JAPAN INTERNATIONAL COOPERATION AGENCY

VICE MINISTRY OF ENERGY AND HYDROCARBONS
THE REPUBLIC OF BOLIVIA

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

FINAL REPORT

APPENDIX I & II

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APPENDIX I AND II

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Abbreviations and Acronyms

(1) Domestic Organization

CINER	Centro de Información en Energías Renovables
CNDC	National Committee of Electricity Supply
COSUDE	Agencia Suiza para el Desarrollo y la Cooperación
CRE	Cooperativa Rural de Electrificación, Santa Cruz
DUF	Directorio Unico de Fondos
ECOTEC	Ecotecnologías Energéticas y Productivas
EDU	Energy Development Unit, VMEH
EDESER	Empresa de Servicios
EFP	Facilitator Team of PRONER Program
ELECTROPAZ	Electricidad de La Paz S.A.
ELFA	Empresa de Luz y Fuerza Aroma
ELFEC	Empresa de Luz y Fuerza de Cochabamba
ELFEO	Empresa de Luz y Fuerza Electrica de Oruro, S.A.
ENDE	National Electric Company
ENERGÉTICA	Energía para el Desarrollo
ESAND	Energía Solar Andina S.R.L.
FNDR	National Fund of Regional Development
FPS	National Fund of Productive and Social Investment
IGM	Instituto Geográfico Militar
IHH	Instituto de Hidaulica e Hidrologia, UMSA
INE	National Statistics Institute
MDE	Ministry of Economic Development
MDSP	Ministry of Sustainable Development and Planning
NOGUB	Programa de Apoyo a Organizaciones no gubernamentales
PRONER	National Program of Rural Electrification
SE	Superintendencia de Electricidad
SENAMHI	Servicio Nacional de Meteorologia e Hidrologia
SERGEOMIN	Servicio Nacional de Geologia y Mineria
SERNAP	Servicio Nacional de Areas Protegidas, MDSP
SIN	National Interconnected System
STI	Interconnected Trunk System
TDE	Transportadora de Electricidad
UMSA	Universidad Mayor de San Andres

VIPFE	Vice Ministry of Public Investment and External Financing
VMARNDF	Vice Ministry of Environmental Natural Resources and Forestry Development
VMEH	Vice Ministry of Energy and Hydrocarbons

(2) International or Foreign Organization

AECI	Spanish International Cooperation Agency
ESMAP	Energy Sector Management Program, World Bank
GEF	Global Environmental Facility, World Bank
GTZ	German Technical Cooperation
IDB	Inter-American Development Bank
JICA	Japan International Cooperation Agency
KfW	German Financial Cooperation
NRECA	National Rural Electric Cooperative Association
UNDP	United Nations Development Program
UNEP	United Nations Environmental Program
UNDCP	United Nations Drug Control Program
USAID	The US Agency for International Development, USA
WB	World Bank

(3) Others

GDP	Gross Domestic Product
NGO	Non Governmental Organization
O&M,O/M	Operation and Maintenance
VAT	Value Added Tax

(4) Technical Term

AC	Alternative Current
CO2	Carbon Dioxide
DC	Direct Current
FC	Fuel Cell
Grid	Transmission Line
H	Head (m)
Hyd	Hydraulic Generator
LDC	Load Dispatching Center
MHP	Micro Hydro Power

PV	Solar Photovoltaic Cell
Q	River Flow Discharge
WG	Wind Generator

(5) Unit

mm	millimeter
m	meter
km	kilometer
El.m	Elevation in meter
l/s	liter per second
m/s	meter per second
m3/s	cubic meter per second
mm^2	square millimeter
km^2	square kilometer
mg	milligram
ton, t	metric ton
V	Volt
W	Watt
kW	kilowatt
MW	Megawatt
Wp	Watt peak
kWp	kilowatt peak
GWh	Gigawatt hour
kWh	Kilowatt hour
MVA	Megavolt ampere
KVA	Kilovolt ampere
Ah	ampere hour
Hz	Herts
RPM	Revolution (revs) per minute
%	percentage

(6) Currency

Bs	Boliviano, Bolivian Currency
US$	US Dollar
M.US$	Million US Dollar
US ‘	US cent

APPENDIX I

PV PILOT PROJECT AND MONITORING

CHAPTER 1 INTRODUCTION

1.1 Objectives

Objective of the whole study is to formulate a Rural Electrification Implementation Plan by Renewable Energy in La Paz and Oruro. The study on PV system focused on the following objectives:

1) to identify appropriate sites and install three hundred of PV systems as pilot project in La Paz and Oruro;

   There installed 200 solar home systems in La Paz and 100 solar home systems in Oruro in order to obtain sustainable scheme for rural electrification.

2) to evaluate PV system and applied operation and maintenance system; and

3) to identify priority sites for PV and incorporate PV development plan into the rural electrification plan.

1.2 Study conducted

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

1) first field survey: August 7, 1999 - September 20, 1999
2) second field survey: January 5, 2000 - February 12, 2000
3) third field survey: May 15, 2000 to July 14, 2000
4) fourth field survey: January 5, 2001 - February 15, 2001
5) fifth field survey: May 10, 2001 - June 8, 2001
6) sixth field survey: August 27, 2001 – September 7,2001

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

- 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

CHAPTER 2 PV INVENTORY AND MARKET SITUATION

2.1 Inventory of PV Installed in La Paz and Oruro

The major system installed in La Paz and Oruro is solar home system (SHS) which is the stand alone type for house lighting. No other type of PV system was identified except solar pumping system in La Paz and Oruro. In general, community people in the Altiplano are not rich enough to purchase Solar home systems by their own account.

International cooperation organizations provided assistance. The USAID installed 480 systems in Oruro since 1998.The Spanish Aid installed 246 systems in La Paz and 500 systems in Oruro during 2000 - 2001.

In addition, 200 systems in La Paz and 100 systems in Oruro were installed through this pilot project. The inventory of the PV system in La Paz and Oruro is summarized in the following table.

Inventory of PV System (as of June 2001)

(Unit: Households)

Department / Year / Organization	La Paz Department				Oruro Department			
	1998	1999	2000	2001	1998	1999	2000	2001
USAID					200	150	3	127
Spanish Aid	80	80	86				430	70
JICA			200				100	
Total	80	80	286	0	200	150	533	197

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

2.1.1 U.S Government

The U.S. Government provided several PV systems all over Bolivia through the USAID. One of them was developed in Oruro of which details are explained below:

- Location: Oruro
- Operator: NRECA (American NGO)
- System: 53W SHS system / Three 7W lamps / 100 Ah Battery
- Procurement Mode: Purchase

- Price: @US$720

  50% = US$ 360 : Oruro Prefecture Subsidy

  25% = US$ 180 : Users (NRECA Finance without interest)

  25% = US$ 180 : Users (NRECA Finance without interest)

  First installment : US$90 = Registration for installation

- Installation

1998: 200 systems (Phase 1)

Location	Beneficiary Households
Salinas	61
Lakaza	27
Pitca & Circuta	18
Ayllu Thnupa	80
Papel Pampa	14
Total	200

1999: 150 systems (Phase 2)

Location	Beneficiary Households
Sajama	16
Papel Pampa	10
Lagunas	4
Urmiri	23
Pazna	18
Cuh Avicaya	19
La Quebrada Antequera	60
Total	150

2000/2001: 130 systems (Phase 3)

Location	Beneficiary Households
Salinas	130

- OM

  The NRECA had a training seminar for 3 days in the communities and training course for staffs of municipality as technicians. No monthly fee is collected from users.

2.1.2 Spanish Government

The Spanish Government provided several PV systems all over Bolivia. Some of them were implemented in La Paz and Oruro of which details are explained below:

- Location: La Paz and Oruro
- Operator: BOLISPANIA (Spanish NGO)
- System: 50W SHS system / Three 15W lamps / 100Ah Battery
- Procurement Mode: Lease (System Owner is Municipality)
- Price: @US$700
  US$ 450: Spanish Government
  US$ 50: Municipality (revolving fund for local projects)
  US$ 200: Users
- Installation

  1996~2000: 246 systems

Location	Beneficiary Households
Quelka Berenguela	246
JunutaLakaza	
Taracollo	
Sique	
Pahaza	
Copacati	
Total	246

- OM
  OM is being done by local NGO upon users' request (50 users from 246)
  Monthly fee: US$2 per user paid to local NGO covering cost of battery water, repair(panel, controller, lamps, replace of fuse) and replacement of controller, battery, PV panel to be paid by each user.

2.2 Market Situation of PV

Several private companies are handling international PV panel and equipment for PV system in Bolivia.

Dealers or agents handling international PV panel are as follows.

1) HANZA: Siemens (Germany, U.S.A.)
2) ESAND: Atersa (Spanish)
3) SERCOIN: Isofoton (Spanish)
4) ENERSOL: Kyocera (Japan, U.S.A.)
5) ALKE: Shell (U.K., Holand)

At present, there are five major private companies which provide equipment and the related services for PV system in Bolivia as listed above. None of these companies manufactures equipment. They are responsible for procurement for all equipment, installation, training for technicians and end users and operation and maintenance.

There is no manufacturer of PV panels in Bolivia. Other than PV panel, these companies import or purchase from the domestic market in Bolivia depending on the project mode. There is one manufacturer, BATEBOL, of solar type battery having a technical agreement with a European company. Only one manufacturer, TEC, produces controller and electrical equipment such as ballast, lamp and DC-DC converter. The company also has a technical agreement with a European company.

CHAPTER 3 SELECTION OF PV PILOT PROJECT SITE

3.1 Scheme of PV Pilot Project

Bolivia has favorable natural conditions for PV power. Because of this, PV power has been introduced in Bolivia. However, the PV systems are not considered as sustainable energy source for power generation yet, not only because of the high equipment cost but also weak operation and maintenance system.

Under the situation, the JICA Study Team implemented the pilot project with the following objectives.

- To install 300 PV systems in La Paz and Oruro as the pilot project
- To monitor the system use, the operation and maintenance and the financial management
- To establish appropriate operation and maintenance system for PV

Through this pilot project, the most appropriate scheme of the PV system was planned to be formulated.

3.2 Selection of Pilot Project Sites

It was planned that 300 PV systems would be installed in La Paz and Oruro prefectures. Candidate sites were initially selected during the preliminary survey conducted in January 1999. After commencement of this study, the JICA Study Team had a series of discussions with VMEH on the candidate sites for the PV system and found that some of the selected sites will be connected by the grid extension in the very near future. Under this situation, the JICA Study Team recognized the necessity for confirmation of the candidate sites by setting up criteria for selection and by conducting field survey on the selected candidates. The process of the final selection of the PV sites is explained below.

3.2.1 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.

The first site survey was conducted focusing on the candidate sites selected by the JICA Study Team applying the following criteria.

1) Sites outside future grid extension plan
   As the monitoring program will continue one year after February 2000, the sites should be outside the future grid extension plan for a minimum of three years .
2) Sites within less than two-hour driving distance from major city
   Distance from a major city such as Patacamaya and Oruro should be within a two-hour drive for convenience.
3) Sites with minimum 50 households
   The number of households in one site should be around 50 for efficient installation and monitoring. (This was not strictly applied due to the candidate sites being very sparsely populated.)
4) Sites within the territories of Operators
   For sustainable operation and maintenance of the PV system, cooperation of Operators such as distribution company and electric cooperative is necessary.
5) Sites where communities have capacity to pay
   Affordability of the residents is an important aspect for the sustainability of the PV system.

3.2.2 Selected Sites

Based on the criteria explained above and discussions with VMEH, candidate sites were preliminarily selected, on which field surveys were conducted during August and September 1999. In the first field survey, features of the pilot scheme including the requirement of payment were explained, and the willingness to participate of the residents was also investigated.

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

La Paz department

1) Calteca

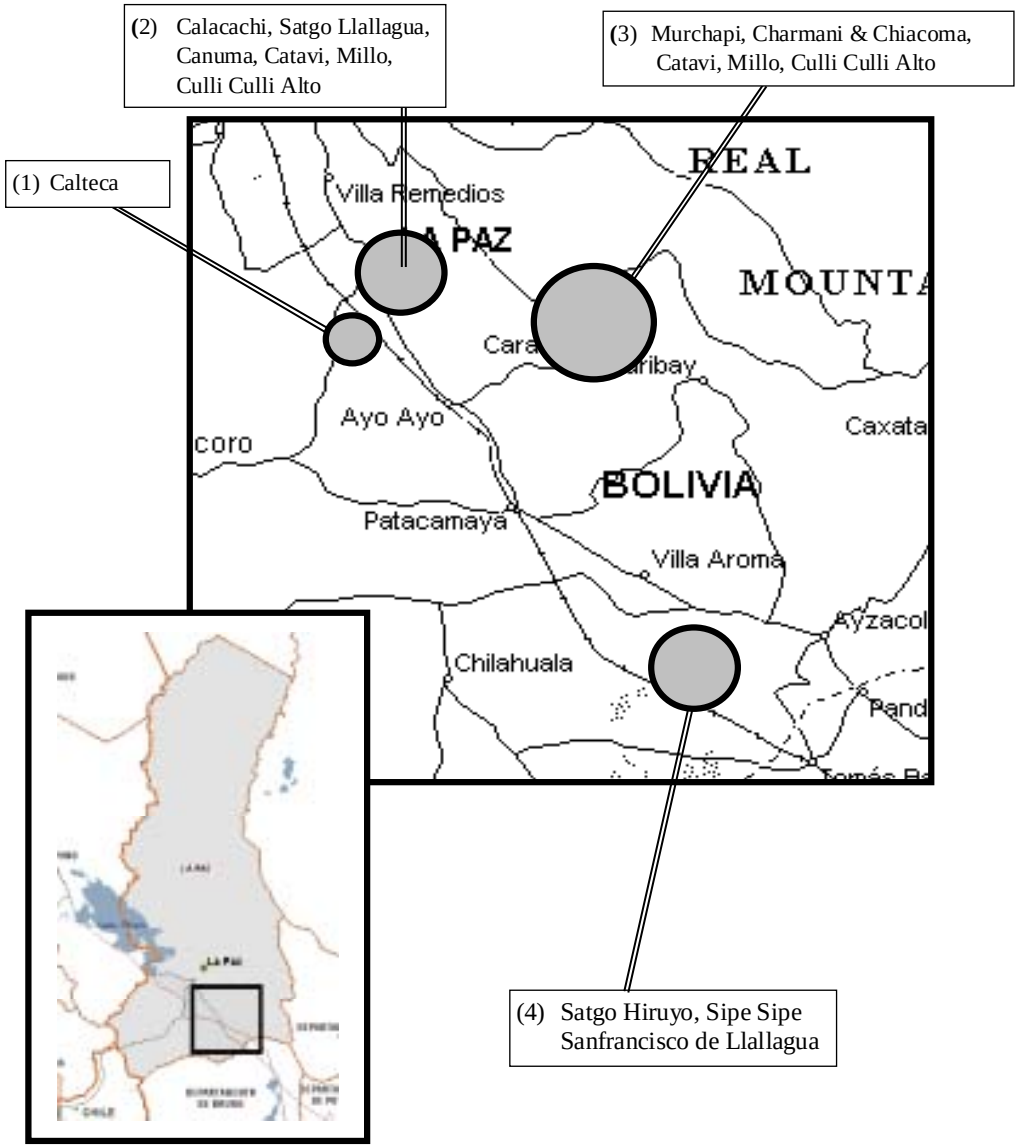
2) Calacachi, Satgo. Llallagua, Canuma
3) Murchapi, Chiarumani & Chacoma, Catavi, Millo and Culli Culli Alto
4) Satgo. Hiruyo, Sanfrancisco Llallagua, Sipe Sipe

Oruro department

1) Paria Pampita
2) Laguna Ancocota
3) Milluni

Location and description of the selected sites are summarized below.

La Paz Department



(1) Calteca

- Location : 35km west from Patacamaya
  : Along the main road to Chili
  : 20km off from the nearest grid line end

- Installed households : 12

- Current energy source and energy cost
  : Gas lamp (initial) Bs 60～70
  : Gas cylinder (initial) Bs 130
  : Kerosene lamp(initial) Bs 1～2
  : Gas (1 cylinder) Bs18 / month
  : Kerosene (3 litter) Bs 6～10 /month

View of Calteca

Interview with a household owner

(2) Muruchapi

- Location : 24km (earth road) east from Patacamaya
  : Behind the mountains (opposite side on the mountains from Patacamaya)
  : 12km off from the nearest grid line end
- Installed households : 23

- Current energy source and energy cost
  : Gas lamp (initial) Bs 90
  : Gas cylinder (initial) Bs 120

: Kerosene lamp(initial) Bs 1～2
: Gas (1 cylinder) Bs15 / month
: Kerosene (5litter) Bs10 /month

(3) –1 Santiago de Hiruyo

- Location : 18.5km (earth road) west from Lawanchaca (30km south from Patacamaya)
  : Behind the hills
  : 9km off from the nearest grid line end
- Installed households : 27

- Current energy source and energy cost
  : Gas lamp (initial) Bs 85
  : Gas cylinder (initial) Bs 130
  : Kerosene lamp(initial) Bs 1～2
  : Gas (1 cylinder) Bs15 / month
  : Kerosene (4 litter) Bs 8 /month

(3) –2 San Francisco de Llallagua

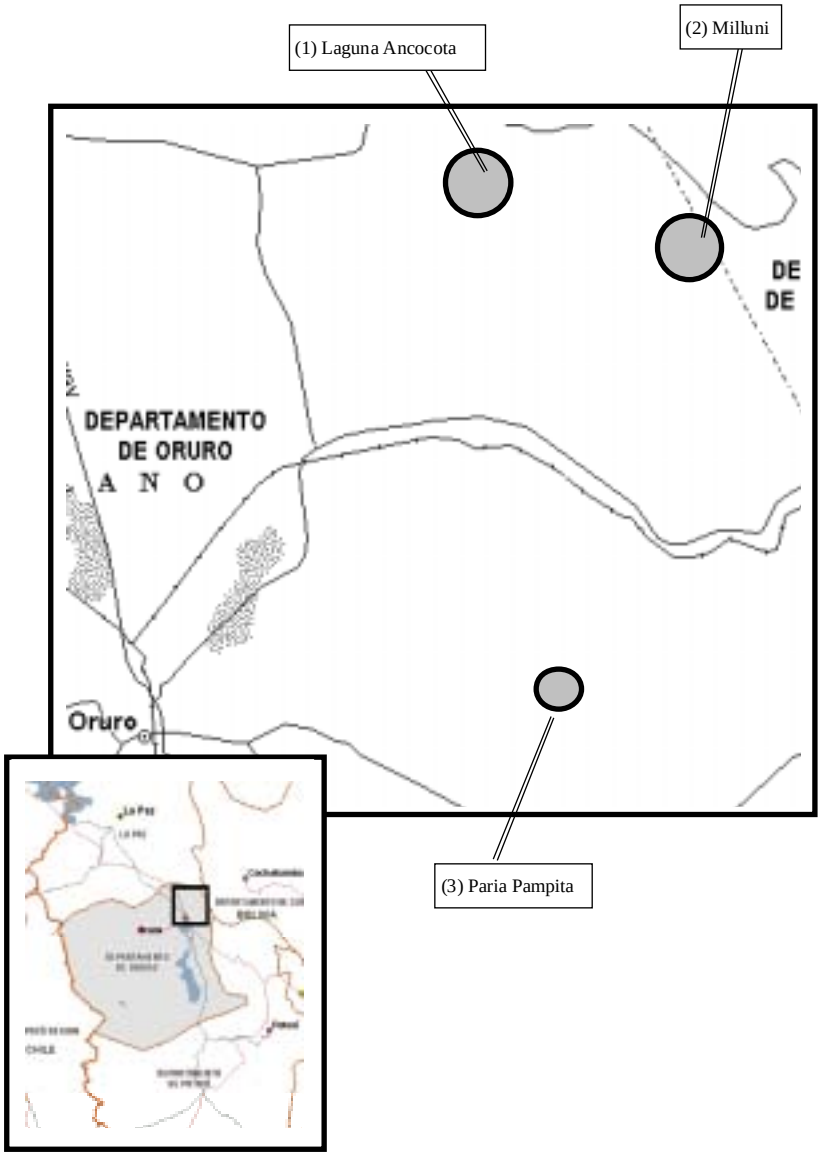
- Location : 17km (earth road) west from Lawanchaca (20km south from Patacamaya)
  : Behind the hills
  : 8km off from the nearest grid line end
- Installed households : 15

- Current energy source and energy cost
  : Gas lamp (initial) Bs 90
  : Gas cylinder (initial) Bs 130
  : Kerosene lamp(initial) Bs 1～2
  : Gas (1 cylinder) Bs15 / month
  : Kerosene (4 litter) Bs10 / month

Chief's house in Sanfrancisco

The lamp installed

Oruro Department



(1) Laguna Ancocota

- Location : 55km north-east from Oruro city
  : 30km (earth road) north-east from Oblahis (25km north-east from Oruro city)
  : 20km off from the nearest grid line end
- Installed households : 44

- Current energy source and energy cost
  : Gas lamp (initial) Bs 120
  : Gas cylinder (initial) Bs 150
  : Kerosene lamp(initial) Bs 1～2
  : Gas (1 cylinder) Bs15 / month
  : Kerosene (4 litter) Bs10 / month

View of Laguna Ancocota

A house with a PV system

(2) Mulluni

- Location : 52km north-east from Oruro city
  : 27km (earth road) north-east from Oblahis (25km north-east from Oruro city)
  : 17km off from the nearest grid line end
- Installed households : 23

- Current energy source and energy cost
  : Gas lamp (initial) Bs 90
  : Gas cylinder (initial) Bs 180
  : Kerosene lamp(initial) Bs 1～2

: Gas (1 cylinder) Bs19 / month
: Kerosene (4 litter) Bs 8 /month

(3) Paria Panpita

- Location : 34km east from Oruro city
  : 16km (earth road) east from the point (18km east from Oruro city)
  : 9km off from the nearest grid line end
- Installed households : 23

- Current energy source and energy cost
  : Gas lamp (initial) Bs 100
  : Gas cylinder (initial) Bs 130
  : Kerosene lamp(initial) Bs 1～2
  : Gas (1 cylinder) Bs15 / month
  : Kerosene (4 litter) Bs10 / month

CHAPTER 4 RURAL SOCIO-ECONOMIC SURVEY

Rural socio-economic survey was conducted using the methods of key informant survey and household survey during the first field survey in August to September 1999. Main objectives of the survey were to collect the following information.

- to get socio-economic profiles of local people and communities,
- to confirm needs and acceptance of local people and communities to rural electrification, and
- to check local participation in the process of rural electrification.

4.1 Location and Sample Size

Target location and size of the survey were determined as presented in the table below. Total numbers of the selected sites were seven: three sites each in La Paz and Oruro, and one existing PV project site in Oruro. In total 110 samples were selected for the household survey.

Location and Size of Socio-Economic Survey

Prefecture	Operating organization	Selected PV Sites	Number of Interviewees	Distance to the nearest town
La Paz	ELFA, S.A.	Calteca	40	35km (Patacamaya)
		Sanfrancisco de Llallagua	10	18.5km (Huachaca)
		Santiago de Hiruyo	10	17km (Huachaca)
Oruro	COSEP	Iruma	20	24km (Oruro-city)
		Paria Pampita	10	30km (Oruro-city)
		Ancocota	10	30km (Oruro-city)
Existing PV Project Site in Oruro	Pazña Municipality / ENRECA	Pazña	10	45km (Oruro-city)
Total		7 sites	110	

Source: JICA Study Team

The altitude of the selected sites was around 3,800 to 5,000 meters above sea level. The area is called 'Alti-Plano'. No extension of distribution line was planed in the sites within three years at least.

The selected sites in La Paz situated in flat area and their households were relatively concentrated, while the households in the selected sites of Oruro were scattered in hilly area.

4.2 Socio-economic Condition

(1) Interviewee's Background

The interviewee's background is briefly summarized in Table 4.1. The largest number was recorded at the age group of 30-39 years followed by that of 40-49 and 50-59. The interviewees of Calteca and Santiago de Hiruyo had relatively higher education compared to those of other communities. All of them in Sanfrancisco de Llallagua, 80% in Ancocota and 70% in Paria Pampita took only elementary education or not educated.

Main occupation of interviewees was farmers except three interviewees. Only eight interviewees devoted full-time to agriculture. The others had also another jobs due to the limited agricultural income. Livestock breeding was another key occupation because of their farming cycle and the available pastureland. 57% of total interviewees (especially all of them in Ancocota and 80% in Paria Pampita) worked as a farmer and a herdsman to maintain their daily life.

Other job opportunities were quite limited in and around the selected sites. Some of them looked for temporary works in urban areas such as La Paz, El Alto and Oruro-city. Seven of ten interviewees in Sanfrancisco de Llallagua and four of ten in Santiago de Hiruyo got income from farm and temporary works as main occupations.

(2) Household Economy

Recent condition of the household economy is presented in Table 4.2.

Average monthly income ranged from Bs.277.4 in Calteca to Bs.348.5 in Santiago in La Paz (Bs.310.3 in average) and from Bs.110.4 in Ancocota to Bs.289.6 in Pazña in Oruro (Bs.269.4 in average).

Average monthly consumption for energy was Bs. 24.9 in the selected communities of La Paz and Bs. 21.4 in Oruro. About 9.8% of total monthly consumption was spent for energy in La Paz and 10.2% in Oruro. In Pazña where PV system had already installed, beneficiaries did not spend for energy except gas for cooking. Beneficiaries of PV system were required to pay US$ 180 for the installation, but without monthly fee.

(3) Agriculture and Holding Livestock

Farmers cultivated various kinds of agricultural products such as potato, kinoa, onion, carrot and pasture under rain-fed agriculture. Most part of the farmland was infertile and lack of agricultural infrastructure including irrigation. The average farmland sizes were 4.7 ha in La Paz and 4.0 ha in Oruro as shown in Table 4.3. Total landless households such as a temporary worker for farmland were nine (8.1% of total interviewees).

Pasturage of sheep was the main activity of livestock raising. 88.3% of interviewees in La Paz and 70.0% in Oruro raised sheep. Even though cattle was fetched a higher price, it was difficult for the farmers to raise larger number of the heads due to the limited pastureland with fodder and capital. Local people did not sell livestock periodically, but sold the animals when they wanted to get cash income. Livestock were regarded as their valuable property for household.

4.3 Household Energy Situation

(1) Electrical Appliance

About 87% of household already used electrical appliance such as radio, radio-cassette recorder and/or TV as shown in Table 4.4. All households in Santiago de Hiruyo and Paria Pampita used radio with dry sell. Two households had a black-and-white television using battery. About 7.5% of total interviewees in Calteca, 15% in Iruma and 20% in Sanfrancisco de Llallagua, did not have any appliance. While, half of the interviewers in Ancocota had electrical appliance.

After PV installation, 85% of interviewees desired to buy a new electrical appliance. Since 87% of them already used a radio and a radio-cassette recorder, 59% of them preferred to buy a television. 32.5% of interviewees in Calteca and 10% of Santiago de Hiruyo and Paria Pampita did not have an idea or did not want to buy any more appliance.

(2) Lighting Situation

Kerosene lamp was mainly being used for lighting in the selected sites. The lamp was usually used after sunset for dinner, housework, study and so on. Average hours using lamp ranged from 1.7 hours per day in Sanfrancisco de Llallagua to 4 hours in Paria Pampita (2.2 hours in average of La Paz and 3.2 hours of Oruro).

The monthly consumption of kerosene for lighting ranged from the lowest consumption of 1.1 liters in Calteca to the highest of 4.2 liters in Iruma (2.2 liters in average of La Paz and 3.4 liters of Oruro). Fuel price of kerosene per liter was Bs.2.2 to Bs.2.5 near the selected sites of La Paz and Bs.1.5 to Bs.1.8 in Oruro. Average monthly consumption of kerosene was Bs. 5.1 in La Paz and Bs. 5.6 in Oruro.

Local people knew a kerosene lamp was darker than candle, gas lamp or other lighting and was not good for health, especially for child's eye. Use of other lighting was, however, more expensive for the local people compared to kerosene lamp. Local people made a kerosene lamp using a fire wick the cost of which is Bs.1.4 to Bs.3 with the life of 1 to 1.6 years. (Use of Kerosene Lamp was summarized in Table 4.5)

4.4 Financial Source of User Charge for PV System

(1) Source for Initial Payment

Beneficiaries had to pay the initial payment of the PV system installation. Nine of total interviewees had enough savings for the charge, while 64 of them intended to sell livestock animals for the payment. Selling of agricultural products and revenue from temporary works were the supplemental means for the payment. The source of the charges for PV system was summarized in Table 4.6.

(2) Source for Monthly Fee

Beneficiaries had to pay as a monthly fee for operation and maintenance of the PV system. Farmers could not get a regular income every month due to the seasonal harvest. They intended to pay by selling livestock (45 interviewees), doing temporary works (35), and/or selling agricultural products (13) if they could not afford to prepare the fee from their savings and/or other incomes. The expected source of the monthly fee was summarized in Table 4.7.

4.5 Needs and Expectations for Rural Electrification

Local people in the selected sites were eager to improve their daily life and to develop community through the rural electrification. Their needs and expectations were explained below.

(1) Income Generation

- to develop irrigated agricultural with pumping up water because agricultural development was lagged behind due to limited water supply, and
- to promote cottage industry in rural area for getting cash income.

(2) Basic Human Needs

- to develop a deep well drinking water because drinking water was being provided by limited amount of spring water or shallow well, and
- to improve educational condition not only for children but also for adults with electricity and audiovisual education aids.

(3) Social Welfare

- to get more information using radio, radio-cassette recorder, TV because new and appropriate information such as agricultural, health and hygienic knowledge was essential for improvement of their dairy life, and
- to enjoy social activities with electrical appliance.

The capacity of the PV system was not sufficient to attain some of the above-mentioned expectation. Larger power system would be required to implement an integrated rural development.

CHAPTER 5 APPLIED PV SYSTEM AND INSTALLATION

5.1 System Components

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

(2) Loads

Available from local market

- Fluorescent lamp : 15W 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

Bolivian made, available from local market

- Solar type
- Nominal capacity : 99.12Ah
- Nominal voltage : 12V

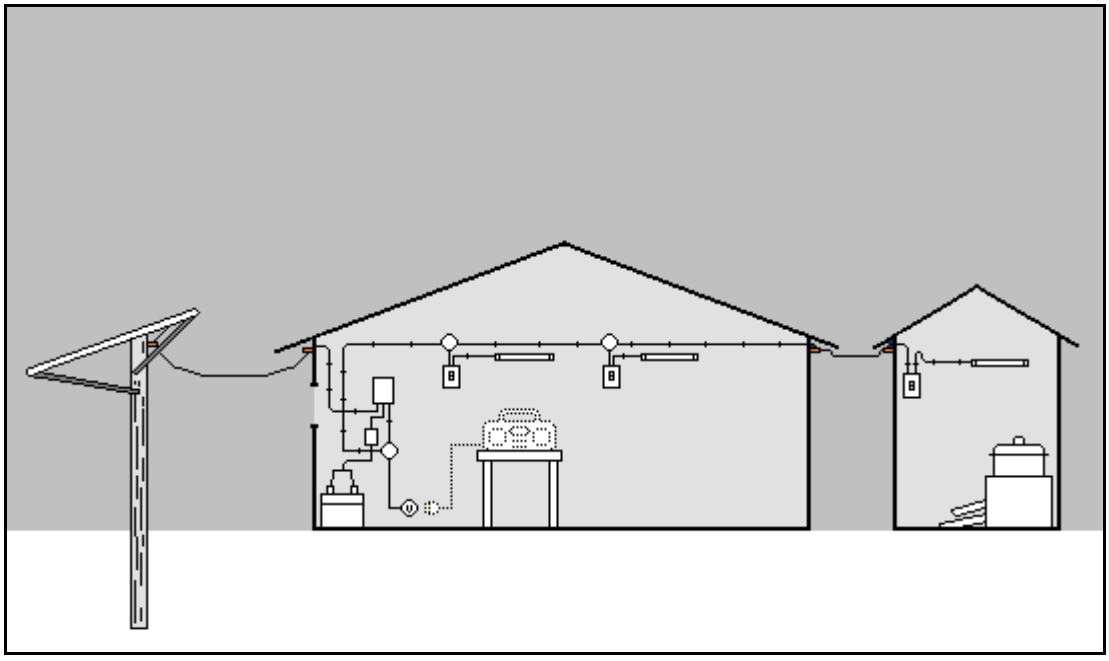
- Final charge voltage : 14.8V

(5) Voltage dropper DC/DC

Available from local market

- 12V → 3, 4.5, 6, 9 V

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



Recommended Pattern of load usage

- Fluorescent lamps : 15W
- Radio : 15W
- B/W TV : 20W

5.2 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 some equipment and materials to be changed as follows:

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

After the inspection and necessary replacement, the first four systems were installed in the chiefs' houses of the communities in La Paz in September 1999 for demonstration and check of the function of the PV system.

An inspection schedule was prepared by the local supplier in consultation with a JICA expert, based on which actual installation work continued during 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.

5.2.1 Reinstallation

The JICA Study Team and VMEH convened the PV supplier and the Management Unit of La Paz and Oruro on February 9, 2000 when the result of the inspection was reported. Solution to the problems, procedure and schedule for re-installation and finalization of the whole installation were discussed. The JICA Study Team suggested the following points to be improved in the re-installation by the local supplier.

1. Some PV poles fixed in the shade of the house
2. Some PV poles not facing the north
3. Insufficient length of wires
4. No junction box
5. Lamps installed outside
6. Connection fixed improper place
7. Voltage dropper fixed improper place
8. Controllers fixed improper place
9. Batteries fixed improper place
10. Batteries insufficient specific gravity
11. Batteries having low voltage
12. PV pole installed at the rooftop of VMEH office be galvanized
13. Radio noise

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.

Regarding the radio noise, the JICA Study Team proposed to install filters by the end of March 2001.

5.2.2 Final Inspection

In the third field survey during May and June 2000, the JICA Study Team chose 27 households (10% of the total 270 households) at random from seven communities in La Paz and two communities in Oruro for final inspection and the inspections were completed on schedule as follows:

Final inspection in La Paz

23 May 2000

1) Sipe Sipe 3 households (out of 25 households installed)
2) Santiago de Hiruyo 3 households (out of 27 households installed)
3) Sanfrancisco de Lallagua 3 households (out of 14 households installed)

25 May 2000

4) Catavi 3 households (out of 12 households installed)
5) Millo 3 households (out of 37 households installed)

30 May 2000

6) Murchapi 3 households (out of 23 households installed)
7) Calteca 3 households (out of 12 households installed)

23 June 2000

8) VMEH rooftop 1 rooftop (one office rooftop installed)

Final inspection in Oruro

26 May 2000

9) Paria Pampita 3 households (out of 18 households installed)

2 June 2000

10) Laguna Ancocota 3 households (out of 44 households installed)

The result of inspection was presented in the meeting at VMEH as follows:

1. The place of battery was not adjusted. (three households: Calteca, Murchapi, Laguna Ancocota)
2. PV holder on the rooftop of VMEH office was not galvanized.
3. Four lamp tubes were found with blackened end. (two tubes in Murchapi, one in Catavi, one in Paria Pampita)

Other than the above, the installation was satisfactory.

The purpose of the final inspection was to check the function of the PV system. The result of the final inspection was basically satisfactory except for some problems reported in the previous section.

Regarding the location of the battery, it was advised to be installed with enough space for efficient operation and maintenance.

It was confirmed that the PV holder on the rooftop of the VMEH office was replaced by the galvanized one on June 23, 2000.

The local supplier replaced blackish lamp tubes upon requests by Operators.

5.2.3 Spare Parts for PV Systems

The 300 PV systems were procured in September 1999. After discussing with the 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 keeps 20 PV systems and Oruro prefecture keeps 10 PV systems as spare parts.

In the fifth field survey, required numbers of the spare parts were modified and reduced from 20 to 5 in La Paz and from 10 to 2 in Oruro.

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

5.2.4 Installation for Public Use

(1) Expected effects

During the fourth field survey, the mayor of Sica Sica Municipality requested to install PV systems for the public facilities using the removed PV systems from the area, where the grid line extended. The expected effects of the proposal are as follows:

- As there is no grid line extended to the public facilities in the area, the installation of the PV system will benefit the social life of the communities.
- The installation of the PV system for the municipality building is to promote and enlighten the community people for the rural electrification by SHS.

Upon approval by JICA Head Office, installation for public use was carried out.

(2) Installation and O&M

The installation both for the public facility (school) and the municipality building was completed in June 2001. High priority of the installation was awarded to schools among public facilities. Because it was the serious problem that teachers in Sica Sica often left schools complaining the inconvenience of the life without basic human needs such as electricity.

The PV systems were installed in ten schools in Sica Sica communities. Lamps were fixed in the teacher's house and classroom at each school. Teachers are enjoying the evening life with light and the radio and may stay longer for the distant duty in the rural areas. Meetings for the community activities were also held in the classroom in the evening.

Sica Sica Municipality pays the power tariff both for Initial Payment and Monthly Fee for 10 schools. The mayor of Sica Sica Municipality appointed three staffs from the municipality as technical assistants to be in charge of operation and maintenance. Three technical assistants visit the schools and are responsible for the operation and maintenance.

PV system at school in Achaya community

One PV system was installed at the terrace of the municipality building in Sica Sica. The training both for the technical assistants from the municipality and

communities and the users were conducted at the office building of Sica Sica Municipality.

For the PV system installed, Sica Sica Municipality pays the Monthly Fee for operation and maintenance and replacement of equipments. Three technical assistants appointed from the staffs of the municipality are directly in charge of the operation and maintenance for the PV system.

Office building of Sica Sica Municiplity

Training the PV system installed at the office of the municipality

Training for technical assistants

CHAPTER 6 OPERATION AND MAINTENANCE OF PV SYSTEM

6.1 Operation and Maintenance System

6.1.1 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 in all the Management Units in La Paz, while Oruro prefecture in all the Management Units in Oruro.

The VMEH-prefecture- JICA Study Team formed a Coordinating Group and were responsible for overall management of the operation and maintenance of the pilot project. The organizations related and their functions are briefly summarized bellow:

(1) Management Unit

- Prefecture (La Paz, Oruro)
  Overall supervision for Management Unit
  Monitoring PV system operation
- Operator (ELFA,COSEP)
  Collect Initial Payment and Monthly Fee
  Management for the Monthly Fee
- REC(Rural Electrification Committee)
  Register members
  Training for REC members
  Responsibility for PV system
- REC Members(User)
  Pay Initial Payment and Monthly Fee to Operator
  Daily OM for PV system

(2) Coordinating Group

- VMEH
  Overall management for the pilot project

Audit the financial matters
Report the financial matters to the JICA Study Team

- Prefecture (La Paz, Oruro)
  Management for the Initial Payment
- JICA Study Team
  Overall management
  Audit the financial matters

6.1.2 User Guide and Training

The JICA Study Team prepared a Users' Guide for PV system and distributed to the users for the purpose of introducing the basic idea and knowledge regarding the PV system for their daily use (refer to Attachment 1).

The orientation for the user guide was conducted on January 23, 2000 at Patacamaya with 70 attendants from three RECS in La Paz. In Oruro, 35 users from three communities attended to the orientation on January 30, 2000. Several staffs in charge of the project including staff from prefectures and Operators attended to the orientations in La Paz and Oruro.

Patacamaya (main city near the sites) in La Pazu

Demonstration for the PV system

The user guidance in Patacamaya

The attendants for the user guidance from Paria REC in 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 the use of the battery and requested careful consumption.

The following are major points of user guide to give the information for safety use and longer lifetime of the system.

- To keep using the PV system at the same level of consumption all year
- To observe water level in the battery
- To report trouble immediately to Operators
- Not to touch and move anything except lights and switches in any case
- Not to let children go close to the battery
- Not to come close to any part of the system in the case of thunder and lightning

Users are to keep the hours in use as indicated in load patterns as follows.

Load Patterns for the Pilot Project

Load Pattern	Lamp only			Lamp& Radio			Lamp &TV		
Numbers of Lamp	1 lamp	2 lamps	3 lamps	1 lamp	2 lamps	3 lamps	1 lamp	2 lamps	3 lamps
Capacity (W)	15	30	45	15+15	30+15	45+15	15+20	30+20	45+20
Use (hours)	7	4+3	3+2+2	4+3	3+2+2	2+2+2+1	4+2	3+2+1	3+1+1+1
Total use (Wh/day)	105	105	105	105	105	105	100	95	95

Source: JICA Study Team

The training of users were conducted in communities both in La Paz and Oruro as follows:

(1) September 1999 : four times

- Calteca (La Paz): 43 attendees
- Hiruyo(La Paz) : 25
- Llallagua(La Paz) : 23
- Pa ria Pampita(Oruro) : 17

(2) January 2000 : three times

- Calteca, Hiruyo,Murcahpi(La Paz): 70 attendees
- Millo, Caytavi(La Paz): 18
- Laguna Ancocota(Oruro): 35

(3) May 2000: four times

- Sipe Sipe, Hiruyo(La Paz): 21 attendees
- Catavi Millo(La Paz) : 23
- Charmani, Chakoma(La Paz) : 18
- Milluni(Oruro) : 15

(4) June 2000: four times

- Catavi, Millo (La Paz): 15 attendees
- Hiruyo, Sipe Sipe(La Paz): 14

- Calteca(La Paz) : 4
- Paria Pampita(Oruro): 3

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

6.1.3 Maintenance Manual and Traning

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 as presented in Attachment 2.

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.

Scheduled Maintenance

- Weekly:
  - To observe battery water level
- Monthly:
  - To inspect array panel for broken panels.
  - To wipe surface of the panel
  - To check and add water to the battery electrolyte
  - To wipe top of the battery
  - To equalize batteries in case that specific gravity difference seen in cells
- Annual:
  - To check array wiring for physical damage, mounting hardware for tightness
  - To inspect wiring for poor connection
  - To inspect battery terminals for corrosion
  - To clean and put grease as needed

Careful maintenance required for batteries

- To make sure the battery enclosure is well ventilated

- To observe water in every cell
- To fill distilled water to the level indicated
- To measure specific gravity of all cells using hydrometer
- To wear gloves and eye protection
- To inspect all terminals for corrosion and loosened cables
- To clean, tighten and cover terminals with grease
- To check all caps for the cells existing or not

Maintenance for the panel

- To check the glass on the PV is not broken
- To wash module surface as needed using soft cloth and water
- To clean in early morning or evening, when the sun is below the horizon
- To check all bolts are secure, that the structure is well attached to pole
- To examine all wiring connection for corrosion or looseness
- To clean and tighten as necessary
- To check that junction boxes are covered
- To inspect module for cells condition

Maintenance for wiring, fixtures and loads

Checking points	To be done in case of trouble
• All items remain as the original	To remove
• Wiring connection for corrosion	To clean
• Wiring connection fastened tight	To fasten
• Wire covering in normal	To taping
• Light bulbs to be clean	To replace
• Circuit breakers function	To repair or replace

The training of Operators were conducted both in La Paz and Oruro as follows:

(1) September 1999 : two times

- ICM(supplier and installer), ELFA(operator in La Paz)
- ICM(supplier and installer),COSEP(operator in Oruro)

(2) January 2000 : two times

- ELFA(La Paz)
- COSEP(Oruro)

(3) May 2000: two times

- ELFA(La Paz)
- COSEP(Oruro)

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

6.2 Power Tariff System

6.2.1 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 checked and 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

Initial payment was to be paid in installment as presented below.

- Before installation Bs. 50 (first payment as registration fee)
- End of Jan. 2000 Bs.100
- End of Mar. 2000 Bs.100
- End of May 2000 Bs.100
- End of Jul. 2000 Bs.100

- End of Sep.2000 Bs.100
- End of Nov. 2000 Bs.100
- End of Jan. 2001 Bs.50

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 to be collected from beneficiaries, which was estimated on the basis of the following conditions:

- Total cost of PV system : US$886 per household
- Manpower cost for OM : US$200 / month
- Maintenance cost per year : 2.5% of total equipment
- Battery : to be replaced every 5 years
- Controller : to be replaced every 7 years
- Operation & Maintenance includes replacement of battery and controller

6.2.2 Modified Payment Scheme

The original payment scheme was modified later in due consideration of the payment situation of users and their capacity to pay.

(1) Monthly Fee

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.

(2) Initial Payment

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.

6.2.3 Individual Contract

For promoting sense of users' ownership and improving the payment situation, an individual contract system was introduced.

There are two contracts; one is for leasing the system between each user and prefecture and the other is for maintenance service between each user and Operator who operates and maintains the PV systems.

According to the contract the ownership of the PV system is as follows.

- Main part of the system:
  PV panel, PV holder and pole, controller, battery, external cables and fixtures are owned by Prefecture
- Internal part of the system:
  Three fluorescent lamps, switches, internal cable and fixtures are owned by users after completion of the Initial Payment.

Forms of the individual contract are presented in Attachment 3 and 4.