharge Hydrograph at Rio Macharipu Proposed MHP Intake Site
(Apolo/ F. Tamayo/ La Paz)

The flow duration curve at the proposed intake site was also estimated as shown below:



% of day	days	Q (m3/s)
50%	= 183	12.27
60%	= 219	9.71
70%	= 256	6.77
80%	= 292	4.27
90%	= 329	2.97
95%	= 347	2.47
97%	= 354	2.28

Estimated Flow Duration Curve at Rio Machariapu Proposed MHP Intake Site
(Apolo/ F. Tamayo/ La Paz)

6.3.2 Socio-economic Conditions and Demand for Electricity

(1) Socio-economic Conditions

The population of Apolo Municipality was 12,857 in 1992. About 54% of the population or 6,989 inhabitants are concentrated in the canton of Apolo including urban areas.

Agriculture still plays a dominant role in the local economy. About 46% of the land is used for grassland and cattle breeding is the main economic activity. About 14% of the land is used for cultivated (temporary and permanent) land where banana, citrus fruits and Yuca are produced as the major crops.

A diesel generator (222 kW) owned and managed by a cooperative is under operation in Apolo town. Electricity supply is restricted to the peak time (3 hours from 7 p.m. to 10 p.m.).

The average monthly household income is as low as Bs 500 to 800 in Apolo town while monthly expenditure on electricity is Bs.30 to 40.

(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, target area would encompass surrounding communities including Apolo town.

1) Target area

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 as presented below:

Block	Name of Block	Nos of Communities	
		Urban	Rural
A	Apolo central town	1	0
B	Apolo central town + Airport + Sta. Teressa	1	7
C	Sta. Cruz del Ameno	0	15
D	Sant. Domingo	0	7
E	Inca and San Pedro	0	8
F	San Jose de Mayo	0	5
G	San. Marcos and Altuncama	0	2
	Sub-total (B~G)	1	44

Note: Block B includes the area of Block A, airport and Santa Teresa village.

2) Estimation of households in 2005

Assuming that the population will increase by the same rate observed during 1995-2000, and the family size remains unchanged, the numbers of households in the future were projected as follows:

Block	Number of Households					
	1999 (Actual)			2005 (Estimated)		
	Urban	Rural	Total	Urban	Rural	Total
A	580	0	580	587	0	587
B	580	251	831	587	253	840
C	0	336	336	0	338	338
D	0	229	229	0	230	230
E	0	335	335	0	337	337
F	0	214	214	0	216	216
G	0	32	32	0	32	32
Total (B~G)	580	1,397	1,977	587	1,406	1,993

3) Demand projection

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

Domestic Demand

For estimating domestic demand, unit rates of power consumption per household were estimated. The estimated unit rates of power consumption are 267 W in urban areas and 135 W in rural areas.

Using these unit rates, domestic demand for electricity in the target areas was estimated as summarized below:

(kW)

Block	Urban Area			Rural Area			Peak Demand
	Evening	Midnight	Daytime	Evening	Midnight	Daytime	
A	157.0	4.1	17.7	0	0	0	157.0
B	157.0	4.1	17.7	34.2	0	2.7	191.2
C	0	0	0	45.7	0	3.6	45.7
D	0	0	0	31.1	0	2.5	31.1
E	0	0	0	45.5	0	3.6	45.5
F	0	0	0	29.2	0	2.3	29.2
G	0	0	0	4.3	0	0.3	4.3
Total (B~G))	157.0	4.1	17.7	190.0	0	15.0	347.0

Non-domestic Demand

Power demand for business, industry and public was also estimated in the same way as domestic demand. The estimated unit rates for non-domestic demand is summarized in the following. The demand in urban areas is applied to the Apolo town (block A) while the demand in rural areas to other blocks (B-G) which belong to the rural area.

Category		Urban Area			Rural Area		
		Evening	Midnight	Daytime	Evening	Midnight	Daytime
Business	kW/block	14.00	0.81	1.33	9.57	0.44	1.00
Industry	kW/block	35.23	0.88	47.74	13.50	0.25	29.65
Public (Facilities)	kW/block	37.06	0.27	28.68	1.47	0.22	7.45
Sub-total	kW/block	86.29	1.96	77.75	24.54	0.91	38.10
Public (Streetlight)	kW/km/HH	0.04	0.04	0	0.06	0.06	0

Total Demand

Both domestic and non-domestic demands were aggregated to estimate total power demand, which is summarized below:

(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.

6.3.3 Formulation of the Optimum Development Scheme

(1) Approach to 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. The optimum development scheme of the project was selected by comparing the alternative cases.

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 José) 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

Note: HH is size of household

Power demand for the alternative cases was estimated as presented in the following.

Power Demand of Alternative Cases for Apolo MHP Project

Target Zone (Block Name)	Name of Block	No. of Electrified Communities		Household (Estimated) in 2005			Proposed Transmission Line Length (km)	HH/L Density	Priority Rank	Power Demand Total (kW)	Case-1	Case-2	Case-3	Case-4	Case-5	Case-6	Case-7
		Urban	Rural	Urban	Rural	Total					A (kW)	B (kW)	B+F (kW)	Case-3 +D (kW)	Case-4 +C (kW)	Case-5 +E (kW)	Case-6 +G (kW)
		a	b	f	g	h=f+g	i	j=h/i	k	l							
A	Apolo Central Town only	1	0	587	0	587	15.0	39.1	-	270	270						
B	A + Apolo Airport + on the route (Cmd. Sta. Teresa)	1	7	587	253	840	27.5	30.5	1	340		340	340	340	340	340	340
C	Sta. Cruz del Ameno	0	15	0	338	338	35.3	9.6	4	90					90	90	90
D	Sant. Domingo	0	7	0	230	230	17.0	13.5	3	70				70	70	70	70
E	Cmd. Inca & San Pedro	0	8	0	337	337	35.4	9.5	5	90						90	90
F	Cmd. San Jose - 1 de Mayo	0	5	0	216	216	13.5	16.0	2	70			70	70	70	70	70
G	Cmd. San Marcos & Altuncama	0	2	0	32	32	8.9	3.6	6	40							40
	Total (B~G)	1	44	587	1,406	1,993	137.6	14.5	-	700	270	340	410	480	570	660	700

Source: JICA Study Team

(2) Estimation of the Cost and Benefit

1) Preliminary Cost Estimate

Economic construction cost includes civil works, electrical-mechanical works and is preliminary estimated by applying unit rates. The operation and maintenance cost was estimated on the basis of the construction cost. The estimated project costs including construction cost and operation and maintenance cost are summarized below:

Project Costs of Alternative Cases for Apolo MHP

(US$)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
.Civil/Mechanical/Electric Works	1,630,700	1,763,000	2,047,300	2,175,800	2,378,400	2,562,400	2,657,300
Transmission/Distribution	142,000	311,900	431,500	574,900	848,900	1,123,300	1,183,300
Total Cost	1,772,700	2,074,900	2,478,800	2,750,700	3,227,300	3,685,700	3,840,600
O&M per year	12,002	17,218	23,227	27,923	36,049	44,371	46,409

2) Benefit

Total benefit measured by the costs of diesel power is summarized below:

Project Benefit (Cost of Diesel Power) of Alternative Cases for Apolo MHP

(US$)

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
Civil/Mechanical/Electric Works	206,827	259,327	311,827	364,327	431,827	499,327	529,327
Transmission/ Distribution	50,157	281,313	400,900	544,317	818,271	1,092,667	1,164,896
Total Cost	256,984	540,640	712,727	908,644	1,250,098	1,591,994	1,694,223
O&M per year	242,392	288,547	322,572	373,517	425,309	475,029	501,628

(3) Selection of the Optimum Scale

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 summarized below:

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	1.3	1.31	**1.33**

*: with the discount rate of 10% per year

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

6.3.4 Preliminary Design and Cost Estimate

(1) Preliminary Design

Proposed layout plan and preliminary design of the Apolo is presented in Figure 6.2.

(2) Cost Estimate

The estimated construction cost (financial cost) of the project is US$ 4.0 million as summarized as follows.

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

Details of the cost estimate of civil and electric/mechanical works are presented in Table 6.1.

6.3.5 Construction Schedule

In due consideration of the present situation in Apolo and required funds, two stage development was proposed. Stage-1 construction includes construction of all the civil works and one set of turbine and generator (350 kW) with the related transmission/distribution lines (for Block A and B), while Stage-2 construction includes construction of additional one turbine and generator (350 kW) and the related transmission/distribution lines (for Block C, D, E, F and G).
Assuming that required time for design including basic design is 6 months, total required period for completion of the project is around 4 years as presented in Figure 6.3.

6.3.6 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.

1) Economic Cost

Economic costs are derived by taking the domestic taxes and subsidies from the financial costs.

Economic Project Cost
Economic project costs are as summarized in the table below.

Economic Project Costs of the Apolo MHP Project (US$)

Preparation Works and Access, etc.	539,000
Civil Works	484,900
Turbine/Generator	633,600
Transmission/Distribution Lines	1,183,300
Mechanical Works	189,400
Transportation	94,900
Administration and Engineering Service	278,400
Total Investment Cost	3,403,500

Source: JICA Study Team

Economic O&M Cost

Annual operation and maintenance costs of the project facilities are estimated as follows.

Turbine/Generator: 2% of the investment cost
Civil Work: 0.5% of the cost
Transmission/Distribution Lines: 2.5% of the investment cost

2) Economic Benefit

Economic benefits are derived by taking the domestic taxes and subsidies from the financial costs.

The costs of the least-cost alternative system, i.e., a diesel engine powered generation system with the capacity to generate the same amount of electricity as the proposed micro-hydro power, is considered to be the economic benefit.

Investment Cost of the Diesel Generation System

Investment cost of the alternative diesel generation system is estimated as follows.

Investment Cost of the Diesel Generation System

	Unit	Unit Cost	Apolo	
			Units	Cost
Capacity of the Diesel Generator	kW	750	700	525,000
Automatic Transfer Switch	-	1,910	1	1,910
Protection Box	-	917	1	917
Building	-	1,500	1	1,500
Transmission Lines	km	5,833	141	824,425
Distribution Lines	km	3,417	100	340,471
Total	-	-	-	1,694,223

Source: JICA Study Team

O&M Cost

Annual operation and maintenance costs of the alternative diesel generation system are estimated as follows.

Diesel Generation System: 5% of the investment
Transmission/Distribution Lines: 2.5% of the investment

Diesel Oil Cost

Economic cost of the diesel oil in Apolo is 3.88 Bs. per liter. Annual diesel oil cost is calculated based on the assumed power generation.

Annual Power Generation and Diesel Oil Cost

Power Generation (kWh/Year)	2,680,925
Fuel Consumption (Litter/Year)	750,805
Diesel Oil Cost (US$/Year)	446,114

3) Results of Economic Analysis

a) EIRR

The EIRR of the Apolo micro-hydro power project on the basis of the above assumptions are computed to be 19.2% as in Table 6.2, using the economic cost and benefit stream shown above. It indicates that the proposed project is economically viable.

b) Sensitivity Analysis

Sensitivity analysis to examine flexibility of the proposed project in economic viability is made under the following adverse assumptions of key factors. The Apolo micro-hydro power project demonstrates sufficient economic viability even under the adverse conditions as follows.

Case I	+10% investment cost and -10% diesel fuel cost	16.6%
Case II	+20% investment cost and -20% diesel fuel cost	14.5%

(2) Financial Evaluation

The financial viability of the Apolo micro-hydro power project is examined by computing the minimum power tariff based on the financial cost to cover the investment and O&M costs of the project.

1) Financial Project Cost

Financial project costs are estimated to be as follows.

Financial Project Costs of the Apolo MHP Project (US$)

Preparation Works and Access, etc.	625,300
Civil Works	562,500
Turbine/Generator	740,000
Transmission/Distribution Lines	1,419,900
Mechanical Works	219,700
Transportation	110,100
Administration and Engineering Service	323,000
Total Investment Cost	4,000,500

Source: JICA Study Team

The tax rates included in the financial costs are summarized below.

Taxes for Domestic Products

VAT (Value Added Tax): 13% for all the categories of products
Transaction tax: 3% for all the categories of products

Taxes for Imported Products

Effective VAT: 14.94% for all the categories of products
Import tax: 5% (turbine/generator)
20%* (transmission/distribution lines)

* Adjusted rate in consideration of the different products used to produce distribution lines

2) Calculation of Power Tariff to Cover the Investment and O&M Costs

Minimum power tariffs of the residential sector to cover both the investment cost and O&M cost are calculated as follows. The power tariff from the non-residential sector is assumed at 50% higher than that of the residential sector.

Minimum Power Tariff to Cover Investment and O&M Costs (US$)

Discount Rate	10%	20%
Residential per kWh	0.05	0.08
Residential per Month	1.27	2.12

Residential users of the diesel generation system, however, pay as much as Bs.30., or US$4.59 per month for the service. Since each residential user of the micro-hydro power project in Apolo is estimated to use 322kWh per year, the monthly payment even with the discount rate of 20% would be US$2.12 (US$0.08/kWh x 322 kWh / 12 months), which is still less than 50% of the amount they pay at present. The micro-hydro power project in Apolo is concluded to be financially viable.

6.3.7 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. Environmental impacts of the project are summarized in the table below.

IEE Matrix for Apolo Micro-hydro Power Project, La Paz

Item			Evaluation	Remarks
Social Environment	1	Resettlement	-	
	2	Economic activities	○	Irrigated agriculture with water pumping system and cottage industry will be promoted.
	3	Traffic and public facilities	○	Public facilities including schools and hospitals will be electrified.
	4	Split of communities	-	
	5	Cultural property	-	
	6	Water rights/Right of common	-	
	7	Public health condition	○	Clean water will be provided by water pumping system.
	8	Waste	-	
	9	Hazards	○	Lighting will enhance safety at night for rural life.
Natural Environment	10	Topography and geology	△	Topography will change in a small part of project site.
	11	Soil erosion	-	
	12	Groundwater	-	
	13	Hydrological situation	□	Water volume of the river will decrease.
	14	Coastal zone	-	
	15	Flora and fauna	△	Some plants will be influenced in the limited area of the riverside.
	16	Climate	-	
	17	Landscape	-	
Pollution	18	Air pollution	-	
	19	Water pollution	-	
	20	Soil contamination	-	
	21	Noise and vibration	△	Noise will occur in the construction stage.
	22	Land subsidence	-	
	23	Offensive odor	-	

Notes: ○= Positive impact, - = Negligible impact, △ = Minor impact, □ = Moderate impact, × = Serious impact, ? = Not clear
This IEE study was implemented by an environmental consultant registered by the Ministry of Sustainable Development and Planification in May, 2001.
The study report of this IEE was submitted to the the Ministry of Sustainable Development and Planification through the Vice Ministry of Energy and Hydrocarbons.
Source: JICA Study Team

6.4 Pre-feasibility Study on Tambo Quemado Micro-hydro Power Project in Oruro

6.4.1 Location, Topography, Meteorology and Hydrology

(1) Location and Topography

The proposed site of 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, which consists of three (3) cantons, namely, Turco, Cosapata and Chachacomani. The Tambo Quemado village is the target area to be electrified by the proposed micro-hydro.

The project site of Tambo Quemado is located at latitude 18° 17' S and longitude 69° 02' W in the zone of the Sajama National Park as presented in Figure 6.4. The elevation of the proposed intake site is around 4,500 m..


Proposed Intake Site-1 (Left)


Proposed Intake Site-2 (Right)

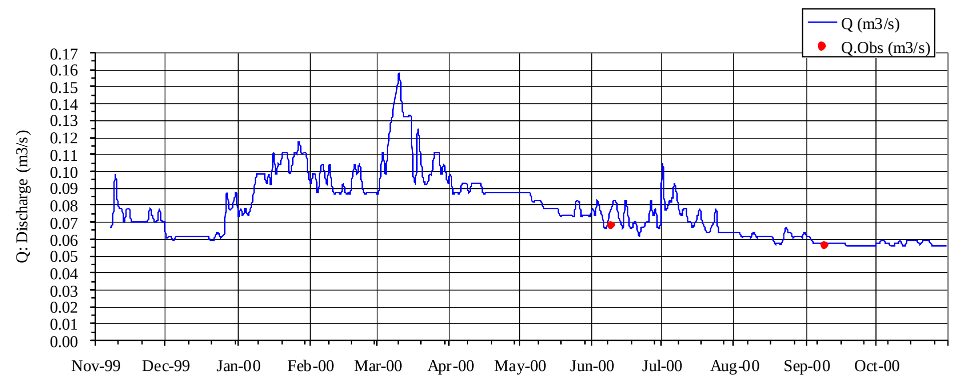
Proposed Intake Site of Tambo Quemado Micro-Hydro Power (Sajama/Oruro)

(2) Meteorology and Hydrology

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% from April to September. The highest monthly record of precipitation is 108 mm observed in January, while precipitation is nil from June to August.

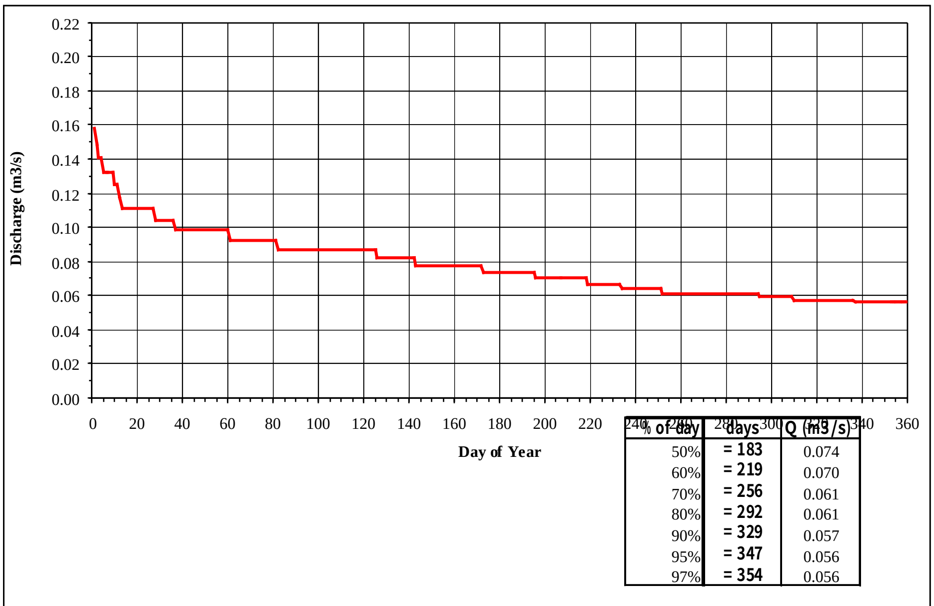
A staff gauge was installed at the Jaruma River during the first field survey in November 1999. The daily water level was measured until October 2000. Based on the collected daily water level data at the Jaruma River, H-Q curve (Water level and Discharge relation curve) was firstly estimated at the water level station of the Jaruma River.

Since there exists no discharge data of the Tambo Quemado River, daily discharge of the Tambo Quemado River was estimated using the correlation between the two rivers. The estimated daily discharge at the proposed intake site of the Tambo Quemado River is shown below.



Estimated Daily Discharge at Rio Tambo Quemado WL.Station (Turko/ Sajama/ Oruro)
(by JICA Study Team)

The flow duration curve at the Tambo Quemado River was also prepared as shown below.



Estimated Flow Duration Curve at Rio Tambo Quemado (Turco/Sajama/Oruro)

6.4.2 Socio-economic Conditions and Demand for Electricity

(1) Socio-economic Conditions

Tambo Quemado located in the Turco municipality is a small village. The number of households in the village is around 55 (45 household + 10 residences/offices). Assuming that the family size per household is 3.3, the population was estimated at about 235 (150 + 90 in residences/offices) in 2000.

Services related to the customs are major economic activities in Tambo Quemado, which is located in the border town with Chile. Livestock breeding in the extensive grassland is another economic activity. The annual average income per household is reported to be 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

1) Target area and methodology of the estimate

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

The methodology and process of the estimate of demand for electricity are as follows.

- estimate present demand for electricity in Tambo Quemado
- project future household and establishment of business in 2005
- project future demand for electricity in 2005

2) Demand projection

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.

Using the number of the households and business establishment, present demand for electricity was estimated at 42 kW. For estimating future demand for electricity, projection of the households, new establishment for business and public facilities was made taking into account the current trend of the development in Tambo Quemado. In 2005, the number of the household is expected to increase from 55 to 69, while the number of business establishments, industry and public facilities from 21 to 37.

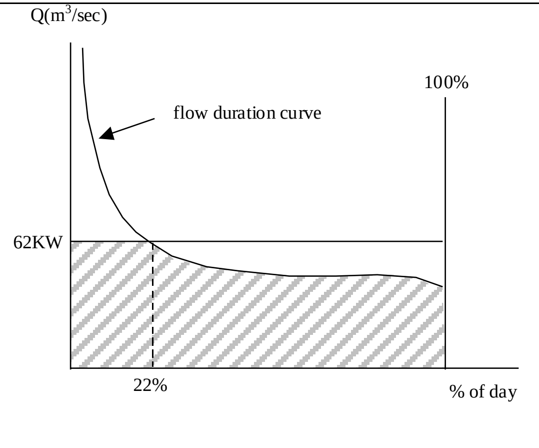
Based on these figures, the estimated demand for electricity in 2005 is 62 kW as summarized in the next table.

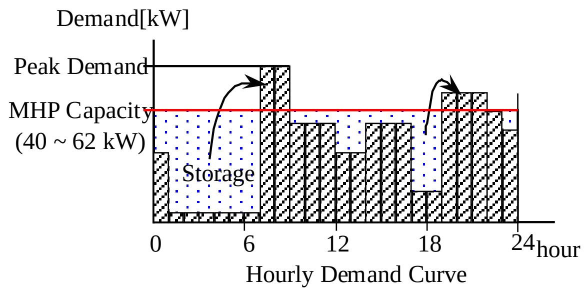
Category	Present (2001)		Future (2005)	
	Number of HH or Facilities	Peak Demand (kW)	Number of HH or Facilities	Peak Demand (kW)
Domestic	55	40.2	69	58.8
Business	20	1.6	34	2.8
Industry	0	0.0	2	0.0
Public	2	0.0	1	0.0
Total	77	41.8	106	61.6

6.4.3 Formulation of the Optimum Development Scheme

(1) Approach to the Optimum Development Scheme

As explained earlier, available water is limited in the Tambo Quemado River. From the hydrological analysis, the proposed micro-hydro power to be constructed guarantees the projected peak demand during only 22% of the day as illustrated below. To meet the peak demand during the remaining 78% of the day, additional power by diesel and/or construction of a storage pond for the micro-hydro are required.





In this study, alternative development plans were formulated under the concept of how to meet the required demand with the constraints of the limited available water.

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)

(2) Selection of the Optimum Scheme

For selecting the optimum scheme of the project, cost and benefit for three alternative plans were estimated and compared.

1) Cost estimate

Economic construction costs of alternative plans excluding tax and duties were estimated as well as the operation and maintenance cost as summarized below.

Project Costs of Alternative Cases for Tambo Quemado MHP

(US$)

	Case A	Case B	Case C
Civil/Mechanical/Electric Works (MHP)	142,900	158,700	185,600
Civil/Mechanical/Electric Works (Diesel)	20,827	13,327	0
Transmission line	21,800	21,800	21,800
Total Investment	**185,527**	**193,827**	**207,400**
O&M per year	**18,583**	**17,523**	**1,703**

2) Benefit

The benefit was estimated by the cost of the alternative diesel power and is summarized below:

Project Benefit of Alternative Cases (Cost of Diesel Power) for Tambo Quemado MHP

(US$)

	Case A	Case B	Case C
Civil/Mechanical/Electric Works (Diesel)	50,827	50,827	50,827
Total Investment (Diesel)	**50,827**	**50,827**	**50,827**
O&M per year (Diesel)	**35,185**	**35,185**	**35,185**

(3) Selection of the optimum scale

The results of economic evaluation for the Tambo Quemado micro-hydro power project are summarized in the following.

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) might be the optimum one. Considering the environmental negative effect of diesel generator and flexibility of power generation corresponding to the future demand increase, Case-C was finally selected as the optimum development plan.

6.4.4 Preliminary Design and Cost Estimate

(1) Preliminary Design

Proposed layout plan and preliminary design of the Tambo Quemado are presented in Figure 6.5.

(2) Cost Estimate

The estimated construction cost (financial cost) of the project is 239,700US$ as summarized in the next table. Details of the cost estimate of civil and electric/mechanical works are presented in Table 6.3.

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.

6.4.5 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 as presented in Figure 6.6.

6.4.6 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.

1) Economic Cost

Economic costs are derived by taking the domestic taxes and subsidies from the financial costs.

Economic Project Cost

Economic project costs are as summarized in the next table.

Economic Project Costs of the Tambo Quemado MHP Project (US$)

	Tambo Quemado
Preparation Workds and Access, etc.	2,000
Civil Works	95,800
Turbine/Generator	33,100
Transmission/Distribution Lines	21,700
Mechanical Works	25,800
Transportation	8,900
Administration and Engineering Service	18,400
Total Investment Cost	205,700

Source: JICA Study Team

Economic O&M Cost

Annual operation and maintenance costs of the project facilities are estimated as follows.

Turbine/Generator: 2% of the investment cost
Civil Work: 0.5% of the cost
Transmission/Distribution Lines: 2.5% of the investment cost

2) Economic Benefit

Economic benefits are derived by taking the domestic taxes and subsidies from the financial costs.

The costs of the least-cost alternative system, i.e., a diesel engine powered generation system with the capacity to generate the same amount of electricity as the proposed micro-hydro power, is considered to be the economic benefit.

Investment Cost of the Diesel Generation System

Investment cost of the alternative diesel generation system is estimated as follows.

Investment Cost of the Diesel Generation System*

	Unit	Unit Cost	Tambo Quemado	
			Units	Cost
Capacity of the Diesel Generator	kW	750	62	46,500
Automatic Transfer Switch	-	1,910	1	1,910
Protection Box	-	917	1	917
Building	-	1,500	1	1,500
Total	-	-	-	50,827

Source: JICA Study Team

* Since the new diesel generator, transmission lines and distribution lines were just installed in 2000, the initial investment costs of these equipment are excluded from the benefit calculation. Only the replacement costs of these equipment are included in the calculation.

O&M Cost

Annual operation and maintenance costs of the alternative diesel generation system are estimated as follows.

Diesel Generation System:	5% of the investment
Transmission/Distribution Lines:	2.5% of the investment

Diesel Oil Cost

Economic cost of the diesel oil in Tambo Quemado is 3.28 Bs. per liter. Annual diesel oil costs is calculated based on the assumed power generation.

Annual Power Generation and Diesel Oil Cost

Power Generation (kWh/Year)	181,147
Fuel Consumption (L/Year)	65,137
Diesel Oil Cost (US$/Year)	32,718

3) Results of Economic Analysis

a) EIRR

The EIRR of the Tambo Quemado micro-hydro power project are computed to be 16.4% as in Table 6.4, using the economic cost and benefit stream shown above. It indicates that the proposed project is economically viable.

b) Sensitivity Analysis

Sensitivity analysis to examine flexibility of the proposed project in economic viability is made under the following adverse assumptions of key factors. The Tambo Quemado micro-hydro power project demonstrates economic viability even under the adverse conditions as follows.

Case I	+10% investment cost and -10% diesel fuel cost	14.6%
Case II	+20% investment cost and -20% diesel fuel cost	13.1%

(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.

1) Financial Project Cost

Financial project costs are estimated to be as follows.

Financial Project Costs of the Tambo Quemado MHP Project (US$)

Preparation Workds and Access, etc.	2,224
Civil Works	111,194
Turbine/Generator	38,700
Transmission/Distribution Lines	26,056
Mechanical Works	29,870
Transportation	10,291
Administration and Engineering Service	21,366
Total Investment Cost	239,700

Source: JICA Study Team

The tax rates included in the financial costs are summarized below.

Taxes for Domestic Products

VAT (Value Added Tax):	13% for all the categories of products
Transaction tax:	3% for all the categories of products

Taxes for Imported Products

Effective VAT:	14.94% for all the categories of products
Import tax:	5% (turbine/generator)
	20%* (transmission/distribution lines)

* Adjusted rate in consideration of the different products used to produce distribution lines

2) Calculation of Power Tariff to Cover the Costs

Minimum power tariffs to cover the costs are calculated as follows. The power tariff from the non-residential sector is estimated at 50% higher than that of the residential and office use.

The minimum tariff to cover all the investment cost and O&M cost is calculated as follows. The minimum power tariff is calculated by annualizing the investment by multiplying CRF (Capital Recovery Factor) of respective discount rates, adding annual O&M cost, and then dividing it by annual power demand.

Minimum Power Tariff to Cover Investment and O&M Costs (US$)

Discount Rate	10%
Residential per kWh	0.13
Residential per Month	3.2

3) Results of Financial Analysis

At present, residential users of the diesel generation system pay on average Bs. 25, or US$ 3.83 per month for the service. Since each residential user of the micro-hydro power project in Tambo Quemado is estimated to use 300 kWh per year, the monthly payment with the discount rate of 10% to cover investment cost and O&M cost would be US$ 3.2 (US$0.13 /kWh x 300 kWh / 12 months), which is lower than the amount they pay at present. It could be concluded that the micro-hydro power project in Tambo Quemado would be financially sustainable.

6.4.7 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 give no serious impacts in/around the project site according to the results of the survey. Anticipated environmental impacts of the project are presented in the table below.

IEE Matrix for Tambo Quemado Micro-hydro Power Project, Oruro

Item			Evaluation	Remarks
Social Environment	1	Resettlement	-	
Social Environment	2	Economic activities	○	Commercial and cottage industries will be promoted.
Social Environment	3	Traffic and public facilities	○	Public facilities including schools and hospitals will be electrified.
Social Environment	4	Split of communities	-	
Social Environment	5	Cultural property	-	
Social Environment	6	Water rights/Right of common	-	
Social Environment	7	Public health condition	○	Clean water will be provided by water pumping system.
Social Environment	8	Waste	-	
Social Environment	9	Hazards	○	Lighting will enhance safety at night for rural life.
Natural Environment	10	Topography and geology	-	
Natural Environment	11	Soil erosion	-	
Natural Environment	12	Groundwater	-	
Natural Environment	13	Hydrological situation	□	Water volume of the river will decrease.
Natural Environment	14	Coastal zone	-	
Natural Environment	15	Flora and fauna	△	Moss plant will be influenced in the limited area of the riverside.
Natural Environment	16	Climate	-	
Natural Environment	17	Landscape	△	Transmission line will be an obstacle to the sightseeing of Mt. Sajama.
Pollution	18	Air pollution	-	
Pollution	19	Water pollution	-	
Pollution	20	Soil contamination	-	
Pollution	21	Noise and vibration	△	Noise will occur in the construction stage.
Pollution	22	Land subsidence	-	
Pollution	23	Offensive odor	-	

Notes: ○= Positive impact, - = Negligible impact, △= Minor impact, □= Moderate impact, × = Serious impact, ? = Not clear
This IEE study was implemented by an environmental consultant registered by the Ministry of Sustainable Development and Planification in May, 2001.
The study report of this IEE was submitted to the the Ministry of Sustainable Development and Planification through the Vice Ministry of Energy and Hydrocarbons.
Source: JICA Study Team

CHAPTER 7 SUMMARY OF STUDY ON WIND POWER

7.1 Survey and Study Conducted

The field survey commenced from August 7, 1999 and continued up to September 7, 2001 intermittently. The study on wind power focused on the following objectives:

1) To identify appropriate sites for wind monitoring and install ten wind monitoring systems; 5 in La Paz and 5 in Oruro.
2) To identify priority sites for wind power development and evaluate cost competitiveness.
3) To select high priority projects

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 Installation of Wind Monitoring System

For the installation of the wind monitoring systems, five systems in La Paz and five systems in Oruro, site selection of the wind monitoring system was conducted. Installation of the wind monitoring systems was carried out from January to February 2000.

7.2.1 Selection Criteria

For the selection of the candidate sites for the wind monitoring, the following aspects were taken into account and compared.

1) Sites where meteorological observation record was available by SENAMHI
2) Sites where other alternative energy sources (except grid extension) are available.
3) Size of population
4) Sites which will not be covered by grid extension within 5 – 10 years
5) Geographical distribution and accessibility for data collection

7.2.2 Selected Sites

Using the criteria mentioned above, appropriate sites for installing the wind monitoring system were selected; five (5) sites in La Paz and five (5) sites in Oruro. The characteristics of the selected sites are summarized below and their location is indicated in Figure 7.1 and Figure 7.2.

(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

7.2.3 Installation and Monitoring

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

After installation of the system, the JICA Study Team commenced monitoring and data collection for the planning of wind power development projects. The collected data for the wind analysis are from February 2000 to January 2001. The table below summarized percentage of collected data throughout a one-year wind monitoring period. The data collection was successfully conducted. However, the barometric pressure was not recorded for 4 months because of SIM card problems.

Collection Rate of Wind Data

ID No.	Site	Collection rate / annual hours
1	Achiri	99.1%
2	Charaña	99.1%
3	Gonzales	97.2%
4	Is. Taquiri	97.3%
5	Llallagua	90.6%
6	Comjo	100%
7	Caripe	99.6%
8	Chachacomani	99.6%
9	Salinas	90.5%
10	Sevaruyo	91.8%

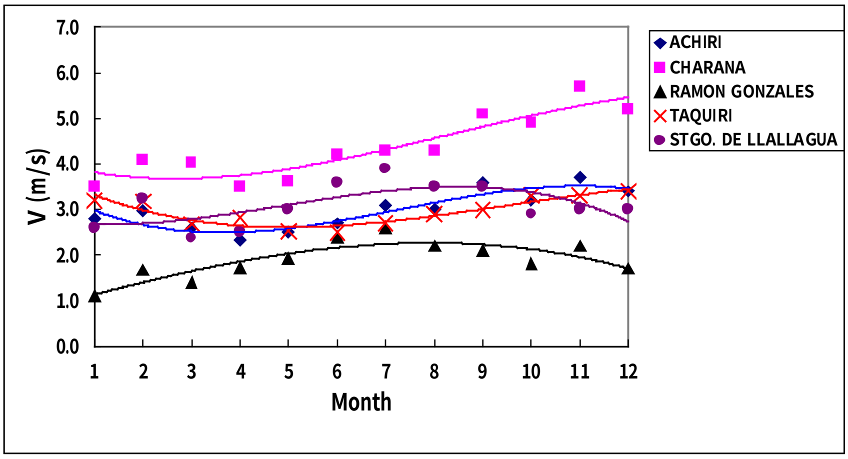
Source: JICA Study Team

7.3 Analysis of the Collected Data

Analysis of the collected data was made for formulating the priority projects for wind power development. The data analysis on annual wind speed and diurnal wind speed are most important for selecting sites for wind power development. Only the results of the analysis on the monthly average wind speed and diurnal wind speed are summarized in this chapter. Details of the data analysis are shown in Appendix II.

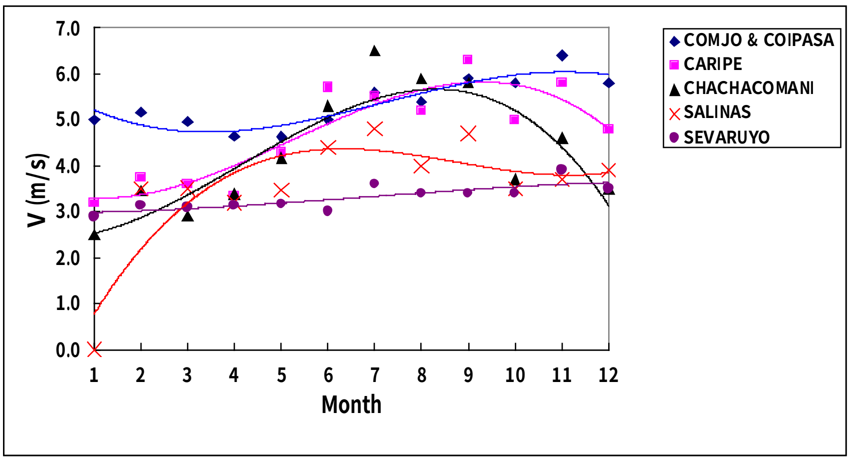
7.3.1 Monthly Average Wind Speed

Wind speed at 20 meters and 10 meters above ground level was monitored for a year. The following figure shows monthly average wind speed at 20 meters height at the monitoring sites in La Paz. The monthly average wind speed at Charaña is the highest throughout a year. The wind speed is the lowest at Ramon Gonzales during the monitoring period. The average wind speeds at the other sites, Achiri, Taquiri and Santiago de Llallagua are at almost the same level. Charaña recorded the highest monthly average wind speed in La Paz.



Monthly Average Wind Speed in La Paz

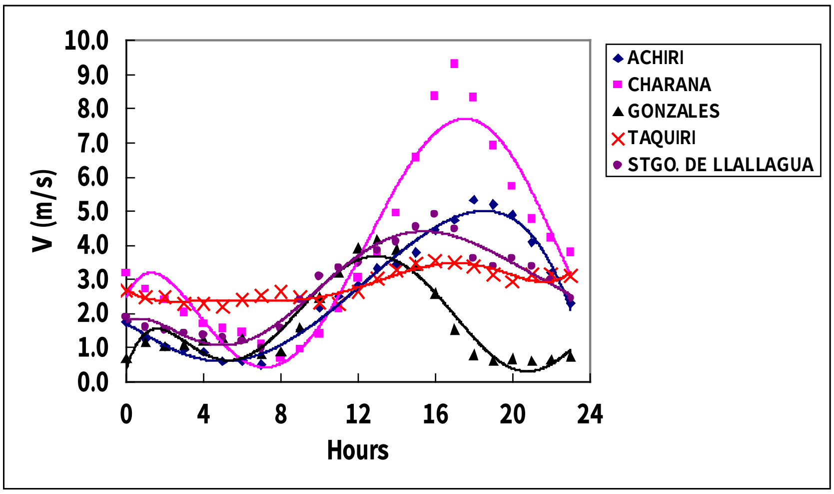
In Oruro, the average wind speed at Comjo / Coipasa recorded the highest throughout the year. The average wind speed recorded at Caripe and Chachacomani is also high. All of the above three sites are located on the west side of Oruro department, adjacent to high mountains. As indicated in the following, strong wind was recorded at the west side of Oruro department.



Monthly Average Wind Speed in Oruro

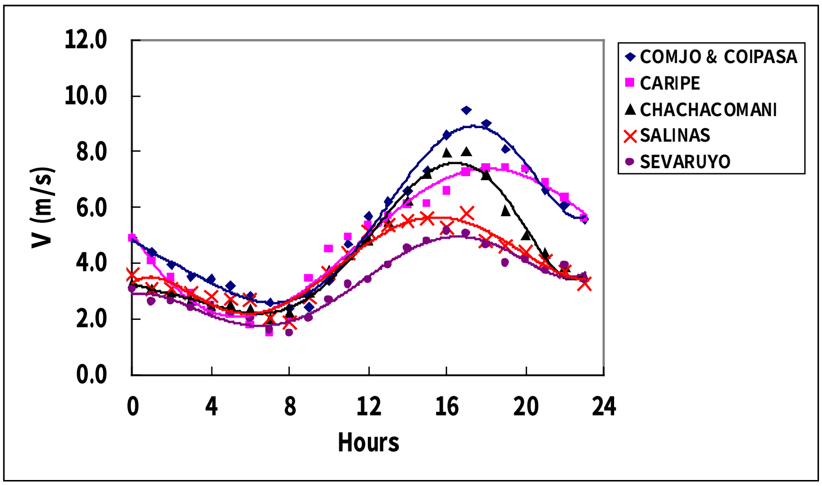
7.3.2 Diurnal Wind Speed

The figure below shows diurnal wind speed at monitoring sites in La Paz department. The diurnal wind speed presented in the figure indicates the average from February 2000 to January 2001. The data of Charaña show unique diurnal wind speed pattern. The average wind speed in a year is 4.4 m/s, however, the average wind speed from 13:00 to 23:00 is high at 7.0 m/s. Since the peak power demand at Charaña is between 19:00 to 21:30, the diurnal wind speed pattern corresponds to the demand. At Achiri and Santiago de Llallagua, the wind speeds become stronger in the afternoon till evening. At Ramon Gonzales, the average diurnal wind speed is the highest at noon. At Taquiri islands, the diurnal wind speed is relatively stable and low.



Diurnal Wind Speed in La Paz

The figure below shows diurnal wind speed at wind monitoring sites in Oruro department. The diurnal wind speed presented in the figure indicates the average from February 2000 to January 2001. The average wind speed of Comjo/Coipasa are 5.3m/s, however, the average wind speed from 13:00 to 23:00 is high at 7.4 m/s. In Chachacomani the average wind speed is 4.5 m/s, but the average during 13:00 to 23:00 is high at 6.2 m/s. In Caripe the average wind speed is 4.8 m/s, while the average during 13:00 to 23:00 is high at 6.6 m/s. The average wind speed in Salinas and Sevaruyo is relatively flat and low.



Diurnal Wind Speed in Oruro

7.4 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 are selected for pre-feasibility study.

La Paz	1	Charaña
Oruro	1	Chachacomani
	2	Caripe

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

7.5.1 Location and Socio-economic Condition

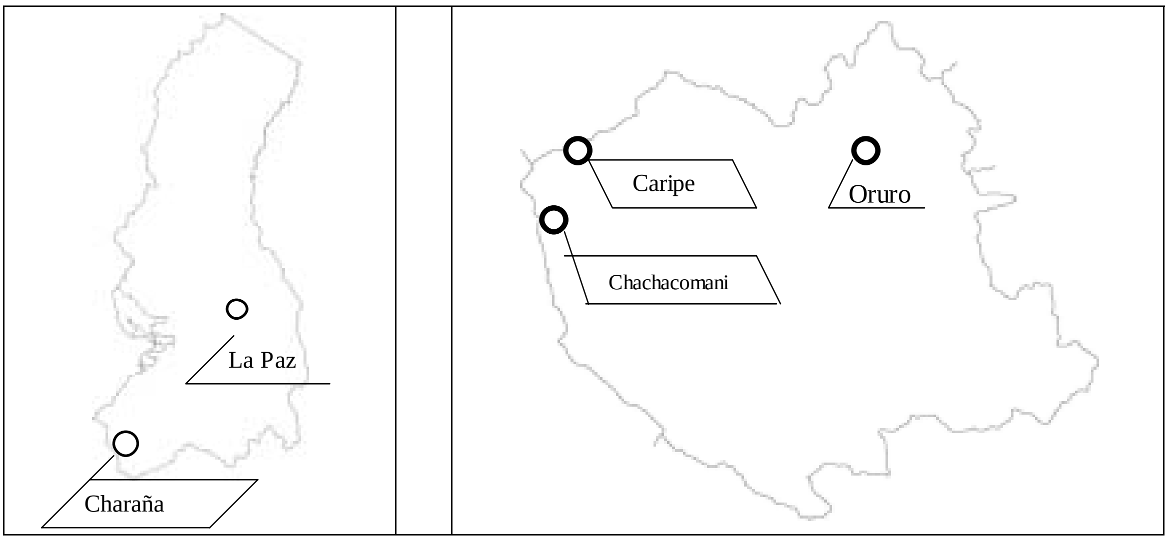
Charaña is a border town between Bolivia and Chile. The temperature in Charaña is low being located at 4,054 meters above sea level and near the high mountains of 6,000 meters. The population of Charaña was 1,037 in 1992, which decreased to 1,016 in 2000. Main economic activities are custom services 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. The monthly electricity tariff is Bs30 per household, while the household without electricity spend about Bs25 for gas lamp.

Caripe is located north of Oruro department. The temperature in Caripe is low, since it is located at 4,149 meters above sea level and near to the Mt.Sajama. 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 temperature in Chachacomani is low, since it is located at 4,220 meters above sea level. 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 Chile. There is no electricity supply service in Chachacomani. People are using candles, kerosene lamps and gas lamps for lighting instead of electricity. The cost of the energy is around Bs.10 to 30 per month.

Location of the three project sites is as presented in the following.



Location Map of Project Sites (for Pre-Feasibility)

7.5.2 Demand for Electricity

The demand for electricity was estimated on the basis of the results of the community interview survey. Since there are commercial and public facilities in addition to residence, 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.

For estimating the demand, power consumption was estimated for each category of the consumer (household, different commercial activities and public services). Then, number of households and, commercial and public facilities was projected in the target year.

Based on these figures, total demand for electricity was estimated. 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

7.5.3 Wind Data Analysis

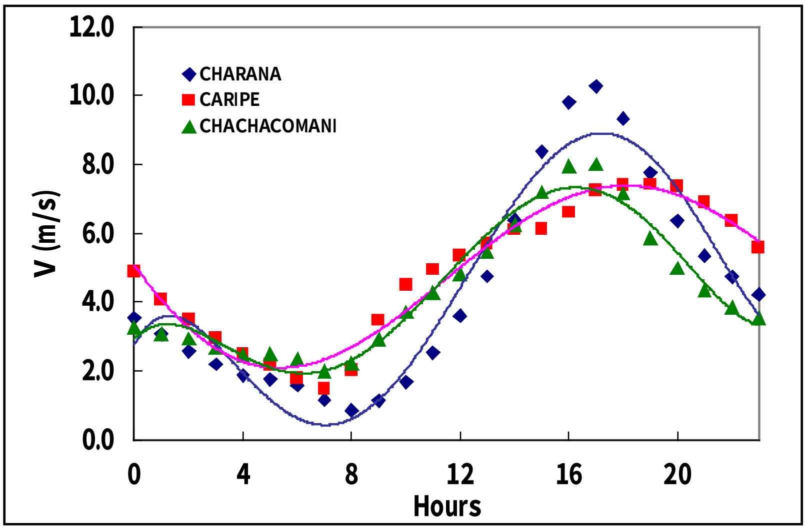
As presented in the following table, the average monthly wind speed is high in the proposed three sites; 4.4 m/s in Charaña, 4.7 m/s in Caripe and 4.3 m/s in Chachacomani. This indicates that the proposed three sites have substantial potential for the wind power.

Monthly Average Wind Speed (m/s) at Three Sites

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Charana	3.5	4.1	4.0	3.5	3.6	4.2	4.3	4.3	5.1	4.9	5.7	5.2	4.4
Caripe	3.2	3.8	3.6	3.3	4.3	5.7	5.5	5.2	6.3	5.0	5.8	4.8	4.7
Chachacomani	2.5	3.5	2.9	3.4	4.2	5.3	6.5	5.9	5.8	3.7	4.6	3.5	4.3

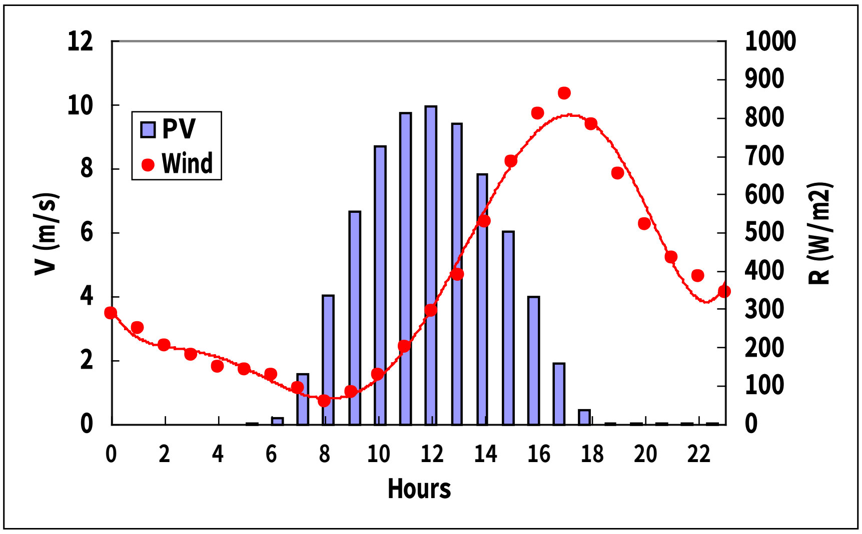
Source: JICA Study Team

The diurnal wind speed for the proposed three sites is also presented in the following figure. As indicated in the figure, the wind is strong from the afternoon to the evening when demand for electricity is high, while the wind is weak during midnight to early morning.



Diurnal Wind Speed at Three Sites

Complementary relation was identified between the wind speed and solar radiation. The diurnal wind speed and solar radiation were compared in the case of Charaña as presented in the following figure. The wind speed is high between two p.m. to eight p.m. when the solar radiation is weak, the solar radiation is strong between nine a.m. to three p.m. when wind speed is still low. This complementary characteristics of the two energy sources indicate that the hybrid system combining wind and solar could produce stable energy.



Diurnal Wind Speed vs. Solar Radiation at Charaña

7.5.4 Formulation of Optimum Development Scheme

Stand-alone wind generation system does not have enough capacity of generating electricity during daytime in Charaña, although there is high demand for electricity from offices and schools. To generate more stable electricity, the wind generation is to be combined with the other energy source.

Various hybrid schemes were conceived for comparison as follows:

1. Wind – Diesel Hybrid System
2. Wind – PV Hybrid System
3. Wind-Micro Hydro Hybrid System

However, hybrid system with diesel were not taken into account due to its high operation cost and environmental effects.

<u>Charaña</u>

For the selection of the optimum development scheme of the Charaña wind power project, five alternative schemes were formulated for satisfying the projected 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 that guarantees 80% of the daytime demand was set at kWp. 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.

Alternative Schemes of Wind-PV Hybrid System in Charaña

No.	1	2	3	4	5
Wind (kW) PV (kWp)	100 5	90 11	80 16	70 22	60 28
Investment Cost (US$)	295,000	311,000	320,000	336,000	352,000

Note: Investment cost includes only wind turbine/generator and PV system
Source: JICA Study Team

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.

Alternative Schemes of Wind-PV Hybrid System in Caripe

No.	1	2
Wind (kW) PV (kWp)	20 0	10 4
Investment Cost (US$)	54,000	55,000

Note: Investment cost includes only wind turbine/ generator and PV system.
Source: JICA Study Team

Chachacomani

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

Prior to comparing the two hybrid systems, the study for selecting the most optimum combination was made for each system. For wind-microhydro hybrid system, selection of the best combination of the two energy sources was made on the basis of the hydrological analysis and result of the cost comparison of the combined system. The best combination of wind-PV system was chosen using the same method applied to the Charaña and the Caripe.

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, which 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.

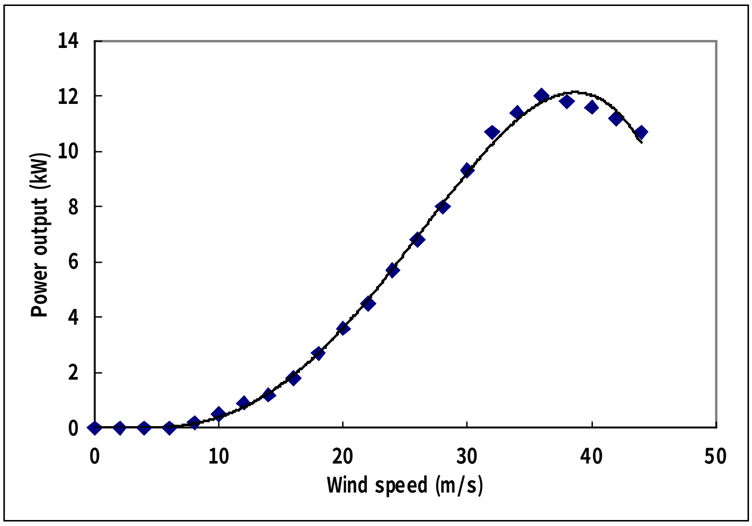
7.5.5 Preliminary Design and Cost Estimate

(1) Preliminary Design for Wind Turbine

Various types of wind turbines are available in the world. The selection of the wind turbine was made taking into account the following aspects.

- The wind tower can be installed by a winch considering the road condition to the project site and for easy maintenance.
- The wind turbine is to have much experience of operation in developing countries.
- The turbine is to have much experience in hybrid with wind and solar hybrid system.
- The wind turbine is available in Bolivia or South / North America.

Considering the above the BWC 10kW type was selected for the project. The performance curve with expected power generation of BWC 10kW is shown in the following figure.



Performance Curve of BWC 10kW Type

(2) Proposed Wind Power System

As explained earlier, the power generation system at Charaña and Caripe consists 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 towns 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 for the Charaña, Caripe and Chachacomani are summarized below.

Proposed Generation System

		Charana	Caripe	Chachacomani
Wind Turbine	(kW)	80	10	20
PV	(kWp)	16	4	-
MHP	(kW)	-	-	3
Inverter	(kVA)	64	8	14
Converter	(kVA)	20	-	10
Battery	(kAh)	44	8	4

Source: JICA Study Team

The proposed generation system and layout plan for each wind power project are shown in Figure 7.3 to 7.8.

Total annual power generation of the wind power project was estimated at 122,560 kWh for the Charaña, 22,643 kWh for the Caripe and 42,671 kWh for the Chachacomani as summarized as follows.

Monthly Power Generation

	Power Generation (kWh/Mo.)		
	Charana	Caripe	Chachacomani
Jan.	8,328	1,750	3,417
Feb	7,765	1,239	2,648
Mar	10,034	1,508	3,087
Apr	8,687	1,341	2,965
May	8,684	1,673	3,270
Jun	9,131	2,157	3,609
Jul	9,840	2,164	3,812
Aug	10,340	2,057	4,695
Sep	11,582	2,551	3,787
Oct	11,575	1,971	4,256
Nov	13,977	2,332	3,236
Dec	12,616	1,899	3,888
Total	122,560	22,643	42,671

Source: JICA Study Team

(3) Cost Estimate

The cost estimate was made on the basis of the some assumptions and conditions as applied in micro-hydro power:

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

7.5.6 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.

1) Economic Cost

Economic costs are derived by taking the domestic taxes and subsidies from the financial costs.

Economic project costs are summarized as follows.

Economic Project Costs of the Wind Power Projects (US$)

	Unit	Unit Cost	Charana		Caripe		Chachacomani (W-M)	
			Units	Cost	Units	Cost	Units	Cost
Wind Turbine	kW	2,700	80	216,000	10	27,000	20	54,000
PV System	kW	7,000	16	112,000	4	28,000	0	0
MHP	kW	34,250	0	0	0	0	3	102,749
Inverter	kVA	500	64	32,000	8	4,000	14	7,000
Converter	kVA	180	20	3,600	0	0	10	1,800
Battery	kAh	500	44	22,000	8	4,000	4	2,000
Control House	(1/village)	10,000	1	10,000	1	10,000	1	10,000
Installation Materials	kW	690	96	66,207	14	9,655	20	13,793
Installation Work	kW	603	96	57,931	14	8,448	20	12,069
Transportation	kg	8	11,200	92,946	1,800	14,938	2,000	16,598
Secondary Distribution Line	km	3,409	-	29,904	-	9,200	-	12,500
Administration (8.8%)	-	-	-	56,548	-	10,141	-	20,461
Total Investment Cost	-	-	-	699,136	-	125,382	-	252,969

Source: JICA Study Team

Annual operation and maintenance costs of the project facilities are estimated as follows.

Wind PV/MHP Power: 2% of the investment
Distribution Lines: 2.5% of the investment

2) Economic Benefit

The costs of the least-cost alternative system, i.e., a diesel engine powered generation system with the capacity to generate the same amount of electricity as the proposed wind power project, is considered to be the economic benefit.

Investment cost of the alternative diesel generation system is estimated as follows.

Investment Cost of the Diesel Generation System

	Unit	Unit Cost	Charana		Caripe		Chachacomani	
			Units	Cost	Units	Cost	Units	Cost
Capacity of the Diesel Generator	kW	750	65	48,750	10	7,500	20	15,000
Automatic Transfer Switch	-	1,910	1	1,910	1	1,910	1	1,910
Protection Box	-	917	1	917	1	917	1	917
Building	-	1,500	1	1,500	1	1,500	1	1,500
Secondary Distribution Lines	km	-	-	29,904	-	9,200	-	12,500
Total	-	-	-	82,981	-	21,027	-	31,827

OM Cost

Annual operation and maintenance costs of the alternative diesel generation system are estimated as follows.

Diesel Generation System:	5% of the investment
Distribution Lines:	2.5% of the investment

Diesel Oil Cost

Economic cost of diesel oil in Charaña, Caripe and Chachacomani are as follows.

Economic Cost of Diesel Oil (Bs./Liter)

Charaña	Caripe	Chachacomani
3.19	3.28	3.28

Annual diesel oil costs of the three sites are calculated based on the estimated power generation.

Annual Power Generation and Diesel Oil Cost

	Charaña	Caripe	Chachacomani
Power Generation (kWh/Y)	122,560	22,643	42,671
Fuel Consumption (L/Y)	53,420	13,032	20,405
Diesel Oil Cost (US$/Y)	26,096	6,546	10,250

3) Results of Economic Analysis

The EIRRs of the three projects on the basis of the above assumptions are computed as in Tables 7.1 to 7.3, using the economic cost and benefit stream shown above.

EIRR of the Wind Power Projects

Charaña	Caripe	Chachacomani
-2.6%	1.0%	-0.9%

The EIRRs of the projects in Charaña and Chachacomani are slightly negative though that of the projects in Caripe is positive. The costs of the wind turbine, inverter, converter and PV systems, however, 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. It is calculated that the investment cost of the projects in Charaña and Chachacomani has to come down by 22% and 8% respectively in order to achieve zero EIRR, ie., the opportunity cost of the projects.

In the light of the possible price reduction of the wind power generation systems as well as the environmental consideration of the diesel power, the proposed three wind power projects should be considered as a viable option to be chosen in the respective three areas.

(2) Financial Evaluation

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

1) Financial Project Cost

Financial project costs are estimated to be as follows.

Financial Project Costs of the Wind Power Projects

	Unit	Unit Cost	Charana		Caripe		Chachacomani (W-M)	
			Units	Cost	Units	Cost	Units	Cost
Wind Turbine	kW	3,238	80	259,070	10	32,384	20	64,768
PV System	kW	8,746	16	139,933	4	34,983	0	0
MHP	kW	40,000	0	0	0	0	3	120,000
Inverter	kVA	600	64	38,381	8	4,798	14	8,396
Converter	kVA	216	20	4,318	0	0	10	2,159
Battery	kAh	580	44	25,520	8	4,640	4	2,320
Control House	(1/villag	11,600	1	11,600	1	11,600	1	11,600
Installation Materials	kW	800	96	76,800	14	11,200	20	16,000
Installation Work	kW	700	96	67,200	14	9,800	20	14,000
Transportation	kg	8	11,200	92,946	1,800	14,938	2,000	16,598
Secondary Distribution Line	km	4,091	-	35,885	-	11,040	-	15,000
Administration (8.8%)	-	-	-	66,145	-	11,914	-	23,834
Total Investment Cost	-	-	-	817,798	-	147,296	-	294,674

Source: JICA Study Team

The tax rates included in the financial costs are summarized below.

Taxes for Domestic Products

VAT (Value Added Tax):	13% for all the categories of products
Transaction tax:	3% for all the categories of products

Taxes for Imported Products

Effective VAT:	14.94% for all the categories of products

Import tax: 5% (wind turbine, MHP, inverter, converter)
10% (PV system)
20%* (distribution lines)

* Adjusted rate in consideration of the different products used to produce distribution lines

2) Calculation of Power Tariff to Cover the OM Costs

Minimum power tariff of the residential sector to cover the OM cost is calculated. The power tariff from the industrial sector is assumed to be 50% higher than that of the residential sector.

From the financial project costs, financial OM cost is estimated at US$9,731 in Charaña, US$1,719 in Caripe and US$4,708 in Chachacomani per year. The following table shows the minimum power tariff to cover OM cost of the projects.

Minimum Power Tariff to Cover OM Costs (US$)

	Charaña	Caripe	Chachacomani
Residential per kWh	0.12	0.15	0.22
Residential per Month	2.65	3.15	4.73

(3) Results of Financial Analysis

1) Charaña

At present, residential users of the diesel generation system pay on average Bs.30, or US$4.59 per month for three-hour service a day in Charaña. Since each residential user of the wind power project in Charaña is estimated to use 265kWh per year, the monthly payment would be US$2.65 (US$0.12/kWh x 265 kWh / 12 months), which is lower than the amount they pay at present. The wind power project in Charaña will be able to recover 100% OM cost and a part of the investment cost through power tariff. Under such condition, the wind power project in Charaña would be financially sustainable.

2) Caripe

At present, residential users of the diesel generation system pay on average Bs.34.1, or US$5.22 per month for kerosene oil and/or candles in Caripe. Since each residential user of the wind power project in Caripe is estimated to use 252kWh per year, the monthly payment would be US$3.15 (US$0.15/kWh x 252 kWh / 12 months), which is lower than the amount they pay at present. The wind power project in Caripe will be able to recover 100% OM cost and a part of the investment cost through power tariff. Under such condition, the wind power project in Caripe would be financially sustainable.

3) Chachacomani

At present, residential users of the diesel generation system pay on average Bs.30, or US$4.59 per month for kerosene oil in Chachacomani. Since each residential user of the wind power project in Chachacomani is estimated to use 258kWh per year, the monthly payment would be US$4.73 (US$0.22/kWh x 258 kWh / 12 months), 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 OM cost is to be covered by the power tariff.

7.5.7 Initial Environmental Evaluation

The study on Initial Environmental Evaluation (IEE) was conducted during the fifth field survey in May 2001. The results of the survey indicate no negative impact on the natural environment as well as the social environment as foreseen in implementing the Charaña, Caripe and Chachacomani wind power projects. The table below shows anticipated environmental impacts in/around the project sites. The expected positive impacts are as follows:

- to provide local farmers with irrigated agriculture with water pumping system in place of rain-fed agriculture,
- to develop cottage industry for job opportunity,
- to improve public services including education and public health in public facilities, and
- to improve public peace and order at night.

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

IEE Matrix for Charaña, Caripe and Chachacomani Wind Power Projects

Item			Evaluation			Remarks
			Charaña	Caripe	Chachacomani	
Social Environment	1	Resettlement	-	-	-	
	2	Economic activities	○	○	○	Irrigated agriculture with water pumping system and cottage industry will be promoted.
	3	Traffic and public facilities	○	○	○	Public facilities including schools and hospitals will be electrified.
	4	Split of communities	-	-	-	
	5	Cultural property	-	-	-	
	6	Water rights/Right of common	-	-	-	
	7	Public health condition	○	○	○	Clean water will be provided by water pumping system.
	8	Waste	-	-	-	
	9	Hazards	○	○	○	Lighting will enhance safety at night for rural life.
Natural Environment	10	Topography and geology	-	-	-	
	11	Soil erosion	-	-	-	
	12	Groundwater	-	-	-	
	13	Hydrological situation	-	-	-	
	14	Coastal zone	-	-	-	
	15	Flora and fauna	-	-	-	
	16	Climate	-	-	-	
	17	Landscape	-	-	-	
Pollution	18	Air pollution	-	-	-	
	19	Water pollution	-	-	-	
	20	Soil contamination	-	-	-	
	21	Noise and vibration	-	-	-	
	22	Land subsidence	-	-	-	
	23	Offensive odor	-	-	-	

Notes: ○ = Positive impact, - = Negligible impact, △ = Minor impact, □ = Moderate impact, × = Serious impact, ? = Not clear
This IEE study was implemented by an environmental consultant registered by the Ministry of Sustainable Development and Planification in May, 2001.
The study report of this IEE was submitted to the the Ministry of Sustainable Development and Planification through the Vice Ministry of Energy and Hydrocarbons.

Source: JICA Study Team

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

8.1 Renewable Energy Sources and Evaluation

8.1.1 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. Each energy source is explained in detail in Chapters 5 to 7.

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

Biomass is not included in this plan. Although it is better than diesel generation, biomass does affect the environment adversely. The VMEH considers biomass as an option after environmentally-friendly renewable energies and grid extension for environmental reasons. Nonetheless, Bolivia has started the study of generating electricity using biomass especially in the areas where the access to diesel fuel is difficult.[1] The department of Oruro doesn’t have potential sites of biomass energy, while there exist potential sites of biomass in Yungas in the north of La Paz. However, availability of the resources is yet to be confirmed as well as the viability of the electrification projects using biomass.

In principle, the VMEH does not consider the diesel power generation as an alternative energy source mainly for environmental reasons. In fact, it promotes replacement almost of 80% of the diesel generators with grid extension, natural gas generation and renewable energy-based generation between 2000 and 2011 by gradually abolishing the subsidy for diesel fuel by 2011.

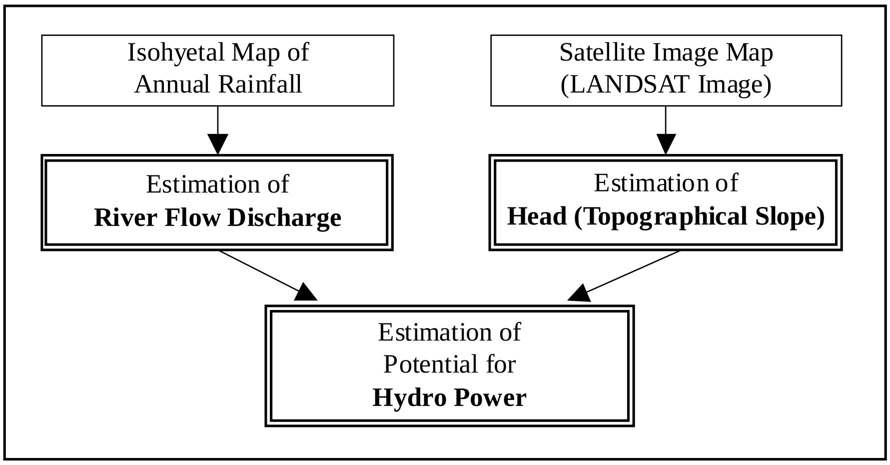
[1] At present there are three projects of biomass generation in the country. These projects use the local material for electricity generation. One is NRECA’s pilot project with 1 MW capacity in Beni using peanuts shells as energy source. Another project is in Pando, which combines diesel and biomass to generate 50 kW electricity, and the last one is in Riberalta -Beni, both under study.

The proposed rural electrification plan of 2002-2011 is formulated using the renewable energy sources micro-hydro, wind power and PV in combination with the grid line extension.

8.1.2 Potential Energy Resources

(1) Hydro Power Potential

To identify hydro power project, potential for hydropower in La Paz and Oruro was reviewed and studied. The evaluation of the hydropower potential is made through the following procedure.



Hydropower potential was measured by quantity of discharge/river flow and available head. For evaluating quantity of discharge isohyetal map of annual rainfall was used, while a satellite map was used for estimating available head.

Maps shows the estimated hydropower potential in the departments of La Paz and Oruro, shown in Figures 8.1 and 8.2.

As indicated in the map, a high potential area for hydropower is located along the northwest - southeast mountain corridor know as the "Cordillera Oriental de Los Andes" in the department of La Paz, while the potential of the hydro power in the department of Oruro is low and its high potential area is quite limited.

(2) Wind Power Potential

Wind data monitored by the SENAMHI is not reliable because the monitoring system collected wind data manually only three times a day. Besides this, the data collected at the airports could not be provided for the study. Therefore, the number of reliable wind data in the project area is quite limited although more than several hundreds of data points are necessary for preparing a complete wind map for all over La Paz and Oruro.

Under this situation, the wind energy potential map was prepared preliminarily on the basis of the wind data collected throughout this study and available topographic data as presented in Figures 8.3 and 8.4.

This wind potential map indicates a high wind potential area where estimated annual average wind speeds exceed 4.0 m/s, and the number in the circle shows annual average wind speed at 20 meters above ground level on the map. The result shows that the wind potential area in Oruro is larger than that of La Paz. The wind potential is especially high in west side of Oruro and southwest area of La Paz. The population of non-electrified villages in the high wind potential area of La Paz is larger than that of Oruro.

(3) PV Power Potential

Solar radiation data was collected from the three data loggers installed at selected PV sites. Additional, data on radiation in La Paz and Oruro was collected by 9 monitoring systems installed for the wind monitoring. To check and confirm the PV potential in La Paz and Oruro, average of the radiation for each station was estimated, on the basis of which classification of PV potential was made in accordance with the following criteria:

- First band: average radiation is over 6.5 kWh / m^2 day
- Second band: 6.0 to 6.5
- Third band: 5.5 to 6.0
- Fourth band: less than 5.5

Though the available records for solar radiation are quite limited, it is widely recognized that radiation levels are high in the north-east direction which continues along the south-west direction. The range of radiation is 3.5 kWh/m^2 to a maximum of 7.5 kWh/m^2 in La Paz and Oruro.

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

As indicated in the map, potential for PV power is very high in Bolivia and Oruro has much more potential for PV than La Paz. About 90% of Oruro department belongs to 2nd band, while one third of La Paz located in the northern part of the department belongs to 4^{th} band. However, as the main residential area located in the southern part of the department belongs to 1^{st} -3^{rd} band, La Paz is considered to have substantial potential for PV.

8.1.3 Cost Comparison of Renewable Energy Sources

Both economic and financial costs of generating electricity using three renewable energy sources (PV, micro-hydro and wind) as well as that of a grid line extension and a diesel power were compared. The costs used in the analysis are based on the following assumptions and not based on the actual costs of particular projects.

1) Electricity is supplied to a village of 100 households.
2) Installed capacity and annual electricity generation/consumption of each energy source are as follows:

Installed Capacity and Annual Electricity Generation/Consumption

	Grid Extension	PV	MHP	Wind	Diesel
Installed Capacity		55W x 100 HH	30 kW	50 kW (15 kW Wind/ 5 kW PV)	30 kW
Annual Electricity Generation/Consumption (kWh/Y)	87,600	70 kWh/Y x 100HH	87,600	87,600	87,600

Source: JICA Study Team

3) For the grid line extension, the primary distribution line is assumed to be 20km long while the secondary line is 3km long. In case of the micro-hydro and wind

power, 3km of the primary distribution line and 3km of the secondary line are used. Diesel power require only 3km of the secondary line.

4) Costs without taxes and subsidies are used as the economic costs.

5) Exchange rates used for the analysis are as follows:

1US$ = ¥120.5 = 6.53 Bs.

Based on the above assumptions, the economic costs of five alternative energy sources (grid extension, PV, micro-hydro power, wind power and diesel) are calculated as presented in Tables 8.1 to 8.5.

The results of the analysis are summarized in the table below. Among the renewable energies, micro-hydro is the most economical, followed by wind power and PV. Grid extension is the most economical energy source based on the present economic and financial cost analyses.

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

8.2.1 VMEH's Policy

Although the VMEH promotes renewable energy-based generation in the potential areas identified , the majorityofrural electrification initiatives are still been done through grid extension because of its cost advantage as viewed in 8.1.3

The VMEH considers the optimum cost of grid extension to be around US$ 700 per household (HH), to US$ 1,200/HH at maximum. If the cost is over US$ 1,200/HH, it recommends to lower the costs by changing the technology. . Electrification projects by micro-hydro power and wind power are promoted in potential areas at less than US$ 1,200/HH but permissibly at higher costs due to very low operation and maintenance costs.

As already mentioned in Chapter 8.1.1, diesel power generation is not considered as an alternative energy source mainly for environmental reasons. The VMEH is currently supporting policy that should replace 80% of existing diesel generation with grid extension and renewable energy-based generation between 2000 and 2011 by gradually abolishing the subsidy for diesel fuel by 2011.

Based on the VMEH's policy and the results of the cost comparison in 8.1.4, it is assumed that rural electrification plans of La Paz and Oruro will be carried out principally through grid extension and will be complemented by renewable energies such as micro-hydro, wind and PV. Allocation of each energy source-based project is explained in the following sections.

As already discussed in Chapter 3.1, the VMEH expects more active participation on the part of 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.

8.2.2 Rural Electrification Investment

(1) Total Investment for Rural Electrification

Progress of rural electrification for La Paz and Oruro depends on the allocated annual investment amount. As the total framework for the electrification, annual investments for rural electrification for 2002 both in La Paz and Oruro are 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[2].

Estimate of Annual Investment for Rural Electrification in 2002

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

(2) Investment by Energy Source

The majority of the investments for rural electrification will continue to be allocated to grid extension. In La Paz, 65% of the total investment for rural electrification is

[2] Estimated GDP growth rate per capita of Bolivia by PRSP (Poverty Reduction Support Program) of the World Bank

expected to be allocated for grid extension during 2002-2006 and 60% during 2007-2011 with the remaining allocated to the renewable energy-based generation. In Oruro, 70% of the total investment for rural electrification is to be allocated for grid extensions during 2002-2006 and 60% during 2007-2011 with the remaining allocated to electricity generation with renewable energies.

Average investment per household by energy source during 2002-2011 is assumed to be as follows.

Average Investment per Household by Energy Source (US$/HH)

	La Paz	Oruro
Grid Extension	1,000	1,000
PV	800	800
MHP	900	1,800*
Wind Power	4,200	3,000

* Includes industrial uses.
Source: VMEH and JICA Study Team

8.2.3 Plan Formulation of Renewable Energy Development and Grid Extension

(1) Micro-hydro Power and Wind Power

Micro-hydro and wind power are resource-oriented energies in principle. Development of these energies, therefore, is to be planned in the areas where the power potential exists. Through the analysis of the collected data on hydrology and wind, formulation of development projects for micro-hydro and wind power were carried out using the following process:

1) Evaluation of potential areas for micro-hydro power and wind power
2) Identification of candidate sites
3) Plan formulation/review of the existing plan in due consideration of the demand
4) Exclusion of projects located in the areas where grid line exist or will be installed in the near future
5) Preliminary cost estimate of the candidate projects
6) Selection of priority projects through economic comparison with grid extension

7) Prioritization of the selected projects for implementation

Details of the plan formulation of micro-hydro power and wind power are presented in the following sub-chapter.

The proposed projects of micro-hydro power and wind power are incorporated in the Implementation Plan for Rural Electrification (2002-2011) if the total amount of investment is within the estimated amount for renewable energies.

(2) PV Power

Since the energy costs of PV systems are the most expensive among renewable energies, installation of PV was planned only in the isolated areas where no other technology are available and outside of the grid extension plan in future. Through the analysis of monitoring data and analysis of the grid line priority, identification of candidate sites were made in the following manner:

1) Evaluation of the potential area for PV
2) Selection of candidate sites for PV from the isolated areas where no grid line will be extended in future.

Since micro-hydro and wind were given high priority for implementation among renewable energies, the number of PV projects was determined by the remaining amount of investment after the allocation to the micro-hydro and wind power.
Details of the plan formulation for PV are presented in the following sub-chapter.

(3) Grid Extension

As explained earlier, the grid line extension will still the main strategy for rural electrification in Bolivia. Since the expansion plan beyond 2003/2004 has not been established yet, future projections have been made using the following process:

1) Preparation of the existing grid line map as of 2001
2) Projection of extension during 2002-2006 on the basis of allocated budget and plans of the VMEH and two prefectures
3) Projection of extension during 2007-2011 based on the priority analysis of related cantons and the projected grid extension map of 2006

Since the allocated amount for investment is predetermined, only the projects, which total costs are within the allocated s budget for grid extension were included in the Implementation Plan for Rural Electrification.

8.3 Rural Electrification Plan (2002-2011)

8.3.1 Micro-hydro Power Development Plan

(1) Formulation of Candidate Projects

Identification of candidate micro-hydro power projects was made on the basis of hydropower potential maps and available micro-hydro power inventory. The available inventory of micro-hydro power was firstly reviewed and was modified using collected information and results of the field investigation and discharge observation conducted during the field surveys.

Since the proposed micro-hydro power plants will be used for rural electrification basically for isolated power generation, the projects which plan to supply electricity in the areas with the existing grid or grid line to be connected in the near future were excluded from the candidate list.

Most of the main figures (installed capacity, number of beneficiaries, etc.) for the identified micro-hydro power plants are the same ones as originally estimated. But, some modification was made taking into account the results of the field survey.

(2) Selection of Priority Projects

The selection of priority projects for micro-hydro power plants, was made based on the cost of the candidate micro-hydro, that is competitive against that of the grid line (if connected) or not. As indicated in the cost comparison of alternative energies, the grid extension is the most economical.

Only the hydropower projects which are more economical 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. This is in line with the VMEH policy, that plans to explore renewable energies for the rural electrification, if they are economical.

The cost comparison between candidate micro-hydro power projects and grid extension was made using the energy cost (US$/kWh).

The priority micro-hydro power projects were selected only if the energy cost was competitive to that of grid extension.

Through this, priority projects of the micro-hydro power for rural electrification were finally selected; 31 projects in La Paz and 3 projects in Oruro as summarized in Table 8.6. The installed capacities of the priority projects are 2,316 kW in La Paz and 102 kW in Oruro. The location map of the selected priority projects is shown in Figures 8.7 and 8.8.

(3) Stage-wise Implementation of the Priority Projects

For ranking the selected priority micro-hydro power projects, the following criteria are applied:

- Distance from the existing grid
- Comparative investment cost: cost of grid extension / cost of micro-hydro power
- Beneficiary household size of micro-hydro power
- Project maturity

Applying the above criteria, scores were estimated for all the selected priority projects.

Based on the result of the ranking study, 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

Capacities are planned to be 2,316 kW with the beneficiaries of 7,730 households in La Paz. In Oruro, the capacity to be installed is rather small of 102 kW . 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.

8.3.2 Wind Power Development Plan

(1) Formulation of Candidate Projects

In this study, the wind power was planned as an independent energy source in the isolated areas where there is wind power potential, in principle. For identifying candidate projects for wind development, review of the wind potential map was made together with monitored wind data.

After this review, potential sites for wind power were selected using the following criteria:

1) the community/canton located in the high wind potential area (from wind potential map)
2) the community/canton having the population over one hundred
3) the community/canton where no grid line extends or will extend within foreseeable future

As for the candidate sites, 12 sites in La Paz and 5 sites in Oruro were selected. 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 through which development plan for each site was formulated. Most of the formulated wind power development projects are hybrid systems 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 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 were selected in Oruro with the installed capacity of 135 kW. Details of the selection are presented in Table 8.7 and the selected priority projects are summarized below. Location of the priority projects is presented in Figure 8.9 and 8.10

Selected Wind Power Development Projects

Department	NO.	Canton	Capacity of System (kW)	Objective HHs	Distance from nearest grid (km)	Economic Cost (USD)	Financial Cost (USD)	Selected Plan
La Paz	1	OKORURO	36	48	100	259,000	305,000	Wind/PV
	2	CHARANA	96	150	80	699,000	811,000	Wind/PV
	3	CHINOCABI	26	44	96	204,000	241,000	Wind/PV
	4	E.ABAROA	22	32	60	155,000	182,000	Wind/PV
	5	GREAL. PEREZ	22	30	44	154,000	181,000	Wind/PV
	6	LADISLAO CABRERA	22	34	74	155,000	182,000	Wind/PV
	7	RIO BLANCO	24	36	94	178,000	209,000	Wind/PV
	8	CATACORA	56	74	46	375,000	440,000	Wind/PV
	9	PAIRUMANI GRANDE	36	46	50	258,000	304,000	Wind/PV
	10	POJO PAJCHIRI	46	60	46	313,000	367,000	Wind/PV
Oruro	1	CARIPE	14	30	64	125,000	145,000	Wind/PV
	2	LAGUNAS	38	62	88	282,000	332,000	Wind/PV
	3	COSAPA	60	146	72	446,000	525,000	Wind/PV
	4	CHACHACOMANI	23	70	100	272,000	292,000	Wind/MPH

Source: JICA Study Team

(2) Priority of Project Implementation

The priority of implementation of the wind power projects was determined using the following criteria.

1) Distance from the grid
   Higher priority was given to further distance from the grid.

2) Size of households
   Higher priority was given to larger households of the target community.

3) Investment cost per household
   Higher priority was given to smaller investment cost per household

4) Preparedness of the project
   Higher priority was given to the project with feasibility study or design

Using the above criteria, priority of the project implementation was determined as presented below.

Result of Priority Selection

Department	No.	Canton	Distance from Grid	Size of objective HH	Investment Cost US$/HHs	Project Preparation	Total Score	Rank
La Paz	1	OKORURO	1	2	2	3	8	3
	2	CHARAÑA	1	1	1	1	4	1
	3	CHINOCABI	1	2	1	3	7	2
	4	E.ABAROA	2	3	1	3	9	5
	5	GREAL. PEREZ	3	3	2	3	11	9
	6	LADISLAO CABRERA	2	3	1	3	9	5
	7	RÍO BLANCO	1	3	1	3	8	3
	8	CATACORA	3	2	1	3	9	5
	9	PAIRUMANI GRANDE	3	2	2	3	10	9
	10	POJO PAJCHIRI	3	2	2	3	10	5
Oruro	1	CARIPE	2	3	1	1	7	2
	2	LAGUNAS	1	2	1	3	7	4
	3	COSAPA	2	1	1	3	7	2
	4	CHACHACOMANI	1	2	1	1	5	1

Source: JICA Study Team

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:

- Phase I period (2002-2006), seven wind power projects, four in La Paz and three in Oruro with the installed capacity of 279 kW
- Phase II (2007-2011). six in La Paz and one in Oruro were planned with the installed capacity of 242 kW

Total investment costs for the wind power projects were $2.1 million and $1.6 million during Phase I and Phase II, respectively. Details of the stage-wise development of the wind power projects are presented in the following table.

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

8.3.3 PV System Development Plan

(1) Selection of PV Priority Areas

As indicated in the alternative cost comparison, the energy cost of PV system is the most expensive among the renewable energy sources. Application of PV system is, therefore, confined to the isolated areas, in principle, where no other renewable energy sources is available.

However, there are many appropriate sites for the PV system in due consideration of the topographical and demographic situation, and high PV potential of Bolivia. For formulating a PV development plan to be included in the Implementation Plan for Rural Electrification, priority sites for PV are to be selected using the following criteria.

1) Sites not covered by grid line
   Sites are far from the existing grid line and outside the expansion plan within the foreseeable future.

2) Sites with low population density
   Sites having lower population density with scattering residence

3) Sites with lower Basic Human Needs indicator
   Sites where BHN are much required.

Based on the above criteria, the priority sites for the PV system were selected using the priority map of grid extension prepared in the succeeding subsection (8.3.4 Grid Extension Plan). As indicated in Figures 8.13 to 8.14, 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 group are also to be 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 assuming that investment cost of PV is around US$ 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

Source: JICA Study Team

8.3.4 Grid Line Extension Plan

Since there exists no grid line extension plan beyond 2006, it was estimated and formulated as follows on the basis of the assumptions and information from the VMEH and the prefectures.

(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. List of the development projects of VMEH and two prefectures were duly incorporated. The projected grid line extension plans by 2006 are as presented in Figures 8.11 and 8.12.

(2) Grid Line Extension Plan for 2007-2011

Since there exists no grid line extension plans beyond 2006, the 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 numbers of the non-electrified cantons in 2006 are estimated at 184 in La Paz and 49 in Oruro. The non-electrified cantons were evaluated, and priority ranking for the electrification was made.

1) Criteria and Scores

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 Human Needs.

40 points are given to the population density and 30 points are given to the distance from the existing grid line and Basic Needs each. Out of the three criteria, the highest points are given to the population density as the grid line extension requires relatively concentrated population to be electrified. Scores are given to each canton as specified below. The breakdown of the population density criteria for the two departments is different due to difference in dispersion of the density figures.

Population density (P: Population per km^2) (40 full points)

La Paz

a) $P \geq 50$: 40 points
b) $25 \leq P < 50$: 35 points
c) $10 \leq P < 25$: 25 points
d) $5 \leq P < 10$: 15 points
e) $1 \leq P < 5$: 10 points
f) $P < 1$: 5 points

Oruro

a) $P \geq 50$: 40 points
b) $10 \leq P < 50$: 30 points
c) $5 \leq P < 10$: 20 points
d) $1 \leq P < 5$: 15 points
e) $P < 1$: 10 points

Distance from Grid Line[3] (L: km) (30 full points)

a) $L < 10$: 30 points
b) $10 \leq L < 20$: 20 points
c) $20 \leq L < 30$: 15 points
e) $L \geq 30$: 10 points

Basic Needs[4] (BN) (30 full points)

a) BN-1 and 2 : 15 points
b) BN-3 : 20 points
c) BN-4 : 25 points
d) BN-5 : 30 points

[3] It is the shortest distance between the largest community of the canton and the nearest grid line as of 2006.

[4] Basic Needs is the same category as Poverty Magnitude used by DUF (Directorio Unico de Fondos) to classify each municipality into five categories. It is based on 1) 1997 population, 2) Unsatisfied Basic Needs. . Cantons in the Basic Need's Category 5 are the 'poorest' and require the most assistance.

2) Priority Evaluation of Cantons

Scores are given to each not-electrified canton based on the three criteria mentioned above and total scores were estimated. All the cantons are categorized into four groups from A to D according to the total scores gained. 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. Distribution of the cantons is summarized below.

La Paz

(A) TS (Total Scores) ≥ 85	:	16 Cantons
(B) 70 ≤ TS < 85	:	56 Cantons
(C) 55 ≤ TS < 70	:	72 Cantons
(D) TS < 55	:	40 Cantons
	:	184 Cantons

Oruro

(A) TS ≥ 70	:	11 Cantons
(B) 65 ≤ TS < 70	:	9 Cantons
(C) 55 ≤ TS < 65	:	15 Cantons
(D) TS < 55	:	14 Cantons
	:	49 Cantons

3) Map of Grid Line Extension Plan (2007-2011)

For the cantons with the priority A and B it assumed that those will be connected by grid line extension by 2011.

Results of the above prioritization are presented in Figures 8.13 and 8.14 as well as the projected grid extension in 2011.

8.3.5 Overall Projection of Rural Electrification

Projection of rural electrification in La Paz and Oruro departments for the years 2002-2011 was made based on the development plans for renewable energies and grid extension proposed in the preceding sections and the following assumptions.

(1) Assumptions

1) The number of rural households for the rural electrification (total number of rural households including electrified households) will change at the same rates as the past trend. As discussed in the subsection 4.4.1, the projected target numbers of rural households are as follows:

Total Number of Rural Households

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

Source: VMEH and JICA Study Team

2) Annual investment for rural electrification of La Paz and Oruro departments for the year 2002 were estimated in US$ 2.7 million and US$ 1.6 million, respectively. The annual investments will increase by 3.6% per annum till 2011[5].

3) In La Paz, 65% of the total investment for rural electrification is allocated for grid extension during 2002-2006 and 60% during 2007-2011 with the remaining going to the renewable energy. In Oruro, 70% of the total investment for rural electrification is allocated for grid extension during 2002-2006 and 60% during 2007-2011 with the remaining spent for renewable energies.

4) Average investment per household by energy source during 2002-2011 is as follows.

Average Investment per Household by Energy Source (US$/HH)

	La Paz	Oruro
Grid Extension	1,000	1,000
PV	800	800
MHP	900	1,800*
Wind Power	4,200	3,000

* Includes industrial use.

5 Estimated economic growth rate per capita of Bolivia by PRSP (Poverty Reduction Support Program)

5) Through the implementation of the proposed projects, new beneficiary households of the micro-hydro and wind power are as follows.

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

6) The number of households receiving electricity by diesel generators decreases by 80% between 2000 and 2011 as the subsidy to the diesel fuel is abolished.

7) For the estimate of electricity consumption, unit consumption rates are used as presented below. Consumption of the new beneficiaries in the first year is 50% of that of the existing beneficiaries in case of micro-hydro and wind power projects while both new and existing beneficiaries of PV consume the same amount. Annual growth rate of electricity consumption is 2.0% during 2002-2011 for all types of energy sources.

Annual Electricity Consumption per Household

Grid Line	300 kWh
PV	65 kWh
Micro-hydro Power	300 kWh
Wind Power	300 kWh
Diesel	300 kWh

Source: VMEH

(2) Results of the Projection

The results of the projection are summarized below. Details of the projection are presented in Tables 8.8 to 8.14.

1) Number of New Beneficiaries

The table below summarizes the number of households newly electrified by energy source. The numbers of total new beneficiaries are 14,212 during 2002-2006 and 17,611 during 2007-2011 in La Paz and 8,610 and 11,060 in Oruro. Details are provided in Table 8.8.

Number of New Beneficiaries by Energy Source

La Paz Prefecture

(No. of Households)

	Phaee (2002-2006)	Phae II (2007-2011)
Grid	9,517	10,484
PV	177	3,361
MHP	4,240	3,490
Wind	278	276
Total	14,212	17,611

Oruro Prefecture

(No. of Households)

	Phaee (2002-2006)	Phae II (2007-2011)
Grid	6,084	6,221
PV	2,235	4,637
MHP	45	140
Wind	246	62
Total	8,610	11,060

Source: JICA Study Team

2) Projected Rural Electrification Rates

The table below 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. Table 8.9 presents the projected rural electrification rates and Table 8.10 presents projected rural electrification investment.

Projected Rural Electrification Rates

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 Beneficiary 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 Households	62,566	61,981	60,846	59,473
Existing No. of HHs with Electricity	7,908	10,268	16,955	27,303
New Beneficiary 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 by Energy Source

Tables below show the number of total beneficiaries and breakdown by energy source. Detailed data are provided in Tables 8.11 and 8.12.

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	Total	1,209	3,141	6,883	14,010
Renewable Energy	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	Total	1,717	2,720	4,640	9,479
Renewable Energy	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. Beneficiaries of the PV are also projected to increase from 1.2% to 4.4%. The ratio of the wind power is still small in La Paz at 0.5% in 2011. 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. Meanwhile, the ratio of the micro-hydro power is expected to decrease from 4.1% in 2000 to 1.8% in 2011 as the number of total beneficiaries increases. The ratio of wind power is expected to account for 1.0% 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 is estimated as summarized below. In La Paz, electricity consumption is expected to increase from 21,377 MWh in 2002, 26,608 MWh in 2006 and then to 34,558 MWh in 2011. In Oruro, it is expected to expand from 2,874 MWh in 2002, 4,835MWh in 2006 and then to 7,951MWh in 2011. Tables 8.13 and 8.14 have more detailed data.

Estimated Electricity Consumption by Energy Source (kWh)

La Paz

		2002	2006	2011
PV	Total	59,508	75,195	335,277
	Share	0	0	0
Micro-hydro	Total	523,500	1,651,305	3,077,232
	Share	2.4%	6.2%	8.9%
Wind	Total	4,500	76,296	186,113
	Share	0.0%	0.3%	0.5%
Total Renewable Energy	Total	587,508	1,802,796	3,598,621
	Share	2.7%	6.8%	10.4%
Grid Extension	Total	20,464,808	24,598,222	30,842,007
	Share	95.7%	92.4%	89.2%
Diesel	Total	324,680	206,574	117,314
	Share	1.5%	0.8%	0.3%
Total	Total	21,376,995	26,607,591	34,557,943
	Share	100%	100%	100%

Oruro

		2002	2006	2011
PV	Total	153,091	277,961	655,583
	Share	5.3%	5.7%	8.2%
Micro-hydro	Total	109,500	133,139	197,190
	Share	3.8%	2.8%	2.5%
Wind	Total	0	67,652	110,427
	Share	0.0%	1.4%	1.4%
Total Renewable Energy	Total	262,591	478,753	963,200
	Share	9.1%	9.9%	12.1%
Grid Extension	Total	2,534,980	4,307,807	6,960,159
	Share	88.2%	89.1%	87.5%
Diesel	Total	76,117	48,429	27,503
	Share	2.6%	1.0%	0.3%
Total	Total	2,873,688	4,834,988	7,950,862
	Share	100%	100%	100%

Source: JICA Study Team and VMEH

8.3.6 Comparison and Review of the Proposed Plan

(1) Comparison with the Projected Power Demand

From the subsection 4.4.2, the projected power demand in the two departments is summarized as follows.

Power Demand (MWh/Y)

	2002	2006	2011
La Paz	48,202	52,008	54,534
Oruro	11,832	12,573	12,732

As presented in the table ‘Estimated Electricity Consumption by Energy Source’, the proposed rural electrification is to meet the following percentage of the demand by 2006 and 2011. In La Paz, 51.2% and 63.4% of the demand will be satisfied by 2006 and 2011, respectively. In Oruro, the proposed plan is expected to help satisfying 38.5% of the demand by 2006 and as high as 62.4% by the year 2011.

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%

(2) Alternative Rural Electrification Plans

The investment amount is the key factor of all the assumptions made for the rural electrification plan in subsection 8.3.5. For verifying the viability of the proposed rural electrification plan, alternative plans with different investment plans are formulated and compared.

1: Alternative Plan 1 (investment for rural electrification with 0% growth rate) To be more conservative about the outlook on the macro-economy of Bolivia and the donor nations, investment for rural electrification for both departments is assumed to stay flat from 2002 to 2011. The results are summarized in the tables below.

Alternative Plan 1 – 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	80,372	92,775
New Beneficiary HHs with Electricity	4,323	2,621	2,417	2,544
Decrease in No. of Electrified HHs by Diesel	-190	-145	-85	-43
Total No. of Rural HHs with Electricity	59,039	73,150	82,704	95,276
Rural Electrification Rate (%)	25.3%	31.4%	35.7%	41.1%

Oruro

	2000	2002	2006	2011
Total No. of Rural Households	62,566	61,981	60,846	59,473
Existing No. of HHs with Electricity	7,908	10,268	16,328	24,259
New Beneficiary HHs with Electricity	1,023	1,678	1,486	1,717
Decrease in No. of Electrified HHs by Diesel	-44	-34	-20	-10
Total No. of Rural HHs with Electricity	8,887	11,912	17,793	25,966
Rural Electrification Rate (%)	14.2%	19.2%	29.2%	43.7%

The rural electrification rate in 2011 is expected to be 41.1% in La Paz and 43.7% in Oruro.

The table below summarizes the required amount of the fund for the two departments during the Phase 1 under the alternative plan 1. The required investment amount from the external source is estimated at US$ 6.6 million. This is below the fund arrangement plan of US$ 7.4 million (cf. subsection 8.5.2) and may be considered as a little conservative.

Alternative Plan 1 – Required Fund

(US$1,000)

	Phase I (2002-2006)	Share
Public Investment	13,168	62.8%
External Source	6,584	(50%)
Internal Source	6,584	(50%)
Private Investment	7,792	37.2%
Total	20,960	100%

2: Alternative Plan 2 (investment for rural electrification with 6% growth rate) To be more optimistic about the outlook on the macro-economy of Bolivia and the donor nations, investment for rural electrification for the two departments is assumed to increase by 6% per annum between 2002 to 2011. The results are summarized in the tables below.

Alternative Plan 2 – 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	82,189	101,931
New Beneficiary HHs with Electricity	4,323	2,792	3,383	4,830
Decrease in No. of Electrified HHs by Diesel	-190	-145	-85	-43
Total No. of Rural HHs with Electricity	59,039	73,320	85,487	106,718
Rural Electrification Rate (%)	25.3%	31.5%	36.9%	46.1%

Oruro

	2000	2002	2006	2011
Total No. of Rural Households	62,566	61,981	60,846	59,473
Existing No. of HHs with Electricity	7,908	10,268	17,397	29,682
New Beneficiary HHs with Electricity	1,023	1,779	2,053	3,075
Decrease in No. of Electrified HHs by Diesel	-44	-34	-20	-10
Total No. of Rural HHs with Electricity	8,887	12,013	19,431	32,747
Rural Electrification Rate (%)	14.2%	19.4%	31.9%	55.1%

The rural electrification in 2011 is expected to be 46.1% in La Paz and 55.1% in Oruro.

The next table summarizes the required amount of the fund for the two prefectures during the Phase I under the alternative plan 2. The required amount of investment from the external source is estimated at US$ 7.8 million, which is larger than the estimated fund arrangement plan of US$ 7.4 million for the Phase 1 as presented in subsection 8.5.2.

Alternative Plan 2 – Required Fund

(US$1,000)

	Phase I (2002-2006)	Share
Public Investment	15,620	62.4%
External Source	7,810	(50%)
Internal Source	7,810	(50%)
Private Investment	9,422	37.6%
Total	25,042	100%

Based on the above review on alternative plans, the proposed rural electrification plan is considered to be the most adequate one in view of the fund requirement and the needs of the two prefectures.

8.4 Implementation Structure

After reviewing the existing organizations for implementation, and based on the PV pilot project, the following implementation structure is proposed for sustainable development of rural electrification by renewable energy.

8.4.1 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 this policy is going to strengthen municipalities in line with the trend of PRSP. However, the human resources of municipality is limited. The municipality is to have technical assistance on management of projects from the private sector and NGOs.

After taking the training of renewable energy development such as the PROPER 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 "know how" to conduct the implementation of this plan. There is no experience of wind power project in Bolivia. Experienced foreign consultants should be employ in the initial stage.

(1) Public-oriented

The public-oriented is that municipality as an implementing organization utilizes the FPS or FNDR funds 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 8.15 presents proposed organization for a project implementation. The role of organizations related to the project implementation is summarized as follows.

DUF (funds source)

- to evaluate, approve and finance a project plan applied by municipality

VMEH (technical support)

- to guide DUF for sectorial criteria s on rural electrification development when evaluates the project plan applied by municipality

Municipality (implementing organization)

- to give a guidance of project scheme and user's responsibilities including initial payment and monthly fee for local people
- to make an agreement with the REC/cooperative after receiving the request of the rural electrification project
- to prepare a project plan with technical support of prefecture and/or consultants/NGO, and apply for the finance to the fund
- to select a private company or NGO which manages and supervises the whole project implementation. (However, most of the municipalities have the limited capacity to manage the project implementation. Consultants/NGO is to be employed by the municipality, which provides necessary services such as selection of supplier/operator and procurement assistance and the supervision of the whole project.)

Private sector / NGOs (installation and training for operation and maintenance)

- to install the system and carry out training on the operation and maintenance for beneficiaries and technical assistants of REC/cooperative

REC/ cooperative (beneficiaries)

- to organize a rural electrification committee (REC) or cooperative after receiving the guidance of project scheme and beneficiary's responsibilities including initial payment and monthly fee through the municipality and/or consultants/NGO

- to request the rural electrification project and make an agreement with the municipality
- to provide labor force and some local materials in kind in case of the micro-hydro power and wind power projects
- to receive the training on the operation and maintenance for beneficiaries and technical assistants of REC

Prefecture (technical support or implementing organization)

- to support municipality for preparing the project plan when municipality applies the plan to DUF
- In case of a project implemented not through DUF, prefecture is to be responsible for the project implementation in cooperation with VMEH.

(2) 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 scheme is, thus, applied for relatively local people who have a capacity to pay for the PV equipment. and work as private businesses.

8.4.2 Operation and Maintenance System

(1) PV System

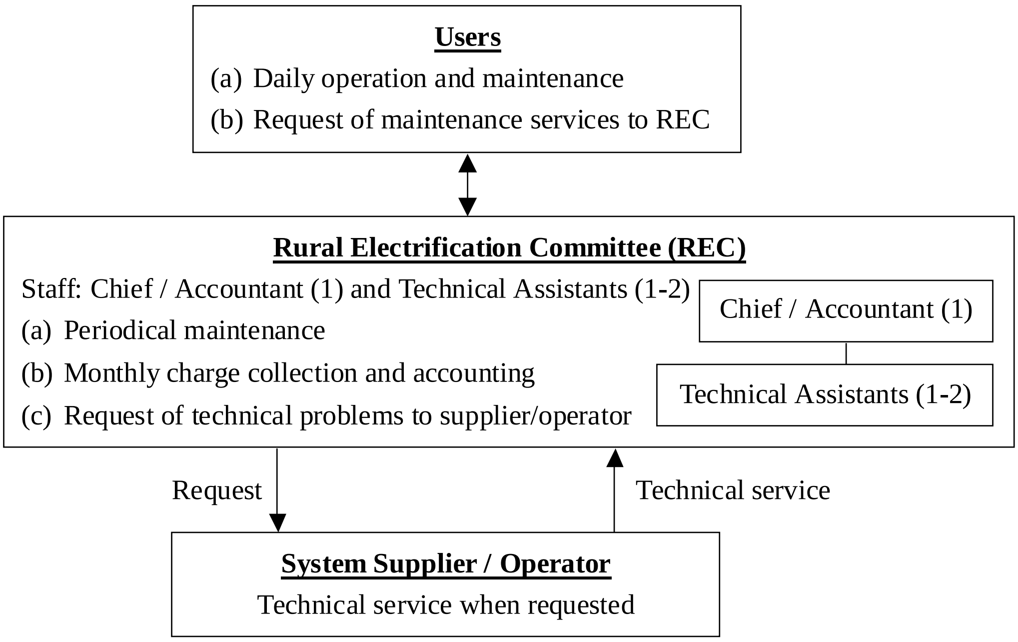
Through the experience of the PV pilot project, users and a rural electrification committee (REC) are to carry out ordinary operation and maintenance of PV system. In this sense, initial training to users and technical assistants of the REC is very important for sustainable operation and maintenance.

The training is to be conducted by the supplier or operator during the project implementation. Proposed training contents of operation and maintenance on PV is summarized below and presented in detail in the Section 6.1 of Appendix I in response to the PV pilot project.

1) Users
- to be responsible for the daily operation and maintenance
- to request maintenance services to the technical assistants of REC, if required

2) REC: Technical assistants
- to carry out the periodical maintenance
- to collect monthly charge and accounting
- to request solving major technical problems to the system supplier/operator

3) System Supplier / Operator
- to provide REC with technical services when requested (under service agreement)



(2) Micro-hydro Power and Wind Power

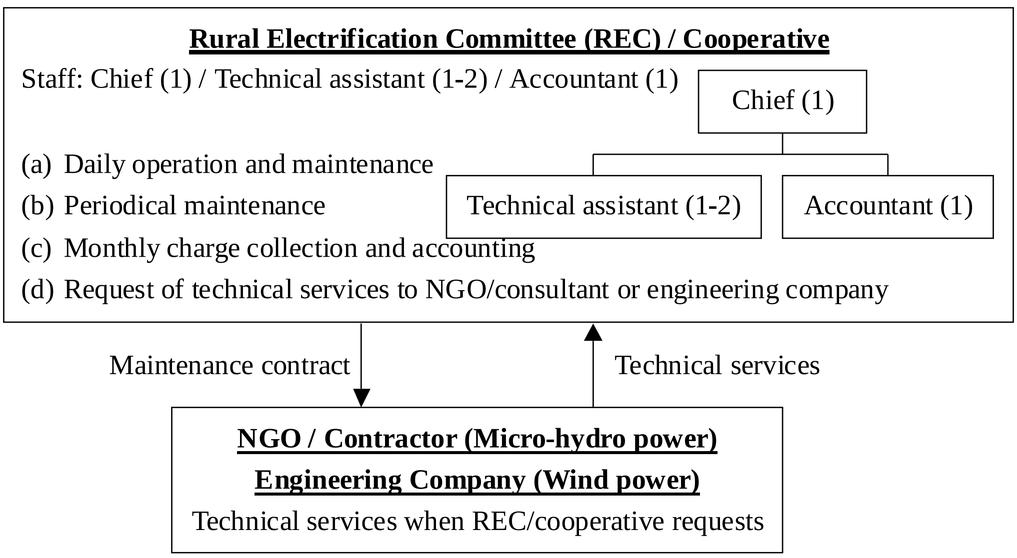
A well-organized system has already been established through cooperation with experienced NGOs and consultants for the operation and maintenance of micro-hydro power projects. A rural electrification committee (REC) or cooperative trained by NGO or consultants manages the daily operation and maintenance.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

There is no experience of wind power projects in Bolivia. The local consultants/ engineering companies is to get the technology transfer of the operation and maintenance through experienced foreign consultants 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 local 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 summarized as follows and presented in detail in the Sections 8.6.2 and 6.6.2 of Appendix II for micro-hydro power and the Sections 8.6, 6.6 and 7.6 of Appendix III for wind power.

1) REC / cooperative
   - to be responsible for the daily operation and maintenance
   - to carry out the periodical maintenance
   - to collect monthly charge and accounting
   - to request technical services to NGO/consultants or engineering company

2) NGO / consultants or engineering company
   - to provide REC or cooperative with technical services (under a maintenance service contract)



8.5 Fund Arrangement for Rural Electrification

8.5.1 Estimate of Fund Requirement

For evaluating the viability of the investment plan for the rural electrification during 2002-2011, required amount of the public fund was estimated assuming the following conditions[6].

1) For grid extension, 70% of the investment comes from the public fund.
2) For PV systems, 40% of the investment comes from the public fund.
3) For micro-hydro and wind powers, 50% of the investment is met by the public fund.

As summarized in the table below, total public fund of US$ 9.2 million and US$ 10.6 million are required in Phases I and II respectively in La Paz. In Oruro, it will be US$ 5.4 million and US$ 6.1 million respectively.

Investment Requirement in La Paz (US$1,000)

	Phase I (2002-2006)	Phase II (2007-2011)
PV[*1]	141	2,689
Public (40%)	57	1,076
Private (60%)	85	1,613
MHP	3,816	3,141
Public (50%)	1,908	1,571
Private (50%)	1,908	1,571
Wind	1,168	1,159
Public (50%)	584	580
Private (50%)	584	580
Grid	9,517	10,484
Public (70%)	6,662	7,339
Private (30%)	2,855	3,145
Total	14,642	17,473
Public	9,210	10,564
(% to total)	63%	60%
Private	5,432	6,909
(% to total)	37%	40%

[6] The investment shares are projected figures of the VMEH on the basis of the past trend.

Investment Requirement in Oruro (US$1,000)

	Phase I (2002-2006)	Phase II (2007-2011)
PV[*1]	1,788	3,710
Public (40%)	715	1,484
Private (60%)	1,073	2,226
MHP	81	252
Public (50%)	41	126
Private (50%)	41	126
Wind	738	186
Public (50%)	369	93
Private (50%)	369	93
Grid	6,084	6,221
Public (70%)	4,259	4,355
Private (30%)	1,825	1,866
Total	8,691	10,369
Public	5,384	6,058
(% to total)	62%	58%
Private	3,307	4,311
(% to total)	38%	42%

Source: JICA Study Team

8.5.2 Fund Arrangement Plan

On the basis of the estimated investment requirement and the past trend of the public investment, the required fund from the external and internal sources was calculated 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	7,277	(50%)*
Internal Source	7,277	(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 to 2001, Bolivia spent approximately US$ 70 million for energy sector from internal and external sources. Assuming 33%[7] of the total amount was allocated to La Paz and Oruro, and 44%[8] 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 between 1996 and 2000. It could be said that the two prefectures would be able to acquire sufficient amount to implement the plan between 2002 and 2006 assuming that the investment in rural electrification will continue with the similar trend of the past records.

Meanwhile, the country has been negotiating with various external sources and at this stage expects external fund of US$23 million for the energy sector between 2002 and 2005. Based on this amount for three years and applying the estimated rate of allocation to La Paz and Oruro, it is estimated that US$ 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 together with Canadian, German, Nordic official aid agencies, of which about two thirds is said to be earmarked for rural electrification. It is estimated that by applying the same rate of allocation to the two departments US$ 4.4 million may be available for the plan in the phase I.

Apart from the above funds, Bolivia will have access to HIPC II fund (US$ 1.3 billion for the next 15 years), some of which can be spent for rural electrification.

Excluding the HIPC II fund, 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 enough to cover the required amount of US$ 7.3 million for the proposed rural electrification plan.

[7] estimated figure on the basis of the accumulated investment during 1998-2000
[8] estimated figure on the basis of the accumulated investment during 1998-2000

(2) Internal Source Fund

The requirement from the internal public source (mainly tax revenues) for the plan during the phase I is estimated at US$ 7.3 million. According to the table 'Public Infrastructure Investment of Bolivia' in subsection 3.3, the combined rural electrification investment during the past five years (1996 - 2000) was US$ 23.6 million, of which approximately US$ 7.8 million is estimated to have been spent in La Paz and Oruro departments. The amount is larger than the estimated internal fund of US$ 7.3 million.

(3) Private Sector Fund

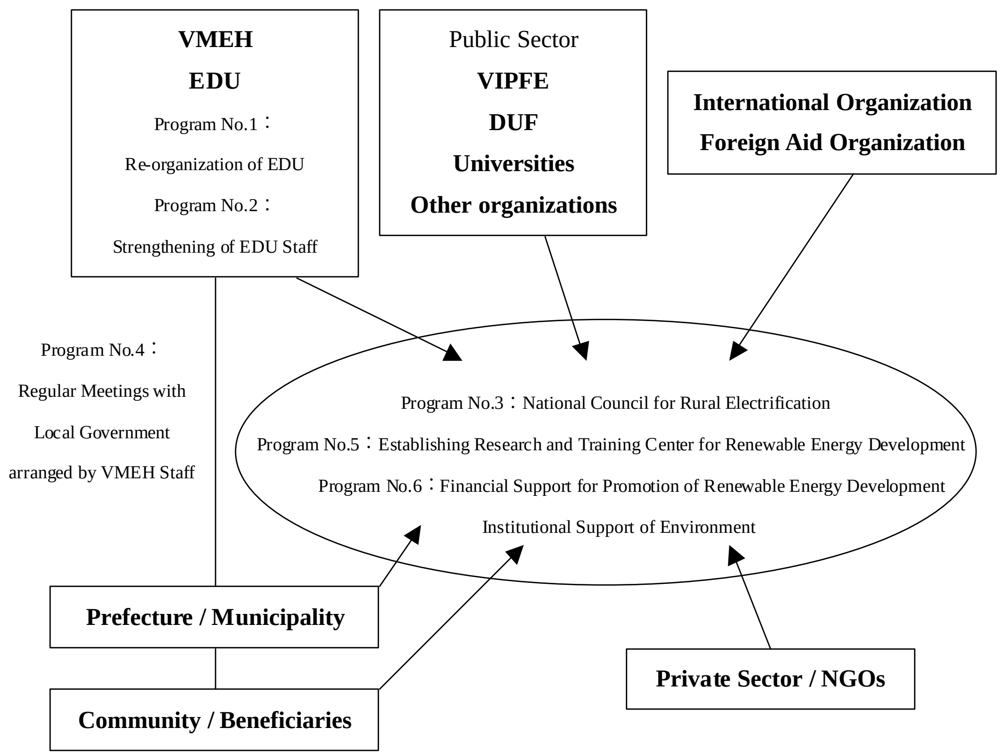
Approximately US$ 8.8 million is required from the private sector for the plan during the Phase I.

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 could be achieved without much difficulty. Development of the renewable energies, especially that of the PV, depends highly on the availability of the private sector fund.

The above analysis indicates that the proposed rural electrification plan would be implemented without serious financial difficulties and in fact, there is more room for rural electrification expansion in the future depending on the fund available from the external sources.

CHAPTER 9 INSTITUTIONAL SUPPORT FOR PROMOTING RURAL ELECTRIFICATION USING RENEWABLE ENERGY

The Vice Ministry of Energy and Hydrocarbons (VMEH) is a responsible central organization for promoting rural electrification, while prefectures and municipalities are implementing organizations for the rural electrification as well as private companies such as distribution companies and PV system suppliers. However, the institutional support has been insufficient to facilitate further rural electrification using renewable energy. The following institutional strengthening and improvement are required.



9.1 Planning Capacity Improvement

9.1.1 Present Situation

The Energy Development Unit (EDU) of the VMEH is in charge of the overall planning of the rural electrification in Bolivia. However, the total numbers of staff are only ten, including six staff of the EFP team, financed by UNDP (outside the government budget).

In spite of the decentralization of the duties as a new role of the Government even in the field of rural electrification, but, overall supervision and management by the central organization like the VMEH seems indispensable for the sustainable development of rural electrification. In view of this required function, the current organizational structure of the VMEH, particularly for the EDU seems quite weak to be strengthened further.

9.1.2 Programs for Improvement

The EDU is to be strengthened as a Unit that formulate strategies, norms and long-term plan for the rural electrification, but also for formulating a guiding for the projects . In order to strengthen this purpose it is necessary to retain a number appropriate of specialist professionals in rural electrification, and especially in renewable energy. The following two programs are proposed to improve the planning capacity in the VMEH.

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

The EDU is to be re-organized as presented in Figure 9.1 under the Director General of Energy, VMEH. The objectives of the re-organization are as follows:

- to dispose appropriate number of experts for rural electrification in new sub-sections in achieving high performance for rural electrification development, and
- to arrange experts with specific skills of renewable energy for promoting renewable energy development and organize a coordinating group of renewable energy in the central government.

The proposed unit has the following five sub-sections with the appropriate number of staff and functions:

1) Policy and Norm Section (1 staff)
   - to arrange the national policy and norm for rural electrification
2) Information and Statistics Section (2 staff)
   - to collect information and statistics and prepare inventories for renewable energy development

3) Rural Energy Development Section (2 staff)
   - to be in charge of development of rural energy including renewable energy

4) Rural Electrification Section (4 staff)
   - to facilitate implementation of projects and programs for rural electrification

5) Isolated System and SIN Development Section (2 staff)
   - to be responsible and control of the isolated system and energy development for national interconnected system (SIN) and the gas plant

Target year of the reorganization would be the fiscal year 2002 to 2003 after completion the first stage of the PRONER.

The expected resultants of the program are:

- to integrate all the information related to rural electrification and renewable energy development
- to update national rural electrification plan and monitor the progress continuously
- to strengthen and support the development of renewable energy
- to strengthen coordination function with local government and related organizations

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

Planning capacity of the EDU staff is to be strengthened by foreign experts of rural electrification as presented in Figure 9.2. The objectives of strengthening of the EDU staff are as follows:

- to redefine the planning function with respect to rural electrification and renewable energy development
- to strengthen capacity of the EDU staff through training
- to promote the technology transfer of planning to local institutions.

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 dispatched by international organizations and/or foreign aids. The program will be carried out in the fiscal year 2002 to 2003/04.

The program expects the following effects:

- to formulate policies and strategy for rural electrification as well as preparation of the indicative long term national plan by the VMEH
- to promote technology transfer of rural electrification to prefectures and municipalities

9.2 Improved Coordination with Local Government and Private Sector

9.2.1 Present Situation

More close coordination is required for promoting rural electrification between the VMEH and the local institutions. Statistics and information on current local power supply and demand is indispensable for long-term development plan. Furthermore coordination with local organizations is increased by the progress of local participation in the rural development supporting rural electrification.

Coordination with the private sector is also very important for the VMEH because rural electrification is practically implemented through grid extension by private distribution companies and private suppliers.

9.2.2 Programs for Improvement

Further coordination and cooperation with the private sector as well as public sector are to be required corresponding to the proceeding of the decentralization of government functions and the progress of the privatization trend in the power sector. The following two programs are proposed to improve the coordination system for rural electrification development.

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

VMEH as a leader of rural electrification is to set up a national rural electrification council for keeping good relationship and communication among organizations related to rural electrification as presented in Figure 9.3. Meeting of the national council is to be held twice a year. This program has the following objectives:

- to keep close coordination and cooperation among organizations related to rural electrification, and
- to facilitate rural electrification development and promote renewable energy development.

The expected participants are as follows:

1. VMEH:
    - Vice Minister (chairman)
    - Energy Development Unit (EDU) (coordinator)
2. Public organization:
    - VIPFE (financial cooperation)
    - DUF (financial cooperation)
        - FPS (financial cooperation)
        - FNDR (financial cooperation)
    - Energy unit of prefecture (rural electrification planner in department)
    - University (units for development energy)
3. International and foreign aid organizations (technical and financial cooperation)
4. Private sector (supplier, distribution / consultants / engineering company)
5. NGOs (rural electrification)

The council is expected to have the following functions:

- to share national policy/strategy for rural electrification
- to facilitate cooperation for rural electrification development
- to promote renewable energy development
- to inform progress of rural electrification in prefectures
- to discuss problems and constraints for rural electrification

Preparation for setting up the council including selection of the members will be done in the fiscal year 2001. The program is expected to start from the fiscal year 2002.

This program, if implemented, will contribute sustainable rural electrification development and promotion of renewable energy development.

(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 program has the following objectives:

- to collect countrywide information including on-going projects and demand for rural electrification
- to coordinate and assist local government staff for planning and implementation of the rural electrification and renewable energy development

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. The following agenda is to be discussed as in Figure 9.4:

1) Agenda from the EDU to local government
- to report the national policy and strategy for rural electrification
- to assist technology for rural electrification development
- to coordinate for financial arrangement

2) Agenda from local government to the EDU
- to report the current situation of on-going projects and local demand
- to report the problems and constraints of rural electrification

The program will be implemented in the fiscal year 2002.

9.3 Research and Training

9.3.1 Present Situation

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 owned by public sector and system suppliers.

9.3.2 Program for Improvement

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. The following program is proposed for the improvement.

(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. The basic plan is to cover energy development plan. In the first stage (2002-2004), the VMEH establishes the center in a universities such as UMSA which have a rich experience and the exiting equipment and facilities of renewable energy in cooperation with private sector and NGOs. In the second stage (2005-), the VMEH establishes a new center and activates the functions in response to the first stage.

Target field of the research is to include the following:

1) PV system development
2) Micro-hydro power development
3) Wind power development
4) Biomass energy development

9.4 Financial Support

9.4.1 Present Situation

Financial support has not been well established for the renewable energy development, no specific fund is available. Lack of their own fund would make it difficult to support private sector and NGOs for promoting renewable energy development.Equipment and facilities for renewable energy are still expensive for diffusing widely to rural areas without governmental financial support.

9.4.2 Program for Improvement

Functions of providing financial support of the VMEH are to be strengthened not only for the public sector such as prefecture and municipality but also for the private sector and NGOs. 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. The following program is proposed to improve the function of financial support in the central government, especially in the VMEH.

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

The following incentives are to be provided to promote rural electrification development by renewable energy for local people as well as the private sector in cooperation with the Ministry of Finance.

Component No.1: Reducing tax of equipment for renewable energy

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

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

Component No.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 such as the initial payment for installation. This component will start from the fiscal year 2003.

9.5 Environmental Impact and PCF

9.5.1 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 gas thermal was selected. The renewable energy-based electricity generation 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.

For the estimate of CO_2 emission under the alternative plan, it is assumed that thermal generation projects using natural gas will be implemented in place of the renewable energy-based projects. Emission of CO_2 by a thermal generation can be derived by the following calculation.

Emission of Carbon Dioxide (ton)

＝Calorie Necessary for Electricity Generation (2,646 kcal/kWh x Electricity Generated x $1/10^9$) x Common Energy Unit Conversion Factor (4.1868TJ/Tcal) x Carbon Emission Factor (17.2tC/TJ) x Fraction of Carbon Oxide (0.995) x 44/12

The following explains each calculation procedure.

1) Estimating the calorie necessary for generating the electricity (Tcal)
   According to the data by METI (Ministry of Economy and Trade Industry of Japan), the calorie necessary for generating one kilowatt electricity by a typical thermal generation is 2,646 kcal/kWh. One Tcal is equivalent to 10^9 kcal.

2) Converting the data to a common energy unit (TJ) using the Common Energy Unit Conversion Factor (4.1868TJ/Tcal)

3) Estimating the carbon content by using the carbon emission factor (17.2tC/TJ)
   The alternative plan assumes natural gas as the fuel for the thermal generation of electricity. According to the IPCC Guidelines for National Greenhouse Gas Inventories, the carbon emission factor for natural gas is 17.2 t C/TJ.

4) Accounting for carbon not oxidized during combustion (0.995)
   Fraction of Carbon Oxidized: According to the IPCC Guidelines for National Green house Gas Inventories, the fraction of carbon oxidized for gas is 0.995.

5) Converting the emissions as carbon to full molecular weight of CO_2 by multiplying by 44/12

The proportion of molecular weight of CO_2 to that of Carbon is 44/12.

9.5.2 Estimate of Reduction Amount of CO_2

From Tables 9.1 and 9.2, electricity consumption of the proposed renewable energy-based generation during each phase can be summarized as in the following tables.

Electricity Consumption of the Renewable Energy-Based Generation

La Paz

(kWh/5 years)

	Phase I (2002-2006)	Phase II (2007-2011)
PV	334,152	1,123,312
Micro-hydro	5,379,067	12,415,850
Wind	190,385	701,680
Total	5,903,604	14,240,841

Oruro

(kWh/5 years)

	Phase I (2002-2006)	Phase II (2007-2011)
PV	1,069,135	2,433,525
Micro-hydro	619,577	860,629
Wind	136,207	498,718
Total	1,824,919	3,792,872

Source: JICA Study Team

Applying the above figures, emission of CO_2 by the alternative plan, or saving of CO_2 by implementing the proposed plan was calculated as follows.

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

From the above tables, reduction amount of CO_2 during the Phase I (2002-2006) and Phase II (2007-2011) are expected to amount to 4,104 tons and 9,900 tons in La Paz and 1,269 tons and 2,637 tons in Oruro, respectively.

9.5.3 Prototype Carbon Fund (PCF)

Following the environmental policy of the VMEH and international measures on environmental issues, the use of environmentally friendly renewable energy sources is to be promoted to save exhaustible energy sources and reduce carbon dioxide emissions.

The VMEH is to promote the rural electrification by renewable energy in line with the institutional supports on environmental issues such as the Prototype Carbon Fund (PCF).

The PCF was established in 2000 and being managed by the World Bank. This fund is a trust with the following strategic objectives:

(1) to demonstrate how project-based emission reductions transactions can promote and contribute to the sustainable development of developing countries,

(2) to share with the parties to the United Nations Framework Convention on Climate Change and other interested parties knowledge gained by the Trustee and Participants in the course of the Fund’s operations, and

(3) to demonstrate how the World Bank can work in partnership with the public and private sectors to mobilize new resources for its borrowing member countries while addressing global environmental concerns.

The PCF has just started to apply for a few countries. However, this fund is to be considered as one of the potential fund source for promotion of the rural electrification in Bolivia.

CHAPTER 10 RECOMMENDATIONS

Through the survey and study conducted during 1999 – 2001, appropriate scheme for operation and maintenance for PV system was reviewed and the priority projects for micro-hydro, wind and PV system were identified. The feasibility of the selected projects, two micro-hydro and three wind power was also confirmed in this study. All the results of the study were incorporated into the proposed Implementation Plan for Rural Electrification for which viability was reviewed and confirmed by the projected fund allocation.

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 in technology development and promotion of wind power.

(Others)

5) The VMEH is to transfer the wind data and hydrological data to SENAMHI for integrated management of the meteorological and hydrological information.

10.2 Recommendation on Institutional Strengthening

As indicated in Chapter 6, institutional support is indispensable for realizing the proposed implementation plan for rural electrification. The following actions are to be taken for the sustainable development.

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 which has an insufficient capacity of project implementation under the PRSP.

Attachment 1

Member of Coordinating Group, Working Group and JICA Study Team

(1) Member List of Coordinating Group

1. Juan Mendoza	Chief, Energy Development Unit, VMEH
2. Carlos Gordillo	Consultant, Energy Development Unit, VMEH
3. Renan Orellana	Consultant, Energy Development Unit, VMEH
4. Ramiro Ostria	Director, Department of Infrastructure, La Paz Prefecture
5. Felix Castañares	Director, Department of Infrastructure, Oruro Prefecture

(2) Member List of Working Group

	(Technical Field)	(Institution)
1. Clemente Rojas	Social survey	La Paz Prefecture
2. Carlos Lopez	PV system	La Paz Prefecture
3. Mario Eguez	Wind power	La Paz Prefecture
4. Marcelo Portillo	Micro-hydro power	La Paz Prefecture
5. Jorge Guzman	PV system	Oruro Prefecture
6. Oswaldo Guzman	Social survey	Oruro Prefecture
7. Ramiro Pinto	Wind power	Oruro Prefecture
8. Jorge Castillo	Micro-hydro power	Oruro Prefecture

(3) Member List of JICA Study Team

1. Toshikazu Tai	Team Leader / Rural electrification planner
2. Hidehito Wakabayashi	PV power development planner
3. Masafumi Ikeno	Sociologist / Institutional planner
4. Kiyoshi Hirata	Micro-hydro power development planner
5. Tsutomu Dei	Wind power development planner
6. Kinuyo Fukuda	Economic analyst / Financial planner

TABLES

Table 4.1 Inventory of Existing Micro Hydro Power Project in La Paz and Oruro

(Completed and Under Construction)

La Paz

No.	Name of Project	Departamento	Province	Municipality	Canton	River Name	MHP No.of Benef. (HH)	No.of Benef. (Popuration)	Year Completed	Plant Discharge (l/s)	Efective Head (Net) (m)	Installed Capacity (kW)	Investment Cost (MHP) (US$)	kW Cost (MHP) (US$/kW)	Anneal Energy (kWh/Year)	Annualized Investment + OM Cost per kWh (MHP) (US$/kWh)	Investment Cost per Household (MHP) (US$/HH)	Conducted by
							a	-	-	b	c	d	e	f =e/d	g =(d*8*365*0.95)	h =(CRF + OM 1.8%) *e / g	i =e / a	
1	La Asunta	La Paz	S. Yungas	La Asunta	La Asunta		200		1996	750	34	150	385,000	2,567	394,200	0.18	1,925	Munc. La Asunta, Prefectura La Paz
2	Chamaca	La Paz	S. Yungas	La Asunta	Chamaca		355			500	26	70	147,000	2,100	183,960	0.15	414	Munc. Asunta, Comunidad, UMSA-IHH
3	Yarija-Chajro	La Paz	S. Yungas	Chulumani	Yarija Chajru		52			180	25	20	125,000	6,250	52,560	0.45	2,404	Munc. De Chulumani, Prefectura La Paz
4	Velo novia	La Paz	S. Yungas	Yanacachi	Villa Aspiasu		10					0.5	1,500	3,000	1,314	0.21	150	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura
5	Chimpa	La Paz	S. Yungas	Chulumani			1,028					20	64,000	3,200	55,480	**0.16**	62	Munc. De Chulumani, Prefectura La Paz
6	Covendo	La Paz	S. Yungas	Palos Blancos	Covendo	Rio Covendo	1		1948		16	2.7	8,100	3,000	7,096	0.21	8,100	Church of Covendo
7	La Cascada	La Paz	S. Yungas	Palos Blancos	La Cascada		80	400	2000	80	68.7	35	94,711	2,706	91,980	0.19	1,184	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura
8	Flor de Mayo	La Paz	S. Yungas	Irupana	Irupana		200		2001	40	58	15	30,000	2,000	39,420	0.14	150	UNDP, UMSA-IHH, Prefectura Alcadia
9	Unduavi	La Paz	Nor Yungas	Coroico	Unduavi	Rio Unduavi	35			150	15	15	25,000	1,667	39,420	0.12	714	UMSA-IHH
10	Quenallata	La Paz	Nor Yungas	Coroico	Quenallata		15					0.3	900	3,000	788	0.21	60	UMSA-IHH
11	Santa Rosa de Quilo Quilo	La Paz	Nor Yungas	Coroico	Mururata		80			80	70	40	72,600	1,815	105,120	0.13	908	Munc. De Coroico, Proy. Ecotecnologico, UMSA-IHH
12	Challa	La Paz	Nor Yungas	Coroico	Challa		119	600	2001	100	80	51	83,850	1,644	134,028	0.12	705	NF-Alisei (Italia), EU, Alcaldia, Munic., Prefectura
13	San Pedro	La Paz	Caranavi	Caranavi	Choro	Rio San Pedro	50		1998	33	150	16	43,164	2,698	42,048	0.19	863	Comunidad de San Pedro, PROPER, UMSA-IHH
14	Choro	La Paz	Caranavi	Caranavi	Choro		66			10		24	72,000	3,000	63,072	0.21	1,091	UMSA-IHH
15	Chojña	La Paz	Caranavi	Caranavi	Chojña		60		2000	60		15	86,000	5,733	39,420	0.41	1,433	Munc. De Caranavi, UMSA-IHH
16	Colonia 18 de Mayo	La Paz	Caranavi	Caranavi	Colonia 18 de Mayo		50		2000	30		12	54,000	4,500	31,536	0.32	1,080	Munc. De Caranavi, UMSA-IHH
17	Taypiplaya	La Paz	Caranavi	Caranavi	Taypiplaya		200		2001			200	280,000	1,400	525,600	0.10	1,400	Munc. De Caranavi, Prefectura La Paz
18	San Isidro Uyunense	La Paz	Caranavi	Caranavi	Uyunense		140	720	2001	100	71	40	63,300	1,583	105,120	0.11	452	NF-Alisei (Italia), EU, Alcaldia, Munic., Prefectura
19	San Pablo	La Paz	Caranavi	Caranavi	San Palblo		120	750	2001	80	96	40	59,250	1,481	105,120	0.11	494	NF-Alisei (Italia), EU, Alcaldia, Munic., Prefectura
20	Pongo I, II, III	La Paz	Murillo	La Paz	Zongo		20			8	50	10	30,000	3,000	26,280	0.21	1,500	UMSA-IHH, GTZ
21	Charazani	La Paz	B.Saavedra	Charazani	Charazani		100		1988			70	183,000	2,614	183,960	0.19	1,830	Munc. De Charazani, Prefectura La Paz
22	Tipuani	La Paz	Larecaja	Tipuani	Tipuani		4000					200	420,000	2,100	525,600	0.15	105	
23	Tumupasa	La Paz	Iturralde	San Buenaventur	Tumupasa	Rio Tumupasa	180			80	80	37	82,427	2,228	97,236	0.16	458	Munc. De S.Buenaventura, PROPER, UMSA-IHH
	TOTAL						**7,161**					**1,084**	**2,410,802**					

Oruro

No.	Name of Project	Departamento	Province	Municipality	Canton	River Name	MHP No.of Benef. (HH)	No.of Benef. (Popuration)	Year Completed	Plant Discharge (l/s)	Efective Head (Net) (m)	Installed Capacity (kW)	Investment Cost (MHP) (US$)	kW Cost (MHP) (US$/kW)	Anneal Energy (kWh/Year)	Annualized Investment + OM Cost per kWh (MHP) (US$/kWh)	Investment Cost per Household (MHP) (US$/HH)	Conducted by
							a	-	-	b	c	d	e	f =e/d	g =(d*8*365*0.95)	h =(CRF + OM 1.8%) *e / g	i =e / a	
1	Todos Santos	Oruro	Mejillones	Todos Santos	Todos Santos	Rio Todos Santos	100			40	50	135	2,500,000	18,519	354,780	1.32	25,000	Prefectura de Oruro
2	Condo	Oruro	Sebastian Pagado	Santiago de Huai	San Pedro de Condo		70			125	62	65	50,000	769	170,820	0.05	714	Prefectura de Oruro, PROPER
	TOTAL						**170**					**200**	**2,550,000**					

Original Sorce : CINER (Centro de Informacion de Energia Renovable, Cochabanba, NGO) & VMEH. (Updated by JICA Study Team, September 1999 & June 2000)

Table 6.1 Construction Cost of Civil, Electric and Mechanical Works for Apolo MHP (Details for Pre-F/S) (1/3)

Item		Unit	Unit Rate (US$	Pre-F/S Case (700kW)		Note
				Quantity	Amount	
Maximum Discharge Qmax				1.815		
Effective Head He				51.70		See Effective Head Calculation
Installed Capacily P				700		9.8*Qmax* He * hc , hc = 0.761
Turbine Number n (max=2)				2		
Type of Turbine				FR	Francis	
3. Civil Works						
3.1 Intake Weir						
Height H		m		1.0		Excavation height.= 1.5 - 2.5
Length L		m		21.5		
Excavation (Intake part)	(rock, with dinamite)	m^3	65.00	64.0	4,160	(L1+L2)/2*H*L = (2.3+4.1)/2*2.0*10.0
Excavation (Stop Log part)	(rock, with dinamite)	m^3	65.00	44.0	2,860	H*B*L = 0.5*8.0*11.0
Concrete (Intake part)		m^3	280	22.0	6,160	T*(B+H1+H2)*L = 0.5*(1.6+1.6+1.1)*10
Concrete (Stop Log part)		m^3	280	14.0	3,920	(Base): T*B*L=0.5*2.0*11, (Gate Post): (H*B*T)*sets = (2*0.75*0.5)*4
Reiforcemnt Bar		t	1,200	1.8	2,160	0.050*Vc
Sub Total					19,260	
3.2 Intake						
Length L		m		5.0		
Excavation	(rock, with dinamite)	m^3	65.00	44.0	2,860	(L1+L2)/2*H*L = (2.0+5)/2*2.5*5
Concrete (water way)		m^3	280	17.5	4,900	$\{(B_{outside}*H_{outside}) - (B_{inside}*H_{inside})\}*L = \{(2.0*2.5)-(1.0*1.5)\}*5 = 3.5m^2/m*5m$
Concrete (gate control tower)		m^3	280	9.0	2,520	(3.5+2.5)*0.5*3
Concrete(flood wall)		m^3	280	22.5	6,300	1/2*(9+6)*3*2*0.5
Reiforcemnt Bar		t	1,200	2.5	3,000	0.050*Vc
Sub Total					19,580	
3.3 Sand Settling Baisn						
Sub Total					0	Sand settling basin is substitute at headtank.
3.4 Headrace						
1) Open Conduit						Headrace channel (open cinduit) is not used.
Length Loc		m		0.0		
Sub Total					0	
2) Tunnnel (Free Flow)						
Waterdepth (plan)		m		0.5		
Width		m		1.2		
Height		m		1.8		H1 + H2 = 0.2 + 1.6
Length Lt		m		143.0		
Excavation	(rock, with dinamite)	m^3	600	292.0	175,200	(B*H*1/2+B*H2)*Lt = (1.2*0.2/2 + 1.2*1.6)*143
Concrete		m^3	280	66.0	18,480	(Side: T*H*2 = 0.1*1.5*2 + Bottom: T*B=0.2*0.8) * Lt
Reiforcemnt Bar		t	1,200	1.3	1,560	0.020 t/m^3 * Vc
Sub Total					195,240	

Table 6.1 Construction Cost of Civil, Electric and Mechanical Works for Apolo MHP (Details for Pre-F/S) (2/3)

	Item	Unit	Unit Rate (US$)	Pre-F/S Case (700kW) Quantity	Amount	Note
3.5	Head Tank					
	Excavation (common excavation)	m^3	9.00	600.0	5,400	(B*H)/2*W = (14*14)/2*6.0 + alfa
	Concrete (Side wall)	m^3	280	173.5	48,580	[(12+16)/2*8 + (20+21)/2*3]* T0.5 * 2set
	Concrete (Downstream side wall)	m^3	280	27.5	7,700	B*H*T = 5.0*11*0.5
	Concrete (Upstream side wall)	m^3	280	21.0	5,880	(10+4)*3*T0.5
	Concrete(Bottom)	m^3	280	145.0	40,600	(1/2*B1*H1*T1)+(1/2*B2*H2*T2) = (1/2*6*3*5) + (1/2*8*5*5)
	Reiforcemnt Bar	t	1,200	3.7	4,440	0.010*Vc
	Sub Total				112,600	
3.6	Penstock					
	Diameter Dp	m		1.11		$0.888*Qpmax^{0.376}$
	Length Lp	m		74.0		
	Excavation (common excavation)	m^3	9.00	243.0	2,187	{ 1/2*(B1+B2)*H1 + 1/2*B2*H2]*Lp = { 1/2*(2.3+3.2)*0.9 + 1/2*3.2*0.5]*74
	Concrete (Invert.)	m^3	280	20.0	5,600	{T*(B1+H)} * L = {0.1*(2.3+0.15)} * 66
	Concrete (Support anchor block)	m^3	280	6.0	1,680	(B*H*W) * set = (1.2*1.1*0.5) * 8
	Concrete (Bottom anchor block) (diverging pipe anchor	m^3	280	83.0	23,240	(B1+L1+H1)+{(B1+B2)/2*L2*H2}+(B2*L2*H3) = (2.0*1.5*1.35*1.35*1.5) + {(2+11)/2*4.5*1.35*1.5] + (11*1*1.35)
	Reiforcemnt Bar	t	1,200	2.2	2,640	0.020*Vc
	Sub Total				35,347	
3.7	Spillway					
	Average Slope i			10		
	Diameter Ds	m		0.8		$0.394*(Qpmax / i^{0.500})^{0.375}$
	Length Ls	m		65.0		
	Excavation (common excavation)	m^3	9.00	440.0	3,960	$9.87*Ds^{1.69}*Ls$
	Foundation (mix cement)	m^3	70	124.0	8,680	$2.78*Ds^{1.70}*Ls$
	Sub Total				12,640	
3.8	Power House					
	1) Foundation Works				113,780	
	Excavation (common excavation)	m^3	9.00	690.0	6,210	1/2*(H1+H2)*B1*L = 1/2*(4.5+3.0)*8 * 23
	Foundation (foundation of power hc (mix cement)	m^3	70	315.0	22,050	{1/2*(H1+H2)* B*L }*2 = {1/2*(2.0+4.0)*7.0*7.5}*2
	Concrete (RC, floorboard)	m^3	280	184.0	51,520	B*L*H = 8.0*23.0*1.0
	Reiforcemnt Bar	t	1,200	1.0	1,200	0.005*Vc
	Concrete (RC, partition wall for tailrace from two turbine	m^3	280	14.0	3,920	H*B*T = 4.0*7.0*0.5
	Concrete (RC, bottom tank)	m^3	280	98.0	27,440	Side wall: (B+L)*2*H*T + Bottom: B*L*T = (7.5+8.0)*2*4*0.5 + 8.0*9.0*0.5
	Reiforcemnt Bar	t	1,200	1.2	1,440	0.010*Vc

Table 6.1 Construction Cost of Civil, Electric and Mechanical Works for Apolo MHP (Details for Pre-F/S) (3/3)

	Item	Unit	Unit Rate (US$	Pre-F/S Case (700kW)		Note
				Quantity	Amount	
	2) Power House (Building)	L.S.			39,916	
	Wooden Window	m^2	75	10.0	750	(B*H) *set = (1.0*1.0) * 10
	Wooden Door	m^2	135	8.0	1,080	(B*H) *set = (2.0*2.0) * 2
	Loof (Calamine Cover)	m^2	23	240.0	5,520	B*L = 10*24
	Brick Wall	m^2	15	518.5	7,778	(B+L)*2*(H1+H2)/2 = (7.5+23)*3*(9+8)/2
	Covering Tile	m^2	24	165.0	3,960	B*L = 7.5*22.0
	Stuructual Steel Frame (H-shape)	m	50	194.0	9,700	H*set + B*set + L*set = 12*6 + 7.5*4 + 23*4
	Crane (chain winch, 20t)	L.S.	7,000	1	7,000	assumed
	Installation of Sanitary	L.S.	500	1	500	
	Others	L.S.			3,629	10% of Power house cost
	Sub Total				153,696	
3.9	Tailrace					
	Length	m		5.0		
	Excavation (common excavation)	m^3	9.00	180.0	1,620	1/2*H3*B2*L = 1/2*3.0*5.0 * 23
	Foundation (mix cement)	m^3	70	180.0	12,600	1/2*H3*B2*L = 1/2*3.0*5.0 * 23
	Sub Total				14,220	
4.(a)	.Electrical Works					
4.1	Turbine/Generator					
	Type of Turbine			Francis		
	Number of Turbine n	-	-	2		
	Unit Capacity per one Turbine			350		
	Unit Cost of Turbine&Generator			370,000		Fransis Turbine Made in Sweaden (TURAB) (350kW: SEK 2,000,000+40%Tax+$110,000)/unit
	Sub Total				740,000	
4.2	Transmission/Distribution Line					
	Transmission Line	km	7,000	137.60	1,011,360	plane length [km] * 105% * unit cost
	Benefit. Household	HH		1,993		
	Disrtibution Line	km	4,100	99.65	408,565	50 m/Household * 2000 HH* unit cost
	Sub Total				1,419,925	
4.3	Mechanical Works					
4.3.1	Intake Weir					
	Stop Log Gate (steel plate)	m^2	*320*	6.8	2,160	(B*L) * set = (3*0.75) * 3set
4.3.2	Intake					
	Screen	m^2	*500*	15.0	7,500	B*L = 1.5*10
	Intake Gate (Electrical Automatic Control)	t	*100,000*	1.7	170,000	1.27*(Dt/2 * Qpmax)$^{0.333}$
4.3.3	Head Tank					
	Sand Flushout Gate	pce	*3,000*	1.0	3,000	
4.3.4	Penstock					
	Tickness tp	mm		6.0		tp = { D(mm) + 400} / 800, tp >= 6 mm
	Weight	t		12.2		π * D * t * 7.85 * Lp ,
	Diameter Dp	m		1.11		0.888*Qpmax$^{0.370}$
	Length	m	500	74.0	37,000	
	Sub Total				219,660	

Table 6.2 Calculation of EIRR (Economic Internal Rate of Return) of the MHP Project in Apolo (La Paz) [Unit: US$]

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Benefit																							
Investment																							
Diesel Generator			525,000										525,000										
Automatic Transfer Switch			1,910										1,910										
Protection Box			917										917										
Building			1,500										1,500										
Transmission Lines			824,425																				
Distribution Lines			340,471																				
OM Cost																							
OM Cost of the Diesel Generator, etc.				26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391	26,391
OM Cost of the Distribution Lines				29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122	29,122
Fuel cost				446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114	446,114
Total Benefit	-	-	1,694,223	501,628	501,628	501,628	501,628	501,628	501,628	501,628	501,628	501,628	1,030,955	501,628	501,628	501,628	501,628	501,628	501,628	501,628	501,628	501,628	501,628
Cost																							
Investment																							
Preparation Workds and Access, etc.	179,667	179,667	179,667																				
Civil Works	161,633	161,633	161,633																				
Turbine/Generator	211,200	211,200	211,200																				
Transmission/Distribution Lines	394,433	394,433	394,433																				
Mechanical Works	63,133	63,133	63,133																				
Transportation	31,633	31,633	31,633																				
Administration and Engineering Service	92,800	92,800	92,800																				
OM Cost																							
Turbine/Generator				12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672	12,672
Civil Works				2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425	2,425
Transmission/Distribution Lines				29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583	29,583
Total Cost	1,134,500	1,134,500	1,134,500	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679	44,679
Balance	########	########	559,723	456,949	456,949	456,949	456,949	456,949	456,949	456,949	456,949	456,949	986,276	456,949	456,949	456,949	456,949	456,949	456,949	456,949	456,949	456,949	456,949

EIRR	19.2%

Table 6.3 Construction Cost of Civil, Electric and Mechanical Works for Tambo Quemado MHP (Details for Pre-F/S) (1/3)

Item		Unit	Unit Rate (US$)	Pre-F/S (62kW) Quantity	Amount	Note
Maximum Discharge Qmax				0.0879		
Effective Head He				99.10		See Effective Head Calculation
Installed Capacily P				62		**9.8*Qmax* He * ηc , ηc = 0.731**
Turbine Number n				1		
1. Preparetion Works						
1.1 Access Roads		m	0	100	0	
3. Civil Works						
3.1 Intake Weir						
1) Upstream						
Height H		m		0.5		
Length L		m		1.5		
Excavation		m^3	7	6.3	44	$8.69*(H*L)^{1.14}$
Concrete	Foundations	m^3	10	5.5	55	$11.8*(H^2*L)^{0.781}$
Sub Total					99	
2) Down Stream						
Height H		m		0.3		
Length L		m		1.0		
Excavation		m^3	7	2.2	15	$8.69*(H*L)^{1.14}$
Concrete	Foundations	m^3	10	1.8	18	$11.8*(H^2*L)^{0.781}$
Sub Total					33	
3.2 Intake						
1) Upstream						
Excavation		m^3	7	1.200	8	3*Dpv * 1.0
Concrete	Foundations	m^3	60	0.800	48	$\{(3*Dpv)*(2*Dpv) - Dpv^2\} * 1.0$
Sub Total					56	
2) Downstream						
Excavation		m^3	7	1.200	8	3*Dpv * 1.0
Concrete	Foundations	m^3	60	0.800	48	$\{(3*Dpv)*(2*Dpv) - Dpv^2\} * 1.0$
Sub Total					56	

Table 6.3 Construction Cost of Civil, Electric and Mechanical Works for Tambo Quemado MHP (Details for Pre-F/S) (2/3)

Item		Unit	Unit Rate (US$)	Pre-F/S (62kW) Quantity	Pre-F/S (62kW) Amount	Note
3.4 Headrace (PVC[Rib-Loc] Pipe)						
Length Lpv		m		2,310		
Diameter Dpv		m		0.40		
Diameter Dpv		m		0.40		
Water Area A				0.079		0.492 *Dpv^2, water depth / Dpv = 0.6
Hyreauric Radius R				0.111		0.2776 *Dpv, water depth / Dpv = 0.6
n_value n				0.010		
Slope				0.002		
Discharge				0.0813		$A/n * R^{2/3} I^{0.5}$
Check				-0.0066	OK	
PVC (Rib-Loc) Unit Cost Cpv		m		23.7		(D<600: 0.0527*D - 0.1179 ,0.0855*D+0.0217) * 1.13Tax
PVC Pipe Setup Cost		m	6	2,310	68,607	Lpv*(Cp+6$/m)
Excavation		m^3	7	1,247	8,732	L*B*H = Lpv*(Dpv+0.1+0.1)*(Dpv+0.2+0.3)
Concrete	Foundations	m^3	60	8.9	534	2*Dpv * 0.3 * 0.4 * Lpv / 25
Sub Total					77,873	
3.5 Head Tank						
Storge Volume				225		
Storage Wall Tickness				0.30		
Storage Slab Tickness				0.50		
Excavation		m^3	7	511.2	3,578	142m^2*6.0m *60%
Concrete	RC(w/o R.bar)	m^3	60	268.5	16,110	142m^2*0.5m*2 + 25.3m^2 *5m
Reiforcemnt Bar		t	732	13.7	10,028	0.051*Vc
Sub Total					29,717	
3.6 Penstock						
Diameter Dp		m		0.36		0.876*$Qpmax^{0.367}$
Length Lp		m		300		
Excavation		m^3	7	21.2	148	L*B*H = Lp*(Dp+0.1+0.1)*(Dp+0.15+0.2)
Concrete		m^3	60	10.8	648	3.1m^2*1.36m + 3.5m^2 *1.0m + 2.3m^2 *1.36
Reiforcemnt Bar		t	732	0.2	146	0.018*Vc
Sub Total					943	

Table 6.3 Construction Cost of Civil, Electric and Mechanical Works for Tambo Quemado MHP (Details for Pre-F/S) (3/3)

Item		Unit	Unit Rate (US$)	Pre-F/S (62kW)		Note
				Quantity	Amount	
3.7	Spillway					
	L	m		20		
	B	m		0.5		
	H	m		0.5		
	Excavation	m^3	7	11.2	78	(B+0.15m*2)*(H+0.2m)*L
	Concrete	m^3	60	6.2	372	{(B+0.15m*2)*(H+0.2m) − (B*H)}*L
	Sub Total				450	
3.8	Power House					
	Excavation	m^3	7	27	189	4.2m²*6.5m
	Concrete	m^3	13	55	715	9.7m² * 6.5m − (3.1m² * 2.0m + 0.7m² * 1.3)
	Reiforcemnt Bar	t	732	0.0	0	Mass concrete
	Building	L.S.	1,000	1	1,000	
	Sub Total				1,904	
3.9	Tailrace					
	Length	m		5		
	Excavation	m^3	7	0	0	
	Concrete	m^3	10	6.2	62	1.0m²*(3m+4m)/2 +0.25m² *1.0m *2 +0.55m²*4m
	Reiforcemnt Bar	t	732	0.0	0	Mass Concrete
	Sub Total				62	
4. Mechanical Works						
4.1	Head Tank					
	Sand Flushout Gate	pce	2,000	1	2,000	0.910*Od^0.813,Qd = 0.05m³/s
4.2	Penstock					
	Diameter Dp	m		0.36		0.876*Qpmax^0.367
	Length Lp	m		300.0		
	PVC Unit Cost	m		91.9		(0.001528231*D^2−0.04373631*D+1.387783)/2
	PVC Pipe setup cost	m	1	300.0	27,870	
	Sub Total				29,870	
5.Electrical Works						
	Unit Cost of Turbine/Generator			600		<10kW:1000$/kW, <50kW:770, <100kW:600, <200: 500, <300: 300
	Turbine/Generator	kW		62	37,200	US$47,000 / 70kW
	Installation and Equipment Test	LS.	1,500		1,500	
	Sub Total				38,700	
	Transmission Line	LS.	19,088	1.3	26,056	1.3km of Transmission line only.

Table 6.4 Calculation of EIRR (Economic Internal Rate of Return) of the MHP Project in Tambo Quemado(Oruro) [Unit: US$]

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Benefit																					
Investment																					
Diesel Generator											46,500										
Automatic Transfer Switch											1,910										
Protection Box											917										
Building											1,500										
Transmission Lines																					
Distribution Lines																					
OM Cost																					
OM Cost of the Diesel Generator, etc.		2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466	2,466
OM Cost of the Distribution Lines		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Fuel cost		32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718	32,718
Total Benefit	0	35,184	35,184	35,184	35,184	35,184	35,184	35,184	35,184	35,184	86,011	35,184	35,184	35,184	35,184	35,184	35,184	35,184	35,184	35,184	35,184
Cost																					
Investment																					
Preparation Workds and Access, etc.	2,000																				
Civil Works	95,800																				
Turbine/Generator	33,100																				
Transmission/Distribution Lines	21,700																				
Mechanical Works	25,800																				
Transportation	8,900																				
Administration and Engineering Service	18,400																				
OM Cost																					
Turbine/Generator		662	662	662	662	662	662	662	662	662	662	662	662	662	662	662	662	662	662	662	662
Civil Works		479	479	479	479	479	479	479	479	479	479	479	479	479	479	479	479	479	479	479	479
Transmission/Distribution Lines		543	543	543	543	543	543	543	543	543	543	543	543	543	543	543	543	543	543	543	543
Total Cost	205,700	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684	1,684
Balance	-205,700	33,501	33,501	33,501	33,501	33,501	33,501	33,501	33,501	33,501	84,328	33,501	33,501	33,501	33,501	33,501	33,501	33,501	33,501	33,501	33,501

EIRR	16.4%

Table 7.1 Calculation of EIRR (Economic Internal Rate of Return) of the Wind Project in Charana (La Paz

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Benefit																				
Investment																				
Diesel Generator	48,750										48,750									
Automatic Transfer Switch	1,910										1,910									
Protection Box	917										917									
Building	1,500										1,500									
Secondary Distribution Line	92,946																			
OM Cost																				
OM Cost of the Diesel Generator, et	1,289	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579	2,579
OM Cost of the Distribution Lines	1,162	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324	2,324
Fuel cost	13,048	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096	26,096
Total Benefit	161,522	30,999	30,999	30,999	30,999	30,999	30,999	30,999	30,999	30,999	84,076	30,999	30,999	30,999	30,999	30,999	30,999	30,999	30,999	30,999
Cost																				
Investment																				
Wind Turbine	216,000																			
PV System	112,000																			
MHP	0																			
Inverter	32,000										32,000									
Converter	3,600										3,600									
Battery	22,000						22,000						22,000							
Control House	10,000																			
Installation Materials	66,207																			
Installation Work	57,931																			
Transportation	92,946																			
Secondary Distribution Lines	29,904																			
Administration Cost	56,548																			
OM Cost																				
Wind PV Hybrid System	3,636	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272	7,272
Secondary Distribution lines	374	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748	748
Total Cost	703,146	8,020	8,020	8,020	8,020	8,020	30,020	8,020	8,020	8,020	43,620	8,020	30,020	8,020	8,020	8,020	8,020	8,020	8,020	8,020
Balance	-541,623	22,979	22,979	22,979	22,979	22,979	979	22,979	22,979	22,979	40,456	22,979	979	22,979	22,979	22,979	22,979	22,979	22,979	22,979

EIRR	-2.6%

Table 7.2 Calculation of EIRR (Economic Internal Rate of Return) of the Wind Project in Caripe (Oruro

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Benefit																				
Investment																				
Diesel Generator	7,500										7,500									
Automatic Transfer Switch	1,910										1,910									
Protection Box	917										917									
Building	1,500										1,500									
Secondary Distribution Line	9,200																			
OM Cost																				
OM Cost of the Diesel Generator, et	258	516	516	516	516	516	516	516	516	516	516	516	516	516	516	516	516	516	516	516
OM Cost of the Distribution Lines	115	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230
Fuel cost	3,273	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546	6,546
Total Benefit	24,673	7,292	7,292	7,292	7,292	7,292	7,292	7,292	7,292	7,292	19,119	7,292	7,292	7,292	7,292	7,292	7,292	7,292	7,292	7,292
Cost																				
Investment																				
Wind Turbine	27,000																			
PV System	28,000																			
MHP	0																			
Inverter	4,000										4,000									
Converter	0																			
Battery	4,000						4,000						4,000							
Control House	10,000																			
Installation Materials	9,655																			
Installation Work	8,448																			
Transportation	14,938																			
Secondary Distribution Line	9,200																			
Administration Cost	10,141																			
OM Cost																				
Wind PV Hybrid System	590	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180	1,180
Secondary Distribution lines	115	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230	230
Total Cost	126,087	1,410	1,410	1,410	1,410	1,410	5,410	1,410	1,410	1,410	5,410	1,410	5,410	1,410	1,410	1,410	1,410	1,410	1,410	1,410
Balance	-101,414	5,882	5,882	5,882	5,882	5,882	1,882	5,882	5,882	5,882	13,709	5,882	1,882	5,882	5,882	5,882	5,882	5,882	5,882	5,882

EIRR	1.0%

Table 7.3 Calculation of EIRR (Economic Internal Rate of Return) of the Wind Project in Chachacomani (Oruro

Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Benefit																				
Investment																				
Diesel Generator	15,000										15,000									
Automatic Transfer Switch	1,910										1,910									
Protection Box	917										917									
Building	1,500										1,500									
Secondary Distribution Line	12,500																			
OM Cost																				
OM Cost of the Diesel Generator, etc	446	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891	891
OM Cost of the Distribution Lines	156	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313
Fuel cost	6,222	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444	12,444
Total Benefit	38,651	13,648	13,648	13,648	13,648	13,648	13,648	13,648	13,648	13,648	32,975	13,648	13,648	13,648	13,648	13,648	13,648	13,648	13,648	13,648
Cost																				
Investment																				
Wind Turbine	54,000																			
PV System	0																			
MHP	102,749																			
Inverter	7,000										7,000									
Converter	1,800										1,800									
Battery	2,000						2,000						2,000							
Control House	10,000																			
Installation Materials	13,793																			
Installation Work	12,069																			
Transportation	16,598																			
Secondary Distribution Lines	12,500																			
Administration Cost	20,461																			
OM Cost																				
Wind PV Hybrid System	1,655	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311	3,311
Secondary Distribution lines	156	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313	313
Total Cost	254,781	3,623	3,623	3,623	3,623	3,623	5,623	3,623	3,623	3,623	12,423	3,623	5,623	3,623	3,623	3,623	3,623	3,623	3,623	3,623
Balance	-216,130	10,024	10,024	10,024	10,024	10,024	8,024	10,024	10,024	10,024	20,551	10,024	8,024	10,024	10,024	10,024	10,024	10,024	10,024	10,024

EIRR	-0.9%

Table 8.1 Economic Cost of Grid Extension

I. Extension Cost of Distribution Lines

1. Assumptions

1.1 Primary Distribution Line (14.4kV, single phase)

Length of the Land the Line is Installe	20	Km
Distance between each electric posi	105	Meters
No. of transformers installed	3	
No. of insulators installed for every electric pos	3	
No. of separators installed	2	
(One at the beginning of the line and additional one every 15km of the lin		
No. of lighting rods installed for each transforme	1	
Allowance for the cable	5	%

1.2 Secondary Distribution Line (0.231kV, single phase)

Length of the Land the Line is Installe	3	Km
Distance between each electric posi	70	Meters
Allowance for the cable	5	%

1.3 Others

No. of families	100	
Exchange rate	6.53	Bs/US$
	120.5	Yen/US$
Tax Rate		
Imported Products (every material except for electric posts)		
Cables (10% Import Tax and 14.94% Effective VAT)	24.94	%
Transformers and other exported products (5% Import Tax and 14.94% Effective VAT	19.94	%
Domestic Products (electric posts):		
Value Added Tax	13	%
Transaction Tax	3	%
Agency Transaction Fee for Imported Products	10	%
Discount Rate	10	%
CRF (20 Years)	0.1175	

The land is assumed to be flat

2. Specifications

2.1 Primary Distribution Line

Cables	ACSR No2 (single phase)
	ACSR No6 (single phase)
Electric post	10m high
Transformer	14.4//0.231 kV
	15kVA
Insulator	ESPIGA
	Carrete 3"
Separator	Fuse 27kV
Lighting rod	21kV

2.2 Secondary Distribution Line

Cable	Duplex No2 (single phase)
Electric post	9m high

3. Unit Cost of Materials

3.1 Primary Distribution Line

Cables		
ACSR No2	0.38	US$/m
ACSR No6	0.30	US$/m
Electric Post	82	US$
Transformer (3 per one kilometer)	959	US$
Insulators		
(2 pieces for every electric post)	13	US$
(1 piece for every electric post)	0.7	US$
Separator	96	US$
Lighting rod	81	US$
Other Metal Costs	35% of the total above costs	
Labor Work and Supervision (including transportation	603	US$/km
Contingency	5% of the total above costs	

3.2 Secondary Distribution Line

Cable	1.2	US$/m
Electric Post	67	US$
Switch and Metallic Box	83	US$/km
Other Metal Costs	20% of the total above costs	
Labor Work and Supervision (including transportation	603	US$/km
Contingency	3% of the total above costs	

3.3 Others

Initial Investment Cost Born by Each User (Valid for 20 years	86	US$/each

4. Extension Cost of the Distribution Lines per Kilometer (US$)

Based on the above assumption and condition, cost of the distribution lines per kilometer i calculated as follows

4.1 Cost of the Primary Distribution Line per Kilometer

Cables		
ACSR No2	403	US$/km
ACSR No6	319	US$/km
Electric Posts	862	US$/km
Transformers	144	US$/km
Separators	10	US$/km
Lighting rods	12	US$/km
Insulators	14	US$/km
Other Metal Materials (35% of the above total)	617	US$/km
Labor Work and Supervision	603	US$/km
Contingency	149	US$/km
Total	***3,134***	US$/km

4.2 Cost of the Secondary Distribution Line per Kilometer

Cable	1,219	US$/km
Electric Posts	1,028	US$/km
Switches and Metallic Boxes	83	US$/km
Other Metal Materials (20% of the above total)	466	US$/km
Labor Work and Supervision	603	US$/km

Contingency		10	US$/km
	Total	***3,409***	US$/km

5. Annualized Extension Cost of Distribution Lines

5.1. Annualized Investment Cost of Distribution Lines

Annual Investment Cost = Total Investment Cost x Capital Recovery Factor (CRF) for 20 Yea

$CRF=(R(1+R)^n)/((1+R)^n-1)$
CRF: Capital Recovery Factor
R: Discount Rate
n: Life time of the Line

$CRF=(0.1(1+0.1)^{20})/((1+0.1)^{20}-1)$
0.1175

Total Primary Line Cost US$3134/km x 20km =	62,672	US$
Annualized Cost of the Primary Lines US$62672 x CRF =	7,361	US$
Total Secondary Line Cost US$3409x 3km =	10,228	US$
Annualized Cost of the Secondary Lines US$10228 x CRF =	1,201	US$
Initial Investment Cost Born by 100 Households		
US$86 x 100 =	8,621	US$
Annualized Initial Investment Cost Born by Households US$8621 x 0.1175 =	1,013	US$
Thus, annualized Investment Cost of the Distribution Lines and Investment Cost Born by Households will be	9,576	US$

5.2 Annual Operation and Maintenance Cost

OM cost is 2.5% of the Initial Investment Cost		
Annual OM Cost for the Primary Distribution Line will b	1,567	US$
Annual OM Cost for the Secondary Distribution Line will b	256	US$
Thus, total Annual OM Cost will be	1,823	US$

5.3 Total Annualized Cost of Extension of Distribution Lines

Total annualized cost of the distribution lines will b *5.1 + 5.2 =*	11,398	US$

5.4 Annualized Cost of Extension of Distribution Lines per kWh

Annual Electricity Demand is		
300W per house x 8 hrs/day x 100 houses x 365 days/Y =	87,600	kWh
Thus, annualized cost of extension of distribution lines per kWh will b	***0.13***	US$/kWh

II. Cost of Generator and Transmission Line

The following data and costs are based on the cost analysis simulation made of a Gas Turbine Generato
by the National Committee of Electricity Supply (CNDC) in April 1999

1. Assumptions

Power to be Installed	64.3	MW
Peak Power to be Used	53.4	MW
Investment Cost of Transmission	2.6	US$MN
Investment Cost of Generation	26.3	US$MN
Operation and Management Cost (% of Investment Costs	1.5	%
Loss Factors:		
Power	20.0	%
Energy in Generation and Transmission	5.0	%
Energy in Distribution (3% in 1st, 5% in 2nd lines and 1% in the transformer)	9.0	%
Efficiency	15.0	%
Marginal Energy Cost	13.1	US$/MWh
Operation Rate	57.5	%
Life time	20.0	Years
Discount rate	10.0	%
CRF (20 Years)	0.1175	

2. Annualized Cost of Generation and Transmission

2.1 Total Investment Cost

Total investment cost will be		
US$2.6MN + US$26.3MN =	28.9	US$MN
Annualized investment cost will be		
US$28.9MN x CRF =	3.4	US$MN
Annualized investment cost per kWh will be		
US$3.4MN / (53.42MW x 24 Hrs x 365 Days x 0.575) =	0.01	US$/kWh
Total annualized costs considering the loss factor and efficiency will be		
US$0.01/kWh / (1-0.2)*(1-0.15) =	0.02	US$/kWh

2.2 Fuel Cost

Energy cost is already calculated as US$0.01314/kWh by CNDC	0.0131	US$/kWh
Energy cost considering the loss factor will be		
US$0.0131/kWh / (1-0.05)*(1-0.09) =	0.0152	US$/kWh

2.3 Operation and Maintenance Cost

Annual Fixed OM Cost will be		
US$28.9MN x 1.5% =	0.43	US$MN
Annual OM Cost per kWh will be		
US$0.4MN /(53.4MW x 24 Hrs x 365 Days x 0.575 x 0.8 x 0.85) =	0.002	US$/kWh

2.4 Annualized Cost of Generation and Transmission per kWh

Annualized cost of generation and transmission per kWh will b
1) + 2) + 3) = ***0.04*** US$/kWh

Thus, the cost of the grid extension per kWh will be

In case of large project:
Cost of the Distribution (I.5.4) + Cost of the Generation and Transmission (II.2.4) = ***0.17*** US$/kWh

In case of a small project:
Cost of the Distribution (I.5.4) + Fuel Cost (II.2.2) = ***0.15*** US$/kWh

Source: ElFASA, National Committee of Electric Supply and JICA Study Team

Table 8.2 Economic Cost of PV System (SHS)

System Size	55	Watt
System Cost per Watt	12	US$
System Cost (Excluding Charge Controller & Battery)	538	US$
Domestic Part	290	US$
Imported Part	248	US$
Installation Cost per System	69	US$
(Including Labor Cost and Transportation Cost)		
Cost of the Charge Controller	60	US$
Battery Cost	78	US$
Cost of Distilled Water for Battery	0.59	US$/Litter
Annual Operation and Maintenance (% of Initial Investment Costs)	1	%
Required Number of Battery	1	Piece
Required Volume of Distilled Water for the Battery	0.08	Litter/Battery･Month
Annually Generated Amount of Electricity	70	kWh/Y
Life Time of the System	20	Years
Life Time of the Charge Controller	5	Years
Life Time of the Battery	4	Years
No. of Households	200	
Discount Rate	10	%
CRF (20 Years)	0.1175	
Exchange Rate	6.53	Bs/US$
	120.5	Yen/US$
Tax Rate		
Imported Products:		
PV System (10% import tax and 14.94% Effective VAT)	24.94	%
Domestic Products:		
Value Added Tax	13	%
Transaction Tax	3	%
Agency Transaction Fee for the Imported Products	10	%

1) Annualized Investment Cost per kWh

The cost of the PV system including the installation cost will be	607	US$
Annualized investment cost will be		
Total system cost x CRF =	71	US$
Annualized investment cost per kWh will be	1.02	US$/kWh

2) Annual Cost of the Charge Controller, Battery and Distilled Water

Charge controller replacement cost per year will be		
Controller cost / controller life =	12.1	US$
Annual charge controller cost per kWh will be	0.17	US$/kWh
Battery cost per year will be		
Battery cost / battery life =	19.4	US$/Y
Annual battery cost per kWh will be	0.28	US$/kWh
Required amount of distilled water per year will be		
0.08 litter/battery･month x 1 piece x 12 months/Y =	0.96	Litter
Annual cost of the distilled water will be		
0.96Litter x US$0.59/Litter =	0.56	US$
Annual cost of the distilled water per kWh will be	0.01	US$/kWh
Thus, annual cost of the charge controller, battery and distilled water per kWh will be	0.46	US$/kWh

3) Operation and Maintenance Cost per kWh

Annualized OM cost per kWh will be (PV system cost x 2.5%) / power generation =	0.09	US$/kWh
4) Total annualized cost of the PV System per kWh		
Total annualized cost of the PV System per kWh will be 1) + 2) + 3) =	1.6	US$/kWh

Source: JICA Study Team

Table 8.3 Economic Cost of Micro-hydro Power

Micro-hydro Power:		
Cost of Micro-hydro per kW	2,500	US$
Installed capacity (kW)	30	kW
Cost of the Micro-hydro:	75,000	US$
Civil works (including engineering)	45,000	US$
Electromechanical equipment	30,000	US$
2 Substations	10,000	US$
Annual Electricity Generation	87,600	kWh/Year
OM Cost of the Electromechanical Equipment (% of investment)	2.0	%
OM Cost of the Civil Engineering (% of investment)	0.5	%
OM Cost of the Substations (% of investment)	2.0	%
Life Time of the Micro-hydro system	20	Years
Life Time of the Substations	20	Years
Distribution Lines:		
Cost of Primary Distribution Line per km	3,083	US$/km
Cost of Secondary Distribution Line per km	3,409	US$/km
Length of Primary Distribution Line	3	Km
Length of Secondary Distribution Line	3	Km
OM Cost of the Distribution Lines (% of investment)	2.5	%
Life Time of the Distribution Lines	20	Years
Discount Rate	10	%
CRF (20 Years)	0.1175	
Exchange Rate	6.53	Bs/US$
	120.5	Yen/US$
Tax Rate		
Imported Products:		
Hydraulic turbine and substations (5% Import Tax and 14.94% Effective VAT)	19.94	%
Domestic Products:		
Value Added Tax	13	%
Transaction Tax	3	%
Agency Transaction Fee for the Imported Products	10	%

1) Investment Cost of Micro-hydro

Total initial investment cost of micro-hydro system including 2 substations is	85,000	US$
Annualized investment cost will be US$85000 x CRF =	9,988	US$
Annual electricity generation will be	87,600	kWh/Year
Thus, annualized investment cost per kWh of the system will be	0.11	US$/kWh

2) Cost of the Distribution Lines

Total costs of the distribution lines will be	19,477	US$
Annualized distribution line costs will be US$19477 x CRF =	2,289	US$
Annualized distribution line costs per kWh will be	0.03	US$/kWh

3) Operation and Maintenance Cost

Annual OM Cost of the micro-hydro system will be

OM cost for the electromechanical equipment (2%)	600	US$
OM cost for civil engineering (0.5%)	225	US$
OM cost of the distribution lines (2.5%)	487	US$
OM cost of the substations (2%)	200	US$

Total OM cost per annual will be	1,512	US$
Thus, total annual OM cost per kWh will be	0.02	US$/kWh
4) Total Cost of the Micro-hydro System per kWh		
Thus, total Cost of the Micro-hydro System per kWh will be 1) + 2) + 3) =	0.16	US$/kWh

Source: UMSA and JICA Study Team

Table 8.4 Economic Cost of Wind Power

Wind PV Hybrid System:		
Installed Capacity: Wind 40 kW, PV 10kWp	50	kW
Cost of Wind Power (wind turbine, tower, etc.) and PV:	300,000	US$
Wind Power US$200,000 ($5,000 x 40 kW), PV US$100,000 ($10,000 x 10 kW)		
(The above costs include costs of installation materials, installation and transportation.)		
Control House	10,000	US$
Cost of Inverter & Converter	11,800	US$
Cost of Batteries	4,000	US$
OM cost of Wind PV Hybrid System (% of investment cost)	3	%
Annual Electricity Generation	87,600	kWh/Y
Life Time of the Wind PV Hybrid System and Control House	20	Years
Life Time of the Inverter and Converter	10	Years
Replacement Period of the Batteries	6	Years
Distribution Lines:		
Cost of Primary Distribution Line per km	3,083	US$/km
Cost of Secondary Distribution Line per km	3,409	US$/km
Length of Primary Distribution Line	3	Km
Length of Secondary Distribution Line	3	Km
OM Cost of Distribution Lines (% of investment cost)	2.5	%
Life Time of the Distribution Lines	20	Years
Discount Rate	10	%
CRF (20 Years)	0.1175	
CRF (10 Years)	0.1627	
Exchange Rate	6.53	Bs/US$
	120.5	Yen/US
Tax Rate		
Imported Products:		
Wind Power System, Inverter, Converter (5% Import Tax, 14.94% Effective VAT)	19.94	%
PV System (10% Import Tax and 14.94% Effective VAT)	24.94	%
Domestic Products:		
Value Added Tax	13	%
Transaction Tax	3	%
Agency Transaction Fee for Imported Products	10	%
1) Investment Cost		
The investment cost of the Wind PV Hybrid System and the control house will be	310,000	US$
Annualized investment cost of the system will be		
US$310000 x CRF =	36,412	US$
The investment cost of the Inverter and Converter will be	11,800	US$
Annualized investment cost of the Inverter and Converter will be		
US$11800 x CRF =	1,920	US$
Total costs of the distribution lines will be	19,476	US$
Annualized investment cost of the distribution lines will be		
US$19476 x CRF =	2,288	US$
Annual cost of batteries will be		
Cost of batteries/life time of the batteries =	667	US$

Total annualized investment cost of the Wind PV Hybrid System will be	41,287	US$
Annual electricity generation will be	87,600	kWh
Therefore, annualized investment cost of the Wind PV Hybrid System will be	0.47	kWh
2) Operation and Maintenance Cost		
Annual OM cost of the Wind PV Hybrid System (3% of investment) will be	9,354	US$
Annual OM cost of distribution lines (2.5% of investment) will be	256	US$
Thus, total annual OM cost will be	9,610	US$
Annual OM cost per kWh will be	0.11	US$/kWh
3) Total annualized cost per kWh of the Wind PV Hybrid System		
Thus, annualized cost per kWh of the Wind PV Hybrid System will be 1) + 2) =	0.58	US$/kWh

Source: JICA Study Team

Table 8.5 Economic Cost of Diesel Generator

Diesel Generator:		
Cost of Diesel Generator	22,500	US$
Generation Capacity	30	kW
Cost of Generator per kW	750	US$/kW
Cost of Automatic Transfer Switch	1,910	US$
Cost of Protection Box	917	US$
Building	1,500	US$
OM Cost of Generator (% of investment cost)	5	%
Operation Hour per Day	10	Hours/Day
Generated Power	87,600	kWh/Year
Life Time of the Generator	10	Years
Diesel Oil Cost per Litter (including transportation cost)	3.1	Bs/Litter
Fuel Consumption	17,228	Litter/Year
Diesel Fuel Cost	8,188	US$/Year
Distribution Lines:		
Cost of Secondary Distribution Line per km	3,409	US$/km
Length of Secondary Distribution Line	3	Km
OM Cost of Distribution Lines (% of investment cost)	2.5	%
Life Time of the Distribution Lines	20	Years
Discount Rate	10	%
CRF (10 Years)	0.1627	
CRF (20 Years)	0.1175	
Exchange Rate	6.53	Bs/US$
	120.5	Yen/US$
Tax Rate		
Imported Products:		
Diesel Generator (10% import tax and 14.94% Effective VAT)	24.94	%
Automatic Transfer Switch and Protection Box (5% import tax and 14.94% Effective VAT)	19.94	%
Domestic Products:		
Value Added Tax	13	%
Transaction Tax	3	%
Agency Transaction Fee for the Imported Products	10	%

1) Investment Cost

Total investment cost of the diesel generator, automatic transfer switch, protection box and building will be	26,827	US$
Annualized investment cost of the diesel generator will be US$26827 x CRF =	4,366	US$
Total costs of the distribution line will be	10,227	US$
Annualized distribution line costs will be Total distribution line cost x CRF =	1,202	US$/Year
Thus, annualized investment cost per kWh will be	0.06	US$/kWh

2) Operation and Maintenance Cost

Annual OM cost of the diesel generator will be Investment cost of the diesel generator x 5% =	1,341	US$

Annual OM cost of the distribution line will be Investment cost of the distribution lines x 2.5% =	256	US$/Year
Annual OM cost per kWh will be	0.02	US$/kWh
3) Fuel Cost		
Total fuel cost per kWh will be	0.09	US$/kWh
4) Total Annualized Cost of the Diesel Generator		
Total annualized cost of the diesel generator per kWh will be (1) + (2) + (3) =	0.18	US$/kWh

Source: JICA Study Team

Table 8.6 Priority Micro Hydro Power Projects in La Paz and Oruro
(Plan 2002 - 2011)

La Paz

Priority Ranking No.	Proposed Implementation Schedule (Term of Year)	Name of Project	Province	Canton	MHP: No.of Benef. Families by MHP (HH)	MHP: Installed Capacity (kW)	MHP: **Investment Cost (MHP) (US$)**	MHP: kW Cost (MHP) (US$/kW)	MHP: Annual Energy (kWh/Year)	MHP: **Annualized Investment + OM Cost per kWh (MHP) (US$/kWh)**	Study Conducted by	Stage of Project
					a	d	e	f =e/d	g =(d*8*365*0.95)	h =(CRF + OM 1.8%) *e / g		j
* 1	2002 - 2006	Apolo (Rio Machariapu) [Phase - I]	F. Tamayo	Apolo, Santa Cruz del Valle Ameno & Aten	1,100	350	*2,000,000*	5,714	*970,900*	*0.28*	JICA Study Team	2
2	2002 - 2006	San José de Chupiamonas	Iturralde	San José de Chupiamonas	80	40	70,200	1,755	*110,960*	*0.09*	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura	2
3	2002 - 2006	San Miguel	Iturralde	San Buena Ventura	80	25	66,900	2,676	*69,350*	*0.13*	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura	2
4	2002 - 2006	25 de Mayo	Iturralde	San Buena Ventura	350	25	65,000	2,600	*69,350*	*0.13*	EU-NF, Prefectura, Alcadia	1
5	2002 - 2006	Yanamayu	S. Yungas	Yanamayu	230	88	183,561	2,086	*244,112*	*0.10*	UMSA-IHH	3
6	2002 - 2006	Colopampa-Santa Rosa	S. Yungas	Colopampa Grande	580	160	270,512	1,691	*443,840*	*0.08*	UMSA-IHH	3
7	2002 - 2006	Calisaya	S. Yungas	Calisaya	80	25	34,300	1,372	*69,350*	*0.07*	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura	2
8	2002 - 2006	Charia	S. Yungas	Charia	200	50	80,000	1,600	*138,700*	*0.08*	ECOTEC	1
9	2002 - 2006	Pichari	S. Yungas	San Jose	162	48	100,000	2,083	*133,152*	*0.10*	ECOTEC	1
9	2002 - 2006	Centro Tocoroni	S. Yungas	Villa Barrientos	828	*60*	*174,773*	*3,000*	*166,440*	*0.14*	UNDP	3
11	2002 - 2006	Suches	F.Tamayo	Suches	140	100	200,000	2,000	*277,400*	*0.10*		1
12	2002 - 2006	Curva - Canlaya (Rio Opinuwaya)	B.Saavedra	Curva	170	*45*	*112,500*	*2,500*	*124,830*	*0.12*	JICA Study Team	1
13	2002 - 2006	Palmar	S. Yungas	Chamaca	150	40	70,000	1,750	*110,960*	*0.09*	ECOTEC	1
13	2002 - 2006	Villa el Carmen	Caranavi	Rosario Entre Rios	90	40	68,100	1,703	*110,960*	*0.08*	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura	2
15	2007 - 2011	Calama	Caranavi	Calama	170	50	175,204	3,504	*138,700*	*0.17*	UMSA-IHH	3
16	2007 - 2011	Ulla Ulla	F.Tamayo	Ulla Ulla	60	20	50,000	2,500	*55,480*	*0.12*		1
17	2007 - 2011	Chairo	Nor Yungas	Pacollo	100	40	56,170	1,404	*110,960*	*0.07*	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura	2
18	2007 - 2011	Pocomayo (Pocomayo, Vilaque, Choquepata)	Munecas	Timusi	102	25	53,842	2,154	*69,350*	*0.11*	Comunidad de Pocomayo, UMSA-IHH	1
19	2007 - 2011	Inicua-Delicias	S. Yungas	Palos Blancos	84	60	141,140	2,352	*166,440*	*0.11*	VMEH/PNUD/Solsticio SRL.	1
20	2007 - 2011	Llallagua	J. Manuel Pando	Sattiago de Machaca	10	8	8,485	1,061	*22,192*	*0.05*	PROPER, Misión Alianza Noruega (MAN)	1
21	2007 - 2011	Incahuara	Caranavi	Incahuara de Ckullu Kuchij	70	30	150,000	5,000	*83,220*	*0.24*	Munc. De Caranavi, UMSA-IHH	1
21	2007 - 2011	Poroma	Larecaja	Santa Rosa de Challana	350	300	300,000	1,000	*832,200*	*0.05*	ECOTEC	1
23	2007 - 2011	Padilla -Thiyumayo	Nor Yungas	Coroico	220	20	39,450	1,973	*55,480*	*0.10*	EU, Prefectura, Alcadia	1
24	2007 - 2011	Villa Barrientos	S. Yungas	Villa Barrientos	100	23	50,000	2,174	*63,802*	*0.11*	ECOTEC	1
25	2007 - 2011	Huarinillas-Coroico [Rehabilitation]	Nor Yungas	Coroico	978	205	279,000	1,361	*568,670*	*0.07*	UMSA-IHH	1
26	2007 - 2011	Oro verde	Caranavi	Suapi Alto Beni	60	25	52,000	2,080	*69,350*	*0.10*	NF-Alisei (Italia), EU, Alcaldia., Munic., Prefectura	2
26	2007 - 2011	Cotosi - Queñi	Camacho	Mocomoco	137	5	20,550	4,110	*13,870*	*0.20*	ORPA, Khana Wayra y PROPER	1
28	2007 - 2011	Nueva Esperanza	Caranavi	Nueva Esperanza	65	30	78,000	2,600	*83,220*	*0.13*	Munc. De Caranavi, UMSA-IHH	1
29	2007 - 2011	Mocori	Nor Yungas	Milluhuaya	22	8.8	*29,600*	3,364	*24,411*	*0.16*	UMSA-IHH	1
30	2007 - 2011	Illimani	Caranavi	Alto Illimani	60	20	58,000	2,900	*55,480*	*0.14*	Munc. De Caranavi, UMSA-IHH	1
* -	2007 - 2011	Apolo (Rio Machariapu) [Phase - II	F. Tamayo	Apolo, Santa Cruz del Valle Ameno & Aten	900	350	*2,000,000*	5,714	*970,900*	*0.28*	JICA Study Team	2
				321 W/HH	*11,783*	*3,788*	*12,596,207*	*2,728*				

		HH	kW	US$
Sub-Total	**2002 - 2006**	**4,240**	**1,096**	**3,496,000**
Sub-Total	**2007 - 2011**	**3,490**	**1,220**	**3,541,000**
TOTAL	**(2002 - 2011)**	**7,730**	**2,316**	**7,037,000**

Note: The total number was rounded.

Average Installed Capacity per Household in the Selected MHP Projects (La Paz) = 300 W/HH **910 [US$/HH]**

Oruro

Priority Ranking No.	Proposed Implementation Schedule (Term of Year)	Name of Project	Province	Canton	No.of Benef. Families by MHP (HH)	Installed Capacity (kW)	Investment Cost (MHP) (US$)	kW Cost (MHP) (US$/kW)	Annual Energy (kWh/Year)	Annualized Investment + OM Cost per kWh (MHP) (US$/kWh)	Study Conducted by	Stage of Project
1	2002 - 2006	Tambo Quemado	Sajama	Chachacomani	69	62	*239,700*	3,866	*171,988*	*0.19*	JICA Study Team, ECOTEC	2
2	2007 - 2011	Juro - Viluyo (Rio Pacokhaua, Est. Viluyo)	Atahuallpa	Negrillos / Juro	80	15	*52,500*	*3,500*	*41,610*	*0.17*	JICA Study Team	1
3	2007 - 2011	Sajama (Rio Jachcha Huancollo)	Sajama	Sajama	60	25	*75,000*	*3,000*	*69,350*	*0.15*	ECOTEC, JICA Study Team	1
				314 W/HH	*2,065*	*649*	*2,976,612*					

		HH	kW	**US$**
Sub-Total	**2002 - 2006**	**69**	**62**	**240,000**
Sub-Total	**2007 - 2011**	**140**	**40**	**128,000**
TOTAL	**(2002 - 2011)**	**209**	**102**	**368,000**

Note: The total number was rounded.

Average Installed Capacity per Household in the Selected MHP Projects (Oruro) = 488 W/HH **1,761 [US$/HH]**

Source : JICA Study Team

Note: *1) Column 'e', 'f', 'g': Italic numbers are assumed.

***2) Column 'g' & 'h' : For the estimation of annual energy of the MHP, following parameter are use**

Effective Operation Hour (Demand) per Day for Estimation of kWh [hour/day] 8
Plant Factor for MHP = 0.95
n : Life Time of the System [Years] = 20
R: Discount Rate [%] = 10%
CRF (Capital Recovery Factor) = (R(1+R)^n)/((1+R)^n-1) = 0.1175
OM Cost for MHP (% of total investment) [%] = 1.8%

Note *: The Apolo micro-hydro power project is one project, but is divided into tow in this table for incorporating annual investment plan.

Table 8.7 Selection of Priority Wind Power Project

La Paz

	Cantons in high wind potential area	Population	Population for Project	Existing grid or the plan	Result
1	OKORURO	339	suitable	no	selected
2	CHINOCABI	264	suitable	no	selected
3	E.ABAROA	116	suitable	no	selected
4	GREAL. PEREZ	159	suitable	no	selected
5	LADISLAO CABRERA	237	suitable	no	selected
6	RIO BLANCO	287	suitable	no	selected
7	CATACORA	278	suitable	no	selected
8	PAIRUMANI GRANDE	124	suitable	no	selected
9	POJO PAJCHIRI	221	suitable	no	selected
10	CHARANA	1016	suitable	no	selected
11	CARACOLLO	61	not suitable	no	not selected
12	THOLA COLLO	87	not suitable	no	not selected

Oruro

	Cantons in high wind potential area	Population	Population for Project	Existing grid or the plan	Result
1	SAJAMA	449	suitable	exsisting	not selected
2	LAGUNAS	235	suitable	no	selected
3	COPASA	685	suitable	no	selected
4	CARANGAS	152	suitable	exisiting	not selected
5	CARIPE	208	suitable	no	selected
6	CHACHACOMANI	476	suitable	no	selected
7	VILLA ROSARIO	96	not suitable	no	not selected

Source: JICA Study Team

Table 8.8 Number of New Beneficiaries by Energy Source

La Paz

	Phase 1					Phase 2				
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	2,851	2,758	2,863	2,975	3,156	3,354	3,349	3,462	3,676	3,771
Renewable Energy	1,080	923	962	1,005	1,116	1,403	1,328	1,368	1,506	1,523
PV	180	73	68	95	244	671	584	794	610	703
Micro-hydro	900	800	844	860	836	700	680	500	850	760
Wind	0	50	50	50	36	32	64	74	46	60
Grid	1,771	1,835	1,901	1,970	2,040	1,951	2,021	2,094	2,170	2,248

Oruro

	Phase 1					Phase 2				
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total	1,739	1,663	1,665	1,732	1,810	2,023	2,028	2,278	2,286	2,445
Renewable Energy	606	490	450	474	506	865	829	1,036	998	1,112
PV	606	415	377	401	436	785	767	1,036	938	1,112
Micro-hydro	0	45	0	0	0	80	0	0	60	0
Wind	0	30	73	73	70	0	62	0	0	0
Grid	1,133	1,173	1,215	1,259	1,304	1,158	1,199	1,243	1,288	1,334

Source: VMEH and JICA Study Team

Table 8.9 Rural Electrification Rate in La Paz and Oruro(%)

La Paz

	Phase 1					Phase 2				
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total No. of Rural Households	232,629	232,398	232,197	232,021	231,879	231,773	231,700	231,663	231,649	231,669
Existing No. of HHs with Electricity	70,673	73,379	76,010	78,762	81,640	84,712	87,991	91,276	94,681	98,307
New Benecifiary HHs with Electricity	2,851	2,758	2,863	2,975	3,156	3,354	3,349	3,462	3,676	3,771
Decrease in No. of Electrified HHs by Diesel	-145	-127	-111	-97	-85	-74	-65	-57	-50	-43
Total No. of Rural HHs with Electricity	73,379	76,010	78,762	81,640	84,712	87,991	91,276	94,681	98,307	102,034
Rural Electrification Rate (%)	31.5%	32.7%	33.9%	35.2%	36.5%	38.0%	39.4%	40.9%	42.4%	44.0%

Oruro

	Phase 1					Phase 2				
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total No. of Rural Household	61,981	61,694	61,410	61,126	60,846	60,568	60,290	60,015	59,743	59,473
Existing No. of HHs with Electricity	10,268	11,973	13,607	15,246	16,955	18,746	20,751	22,765	25,029	27,303
New Beneciary HHs with Electricity	1,739	1,663	1,665	1,732	1,810	2,023	2,028	2,278	2,286	2,445
Decrease in No. of Electrified HHs by Diesel	-34	-30	-26	-23	-20	-17	-15	-13	-12	-10
Total No. of Rural HHs with Electricity	11,973	13,607	15,246	16,955	18,746	20,751	22,765	25,029	27,303	29,739
Rural Electrification Rate (%)	19.3%	22.1%	24.8%	27.7%	30.8%	34.3%	37.8%	41.7%	45.7%	50.0%

Source: VMEH and JICA Study Team

Table 8.10 Annual Investment Amount for Rural Electrification by Energy Source (US$)

La Paz

	Phase 1					Phase 2				
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total	2,725,000	2,823,000	2,925,000	3,030,000	3,139,000	3,252,000	3,369,000	3,490,000	3,616,000	3,746,000
Renewable Energy	954,000	988,000	1,024,000	1,060,000	1,099,000	1,301,000	1,348,000	1,396,000	1,446,000	1,498,000
PV	144,000	58,000	54,400	76,000	195,400	536,600	467,200	635,200	487,800	562,000
Micro-hydro	810,000	720,000	759,600	774,000	752,400	630,000	612,000	450,000	765,000	684,000
Wind	0	210,000	210,000	210,000	151,200	134,400	268,800	310,800	193,200	252,000
Grid	1,771,000	1,835,000	1,901,000	1,970,000	2,040,000	1,951,000	2,021,000	2,094,000	2,170,000	2,248,000

Oruro

	Phase 1					Phase 2				
	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Total	1,618,000	1,676,000	1,736,000	1,798,000	1,863,000	1,930,000	1,999,000	2,071,000	2,146,000	2,223,000
Renewable Energy	485,000	502,800	520,800	539,400	558,900	772,000	799,600	828,400	858,400	889,200
PV	485,000	331,800	301,800	320,400	348,900	628,000	613,600	828,400	750,400	889,200
Micro-hydro	0	81,000	0	0	0	144,000	0	0	108,000	0
Wind	0	90,000	219,000	219,000	210,000	0	186,000	0	0	0
Grid	1,133,000	1,173,200	1,215,200	1,258,600	1,304,100	1,158,000	1,199,400	1,242,600	1,287,600	1,333,800

Source: VMEH and JICA Study Team

Table 8.11 Number of Total Beneficiaries and Breakdown by Energy Source, La Paz

La Paz

		Phase 1					Phase 2				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
PV	Total	1,073	1,146	1,214	1,309	1,553	2,224	2,808	3,602	4,211	4,914
	Share	1.5%	1.5%	1.5%	1.6%	1.8%	2.5%	3.1%	3.8%	4.3%	4.8%
Micro-hydro	Total	2,195	2,995	3,839	4,699	5,535	6,235	6,915	7,415	8,265	9,025
	Share	3.0%	3.9%	4.9%	5.8%	6.5%	7.1%	7.6%	7.8%	8.4%	8.8%
Wind	Total	0	50	100	150	186	218	282	356	402	462
	Share	0.0%	0.1%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	0.4%	0.5%
Total Renewable Energy	Total	3,268	4,191	5,153	6,158	7,274	8,677	10,005	11,373	12,878	14,401
	Share	4.5%	5.5%	6.5%	7.5%	8.6%	9.9%	11.0%	12.0%	13.1%	14.1%
Grid Extension	Total	69,102	70,937	72,838	74,808	76,848	78,799	80,820	82,914	85,084	87,332
	Share	94.2%	93.3%	92.5%	91.6%	90.7%	89.6%	88.5%	87.6%	86.5%	85.6%
Diesel	Total	1,010	883	772	675	591	516	452	395	345	302
	Share	1.4%	1.2%	1.0%	0.8%	0.7%	0.6%	0.5%	0.4%	0.4%	0.3%
Total	Total	73,379	76,010	78,762	81,640	84,712	87,991	91,276	94,681	98,307	102,034
	Share	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: VMEH and JICA Study Team

Table 8.12 Number of Total Beneficiaries and Breakdown by Energy Source, Oruro

Oruro

		Phase 1					Phase 2				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
PV	Total	2,355	2,770	3,147	3,548	3,984	4,769	5,536	6,571	7,509	8,621
	Share	19.7%	20.4%	20.6%	20.9%	21.3%	23.0%	24.3%	26.3%	27.5%	29.0%
Micro-hydro	Total	365	410	410	410	410	490	490	490	550	550
	Share	3.0%	3.0%	2.7%	2.4%	2.2%	2.4%	2.2%	2.0%	2.0%	1.8%
Wind	Total	0	30	103	176	246	246	308	308	308	308
	Share	0.0%	0.2%	0.7%	1.0%	1.3%	1.2%	1.4%	1.2%	1.1%	1.0%
Total	Total	2,720	3,210	3,660	4,134	4,640	5,505	6,334	7,369	8,367	9,479
Renewable Energy	Share	22.7%	23.6%	24.0%	24.4%	24.8%	26.5%	27.8%	29.4%	30.6%	31.9%
Grid Extension	Total	9,016	10,190	11,405	12,663	13,968	15,126	16,325	17,568	18,855	20,189
	Share	75.3%	74.9%	74.8%	74.7%	74.5%	72.9%	71.7%	70.2%	69.1%	67.9%
Diesel	Total	237	207	181	158	138	121	106	93	81	71
	Share	2.0%	1.5%	1.2%	0.9%	0.7%	0.6%	0.5%	0.4%	0.3%	0.2%
Total	Total	11,973	13,607	15,246	16,955	18,746	20,751	22,765	25,029	27,303	29,739
	Share	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: VMEH and JICA Study Team

Table 8.13 Estimated Electricity Consumption by Energy Source, La Paz (kWh)

La Paz

		Phase 1					Phase 2				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
PV	Total	69,745	74,458	78,878	85,053	100,929	144,528	182,488	234,098	273,731	319,394
	Share	0	0	0	0	0	0	0	0	0	0
Micro-hydro	Total	523,500	778,500	1,025,100	1,280,700	1,535,100	1,765,500	1,972,500	2,149,500	2,352,000	2,593,500
	Share	2.4%	3.5%	4.5%	5.4%	6.2%	6.9%	7.5%	7.9%	8.4%	8.9%
Wind	Total	0	7,500	22,500	37,500	50,400	60,600	75,000	95,700	113,700	129,600
	Share	0.0%	0.0%	0.1%	0.2%	0.2%	0.2%	0.3%	0.4%	0.4%	0.4%
Total Renewable Energy	Total	593,245	860,458	1,126,478	1,403,253	1,686,429	1,970,628	2,229,988	2,479,298	2,739,431	3,042,494
	Share	2.8%	3.9%	4.9%	5.9%	6.8%	7.7%	8.5%	9.1%	9.8%	10.5%
Grid Extension	Total	20,464,808	21,005,708	21,566,108	22,146,758	22,748,258	23,346,908	23,942,708	24,559,958	25,199,558	25,862,258
	Share	95.7%	94.8%	94.0%	93.2%	92.4%	91.6%	91.0%	90.4%	89.8%	89.2%
Diesel	Total	324,680	283,928	248,291	217,126	189,874	166,042	145,201	126,976	111,039	97,102
	Share	1.5%	1.3%	1.1%	0.9%	0.8%	0.7%	0.6%	0.5%	0.4%	0.3%
Total	Total	21,382,733	22,150,093	22,940,876	23,767,137	24,624,561	25,483,578	26,317,897	27,166,232	28,050,028	29,001,854
	Share	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: VMEH and JICA Study Team

Table 8.14 Estimated Electricity Consumption by Energy Source, Oruro (kWh)

Oruro

		Phase 1					Phase 2				
		2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
PV	Total	153,091	180,050	204,571	230,604	258,952	309,977	359,832	427,139	488,109	560,357
	Share	5.3%	5.5%	5.6%	5.7%	5.8%	6.3%	6.7%	7.4%	7.8%	8.4%
Micro-hydro	Total	109,500	116,250	123,000	123,000	123,000	135,000	147,000	147,000	156,000	165,000
	Share	3.8%	3.6%	3.4%	3.0%	2.7%	2.7%	2.8%	2.5%	2.5%	2.5%
Wind	Total	0	4,500	19,950	41,850	63,300	73,800	83,100	92,400	92,400	92,400
	Share	0.0%	0.1%	0.5%	1.0%	1.4%	1.5%	1.6%	1.6%	1.5%	1.4%
Total Renewable Energy	Total	262,591	300,800	347,521	395,454	445,252	518,777	589,932	666,539	736,509	817,757
	Share	9.1%	9.3%	9.5%	9.7%	9.9%	10.5%	11.0%	11.5%	11.8%	12.2%
Grid Extension	Total	2,534,980	2,880,910	3,239,170	3,610,240	3,994,645	4,363,960	4,717,570	5,083,870	5,463,400	5,856,610
	Share	88.2%	88.7%	88.9%	89.0%	89.1%	88.7%	88.3%	88.0%	87.8%	87.4%
Diesel	Total	76,117	66,563	58,209	50,902	44,513	38,926	34,041	29,768	26,032	22,764
	Share	2.6%	2.0%	1.6%	1.3%	1.0%	0.8%	0.6%	0.5%	0.4%	0.3%
Total	Total	2,873,688	3,248,273	3,644,899	4,056,596	4,484,410	4,921,663	5,341,542	5,780,177	6,225,941	6,697,131
	Share	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: VMEH and JICA Study Team