Ministry of Energy and Mines

Republic of Peru

Master Plan Study for Rural Electrification by Renewable Energy in the Republic of Peru

Volume 2

Field Study at Pre-feasibility Level

Final Report

August 2008

Japan International Cooperation Agency

Electric Power Development Co., Ltd.
Nippon Koei Co., Ltd.

PREFACE

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

JICA selected and dispatched a study team headed by Mr. Tetsuro TANAKA of Electric Power Development Co., Ltd. (J-Power), and consisted of J-Power and NIPPON KOEI Co., LTD. between February 2007 and August 2008.

The team held discussions with the officials concerned of the Government of Peru and conducted field surveys at the study area. Upon returning to Japan, the team conducted further studies and prepared this final report.

I hope that this report will contribute to the promotion of this project and to the enhancement of friendly relationship between our two countries.

Finally, I wish to express my sincere appreciation to the officials concerned of the Government of Republic of Peru for their close cooperation extended to the study.

August 2008

Seiichi NAGATSUKA,
Deputy Vice President
Japan International Cooperation

August 2008

Mr. Seiichi Nagatsuka
Deputy Vice President
Japan International Cooperation Agency

Letter of Transmittal

We are pleased to submit to you the Final Report on "The Master Plan Study for Rural Electrification by Renewable Energy in the Republic of Peru". Under the contract with your esteemed organization, the Study was conducted by Electric Power Development Co., Ltd. and Nippon Koei Co., Ltd. from February 2007 up to August 2008.

This Final Report compiles a master plan for rural electrification by renewable energy (solar power and mini hydropower) in remote villages difficult of electrification by grid extension scattered mainly in Andes and Amazon areas of Peru. The Master Plan proposes policy propositions on legal/institution, organization, finance, environment and gender issues as well as technical issues of solar power, mini hydropower and transmission/distribution lines regarding promotion of rural electrification. At the same time, a long-term plan was prepared for electrification by renewable energy in unelectrified villages.

It is our sincere hope that this Master Plan will contribute to promotion of rural electrification of Peru and, eventually, to mitigation of poverty and improvement of quality of life of inhabitants of remote villages.

We wish to take this opportunity to express our sincere gratitude to the officials of JICA, the Ministry of Foreign Affairs and the Ministry of Economy, Trade and Industry for their direction and support. We also wish to express our deepest appreciation to the officials of the Ministry of Energy and Mines and other pertinent government organizations of Peru as well as the regional/local governments and village inhabitants where we made visits to conduct our surveys and studies.

Very truly yours,

Tetsuro Tanaka
Team Leader
Master Plan Study for Rural Electrification
by Renewable Energy
in the Republic of Peru

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Map No. 3838 Rev. 1 UNITED NATIONS
September 2000

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Acronyms/Acrónimos	
ADINELSA	Administration Company of Electrical Infrastructure (Empresa de Administración de Infraestructura Eléctrica)
BCS	Battery Charging Station (Estación de Recargo de Batería)
CERER	Renewable Energy Center for Rural Electrification (Centro de Energías Renovales para Electrificación Rural)
CIRA	Certificate of Non-existence of Archaeological Relics (Certificado de Inexistencia de Restos Arqueológicos)
COES	Committee of Economical Operation of the System (Comité de Operación Económica del Sistema)
CONAM	National Council of Environment (Consejo Nacional del Medio Ambiente)
CTE	Electricity Tariff Commission (Comisión de Tarifas Eléctricas)
DEP	Executive Directorate of Projects (Dirección Ejecutiva de Proyectos)
DGER	General Diretorate of Rural Electrification (Dirección General de Electrificación Rural)
DGAAE	General Directorate of Energetic Environmental Affairs (Dirección General de Asuntos Ambientales Energéticos)
DGE	General Directorate of Electricity (Dirección General de Electricidad)
DIGESA	General Directorate of Environmental Health (Dirección General de Salud Ambiental)
DPR	Directorate of Projects (formerly DEP) (Dirección de Proyectos)
DREM	Regional Directorate of Energy and Mines (Dirección Regional de Energía y Minas)
FONCODES	National Fund of Cooperation for Development (Fondo Nacional de Cooperación para el Desarrollo)
FONER	National Fund for Rural Electrification (Fondo Nacional de Electrificación Rural)
FOSE	Electrical Social Compensation Fund (Fondo de Compensación Social Eléctrica)
F/S	Feasibility Study (Estudio de Factibilidad)
INRENA	National Institute of Natural Resources (Instituto Nacional de Recursos Naturales)
ITDG	Intermediate Technology Development Group (Soluciones Prácticas)

Acronyms/Acrónimos	
JBIC	Japan Bank for International Cooperation (Banco del Japón para Cooperación Internacional)
JICA	Japan International Cooperation Agency (Agencia de Cooperación Internacional del Japón)
MEF	Ministry of Economy and Finance (Ministerio de Economía y Finanzas)
MEM	Ministry of Energy and Mines (Ministerio de Energía y Minas)
MP	Master Plan (Plan Maestro)
OM	Operation and Maintenance (Operación y Mantenimiento)
OSINERGMIN	Supervisory Body of Investment in Energy and Mining (Organismo Supervisor de la Inversión en Energía y Minería)
OPI	Planning and Investment Office (Oficina de Programación e Inversiones)
PERNC	Plan of Non-conventional Renewable Energy (Plan de Energía Renovable Non Convencional)
PNER	National Plan of Rural Electrification (Plan Nacional de Electrificación Rural)
Pre F/S	Prefeasibility Study (Estudio de Prefactibilidad)
PSE	Small Electrical System (Pequeño Sistema Eléctrico)
SENAMHI	National Meteorology and Hydrology Services of Peru (Servicio Nacional de Meterorología e Hidrología del Perú)
SHS	Solar Home System (Sistema Fotovoltaico Domiciliario)
SIER	Information System for Rural Electrification (Sistema de Información de Electrificación Rural)
SNIP	National System of Public Investment (Sistema Nacional de Inversión Pública)
SPERAR	Peruvian Solutions to Rural Electrification in Isolated and Frontier Areas with Renewable Energies (Soluciones Peruanas a Electrificación Rural en las Areas Aisladas y de Frontera con Energías Renovables)
UNDP/GEF	United Nations Development Program/Global Environment Facility (Programa de Naciones Unidas de Desarrollo/ Fondo para el Medio Ambiente Mundial)
VAD	Value Added for Distribution (Valor Agregado de Distribución)

Volume 2 Field Study at Pre Feasibility Level

III. Field Study at Pre Feasibility Level

The field studies at prefeasibility level conducted on 2 solar power sites and 2 mini hydropower sites in this Master Plan are aimed to grasp the actual conditions of the specific villages in order to prepare the long-term electrification plan described in the Chapter II-1.6 “Rural Electrification Plan”of this Final Report Volume I. Such parameters as power demand, design, cost, tariff, managing organization are standardized to apply to the said electrification plan of unelectrified villages.

III-1 PV System (San Juan in Puno Region)

III-1.1 Natural Conditions

Sun Juan village is located in the valley from 170 km north of Puno city. The altitude of Sun Juan is as high as over 4,000 meters above sea level. Annual average temperature of Juliaca, located around 150 km away from Sun Juan, is as low as around 10°C. The annual precipitation is as small as 576.5 mm. Therefore, it can be said that the feature of climate at Sun Juan is low temperature and dry. The annual ambient temperature, precipitation and sunshine duration in Juliaca are shown in Table III-1.1-1.

The Table III-1.1-2 shows monthly average of solar irradiation in Puno. The average of annual solar irradiation is 5.2 kWh/m^2. It is obvious that solar irradiation in Puno is high compared to that of Tokyo at 3.5 kWh/m^2. Maximum monthly average of solar irradiation was recorded in October and November at 6.0 kWh/m^2 and that of minimum is recorded in June at 4.4 kWh/m^2.

Table III-1.1-1 Monthly Average of Temperature, Precipitation and Sunshine Duration

Month	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ambient Temperature (°C)	10.2	10.3	10.4	9.1	5.2	3.3	3.1	5.7	7.8	9.4	10.1	11.0	8.0
Precipitation (mm)	238.4	96.3	69.4	28.2	0	0.2	1.5	24.3	38.5	7.2	17.6	72.0	49.5
Sunshine Duration (hours)	149.8	196.9	214.7	243.8	299.0	243.4	266.0	241.3	256.0	291.5	276.4	263.6	245.2

Source: SENAMHI 2004

Table III-1.1-2 Monthly Average of Solar Irradiation (Puno)

Month	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Irradiation (kWh/m^2)	5.1	5.2	5.1	5.1	4.6	4.4	4.6	5.0	5.5	6.0	6.0	5.6	5.2

Source: Generacion de Electricidad a pequeña escala con Energia Solar Fotovoltaica, CENERGIA and ECOFYS

III-1.2 Social and Economic Conditions and Gender Issues

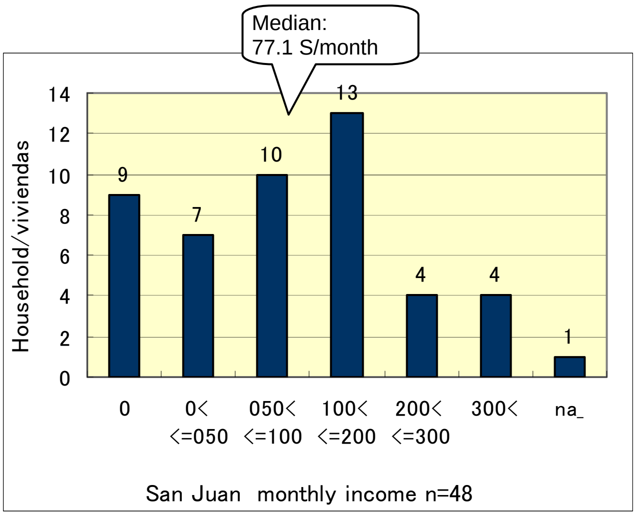
1. Community (Localidad) and Population

- San Juan is located in the catchment area of Rio San Juan with the altitude of 4,020 m to 4,040 m above sea level. The catchment area consists of five communities, one of which is San Juan.
- The accurate population of San Juan is in question. Though Database of MEM shows that the number of households of San Juan is 60, community elders said it might be 150 and the population is between 450 and 500. The Antauta District Office has the data of the latest census (21st October 2007) but it was not open to the JICA study team when they visited it in February 2008.
- There is one primary school in San Juan, also, there is a room used as temporary health post.

2. Industry and Main Income Sources

Due to the high altitude, agriculture is difficult to yield good harvest. Almost all households cultivate potato and cañahua (green vegetable) as staple food for domestic use.

- Main income sources are sale of animals and milk. A household possess 7.1 llamas and 28.5 heads of sheep and 6.2 heads of cow in average.
- Also, some crops such as potato, cañihua and quinua (bean) are sold.
- Income distribution is shown in the figure below.



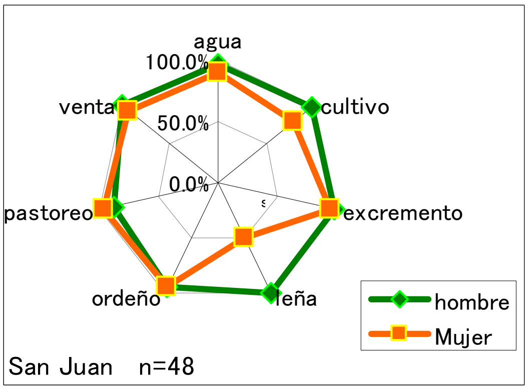
Note: data is estimated by accumulation of product sales and possibly less than the real income.
Source: JICA study team, 2008

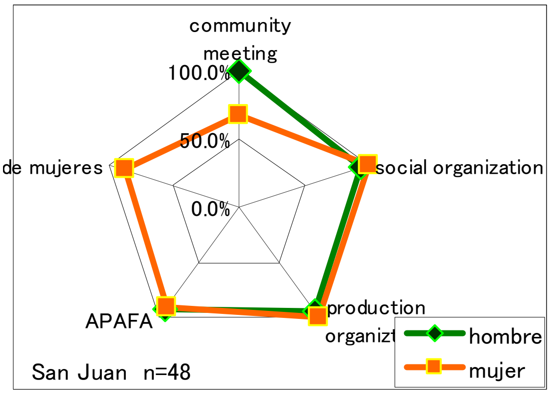
Fig. III-1.2-1 Income Distribution in San Juan

3. Gender

Prof. Tomoeda[1] wrote that the gender difference in work, right and duty, and role is very small in Andean farmer society (1985). The survey result indicates that, except firewood (leña) collection and participation in community meeting, both women and men work for livelihood activity and social activity in San Juan. Comparing with other surveyed areas, gender equality is higher than other sites. It may mean that they have higher potential to achieve gender equality in electrification project if capacity building of technical and management is properly given to them. Fig. III-1.2-2 shows the actual situation.

[1] Tomoeda, Hiroyasu, 1986, "Ox and Condor", Tokyo.





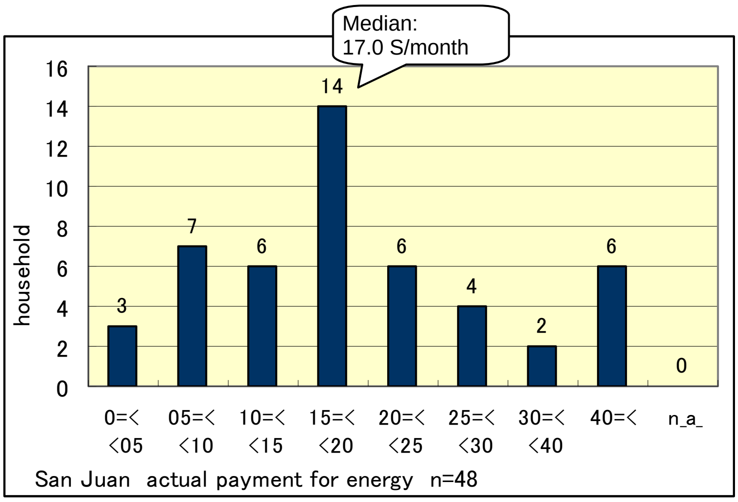
Source: JICA study team 2008

Fig. III-1.2-2 Gender Distribution in Daily Livelihood Activity (left) and Social Activity (right)

III-1.3 Demand of Electricity and Affordability

1. Actual Energy Use

- Candle is the first energy for lighting and followed by battery torch and kerosene lamp.
- No household possesses television set but 41 households (85.4% of all respondents) listen to the radio.
- Monthly payment for energy is 17.0 Soles on median at present.



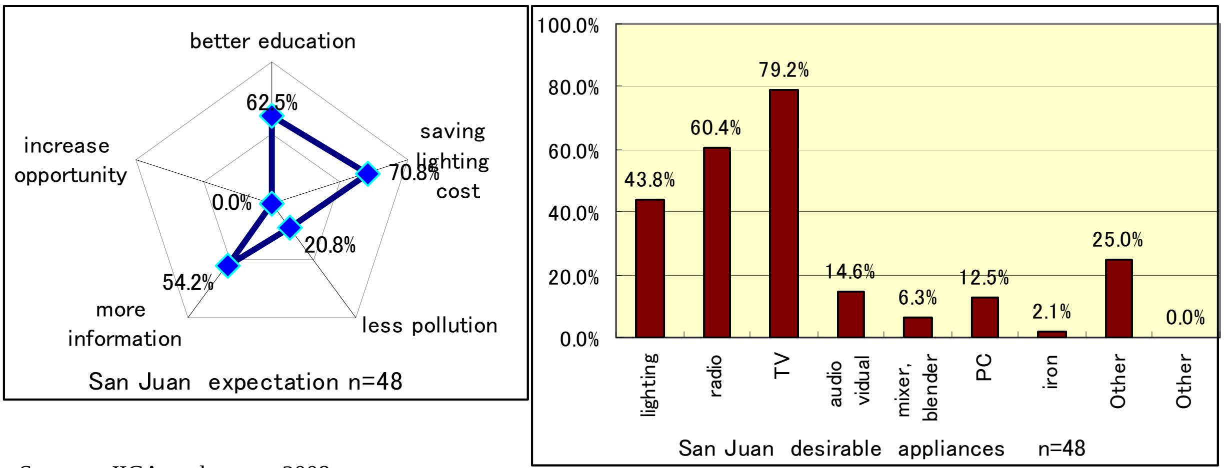
Source: JICA study team 2008

Fig. III-1.3-1 Actual Payment for Energy

2. Intention of Electrification

- Inhabitants of San Juan said that the late mayor of Antauta District declared to them that the district would implement electrification by grid extension next year (2008). However, according to the mayor and staff of district office, there is neither concrete plan nor budget of grid extension.

- Inhabitants intended to supply electricity to their communities by extending line from the national grid. Many of them think that it is cheaper by transmission line (7-8 Soles per month, in the case of near town) than 18 Soles per month for PV system estimated in the master plan.
- Community survey revealed that only 41.7% of interviewed people knew what renewable energy was even though many persons heard about solar panel. After the JICA study team explained to them about PV system and the draft implementation plan of San Juan, inhabitants began to be interested in electrification by PV system but they wanted that not only San Juan but all five communities in the same catchment basin would be electrified in the project.
- Inhabitants of San Juan expect first that they will be able to reduce expenses for light after electrification and then, get better education thanks to light and electric appliances, and get more information by TV and radio. Thus, the electric appliance that they want to buy first is TV (color and B&W), radio and lights. Intention to buy PC is rather high than other sites.
- Inhabitants eagerly want to develop industry, especially cheese production, by using electricity. Productive use is an important incentive to the sustainable electricity use and MEM recommends it. However, at present, neither cheese nor milk is used as commercial good due to the poor pasture and low technology.



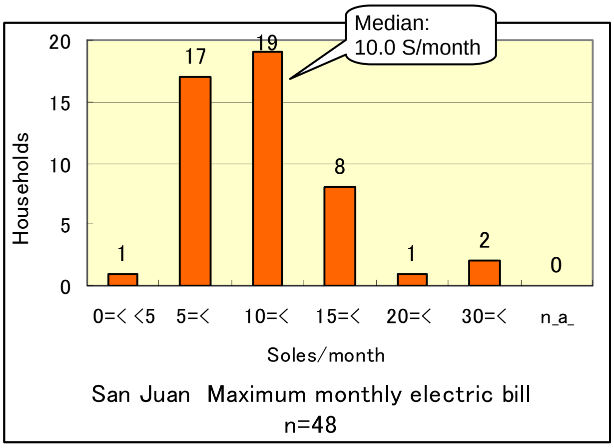
Source: JICA study team, 2008

Fig. III-1.3-2 Expectation of Electrification (left) and Desirable Electric Appliances (right)

3. Affordability

- The result of the community survey shows that the maximum amount that the respondent can pay every month for electricity is 10.0 Soles in median (10.9 Soles on average). It is 58.8% of actual payment for energy and 13.0% of monthly income (comparison by median). This is one of the reasons why inhabitants want electrification by extension of grid line (the monthly payment in the near electrified town is approximately 7 soles per month.)

- Inhabitants think that the Ministries should pay for electricity bill of school and health post that the draft master plan proposes.
- More than 80% of respondents say that they prefer to pay every month.



Source: JICA study team 2008

Fig. III-1.3-3 Maximum Affordable Monthly Electric Bill

III-1.4 Comparison of Initial Investment Amount by Electrification Method

The team studied the electrification method most suitable to the location, taking the number of the households as parameter. The assumption is as follows;

<Assumption>

[Village Information]	Number of Localidad	:	1
	Number of User	:	100 (Tentative)
	Connecting Rate	:	0.8
[Grid Extension]	Length of Linea Primarias from end of Existing Grid	:	11.93 (km)
	Linea Primarias	:	4,700 (US$/km)
	Redes Primarias	:	90 (US$/User)
	Redes Secundaria	:	480 (US$/User)
[Photovoltaic]	PV	:	780 (US$/User)

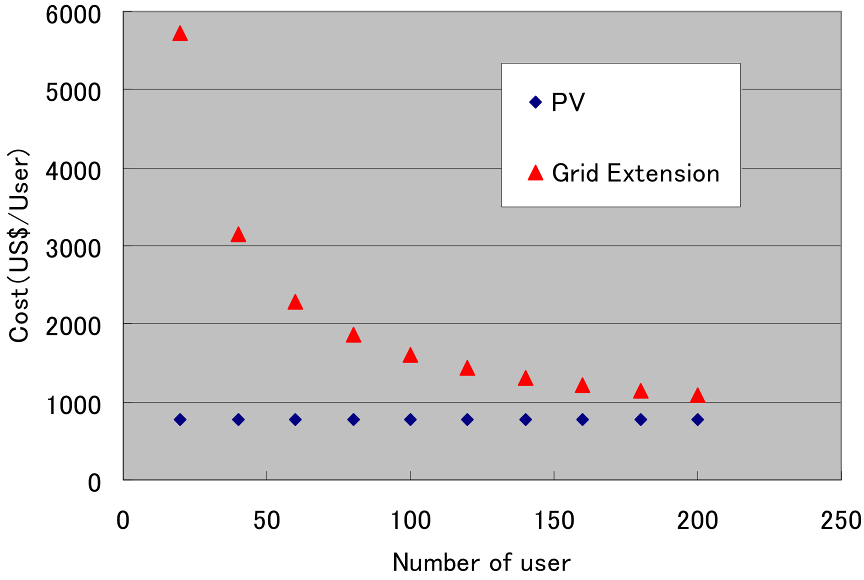


Fig. III-1.4-1 Comparison of Initial Investment Amount by Electrification Method (1)

The number of the households targeted to be electrified at this location is 80 (Household: 100, Target rate: 0.8). As Fig. III-1.4-1 shows, PV is more preferable to grid extension for electrification method in terms of initial investment amount.

Furthermore, not only initial investment amount but operation & maintenance expense, future power usage expected in a productive manner, and future socio- economic development at this location should be studied to decide the most appropriate method of electrification.

III-1.5 Design and Cost

III-1.5.1 Design

1. Result of Household Survey

Household survey was carried out for 45 households out of 200 households in Sun Juan. The results are shown in the tables below. In Sun Juan, 23 soles are being paid for the basic energy consumption such as kerosene lamp and candle for lighting, dry cell battery for radio. The average of lighting hours is 2 hours 43 minutes and that of radio is 3 hours 15 minutes. On the other hand, affordability of payment for electricity is as small as 12 soles per month. Most of the households require more than 2 lights after electrified. All of the households answered that they expected use of radio and 60% of the respondents television after electrified. Around 50% of the respondents are expecting power supply by pay for service, 20% of the respondents are expecting battery charging station. In addition, there is a plan for extension of power grid line in Sun Juan, so that 24% of the respondents are expecting grid extension instead of PV system. In Sun Juan, the locations of households are scattered because the main economical activity is grazing of domestic livestock. The interviewed households are located within 4.5 km × 7.0 km as shown in Fig. III-1.5.1-1.

Monthly expenditure for energy

(sol/Mo.)

Lighting	(candle, kerosene, etc)	14.9
Radio	(dry cell battery)	7.8
Lighting + Radio		22.7

Average of energy consumption hours for lighting and radio

Lighting	2 hr. 43 min.
Radio	3 hr. 15 min.

Expecting power consumption hours after electrified

	hours	household
Room 1	2 hr. 46 min.	100%
Room 2	2 hr. 43 min.	96%
Room 3	2 hr. 34 min.	47%
Outside	2 hr. 25 min.	56%
Radio	5 hr. 30 min.	100%
TV	3 hr. 42 min.	60%

System for payment

System owner (US$750 cash)	0%
System owner (US$750 loan)	2%
Fee for service 18 (s/mo.)	53%
Battery charge 1.5 (s/charge)	20%
No interest for PV system	24%

In the field study at pre-feasibility level, the number of target households is decided as 100 households. In the plan, the number of users is decided as follows. For SHS users, 50% of the target households, so that 50 households are the target of households. For BCS users, 20% of the target households, 20 households are the target number of households. The other 30% of households can receive services through electrified public facilities such as rural school and health clinic.

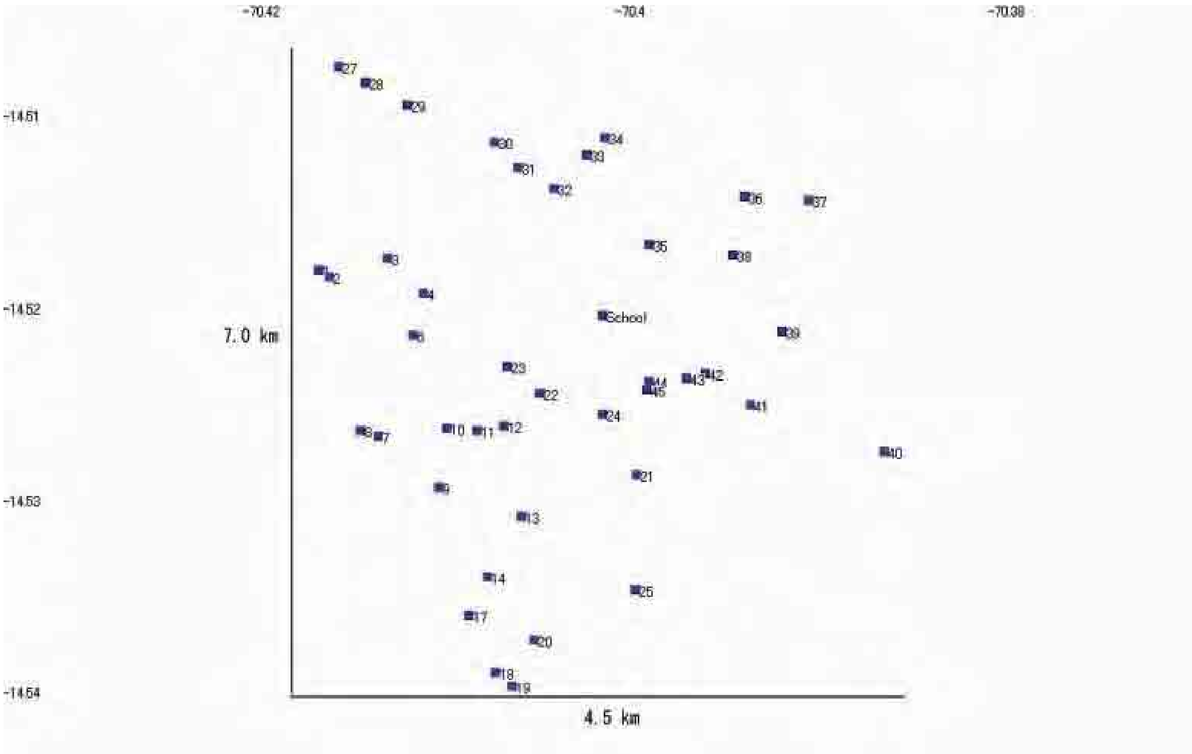


Fig. III-1.5.1-1 Location of Interviewed Households

2. Solar Irradiation Potential

The capacity of PV system is designed based on the smallest monthly solar irradiation in June. For the design of PV system, the tilting angle of PV module in the smallest irradiation month was calculated to make larger irradiation value from the latitude and longitude with the globe model. Fig. III-1.5.1-2 shows the relation between tilting angle and surface irradiation at Puno. The result shows the optimum tilting angle in Puno is 10 degrees.

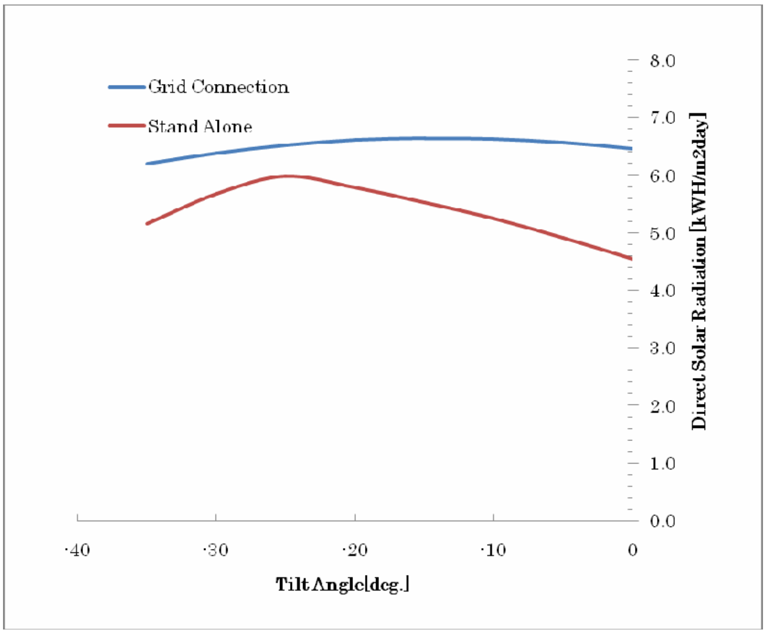


Fig. III-1.5.1-2 Solar Irradiation vs. Tilting Angle (Puno)

Table III-1.5.1-1 Monthly Irradiation (horizontal, tilting angle 10 deg.)

Month	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Irradiation Horizontal (kWh/m^2)	5.1	5.2	5.1	5.1	4.6	4.4	4.6	5.0	5.5	6.0	6.0	5.6	5.2
Irradiation tilt angle 10 degree	4.8	5.1	5.2	5.5	5.2	5.1	5.3	5.5	5.8	6.0	5.7	5.2	5.4

Source: JICA study team

3. Structure of Household

The following drawing shows a typical household in Sun Juan. Most of the households are constructed by stone or brick of sun-dried mud. The roof is made by galvanized iron or straws. Most of the families own more than two house buildings; bed room and kitchen are separated. Sun Juan is located at a high altitude, therefore many house buildings have no windows. In the case of windows installed at house buildings, the window is small. Additionally, the size of door is small to keep warm temperature in the room. Due to the construction mentioned above, the inside of the room is dark because it is difficult to receive light from outside of the building. For SHS user, it is necessary to install one light in one building. Therefore, wiring works out of buildings are necessary. Fig. III-1.5.1-3 shows an example of wiring work. Photo III-1.5.1-1 ~ Photo III-1.5.1-3 show typical households.

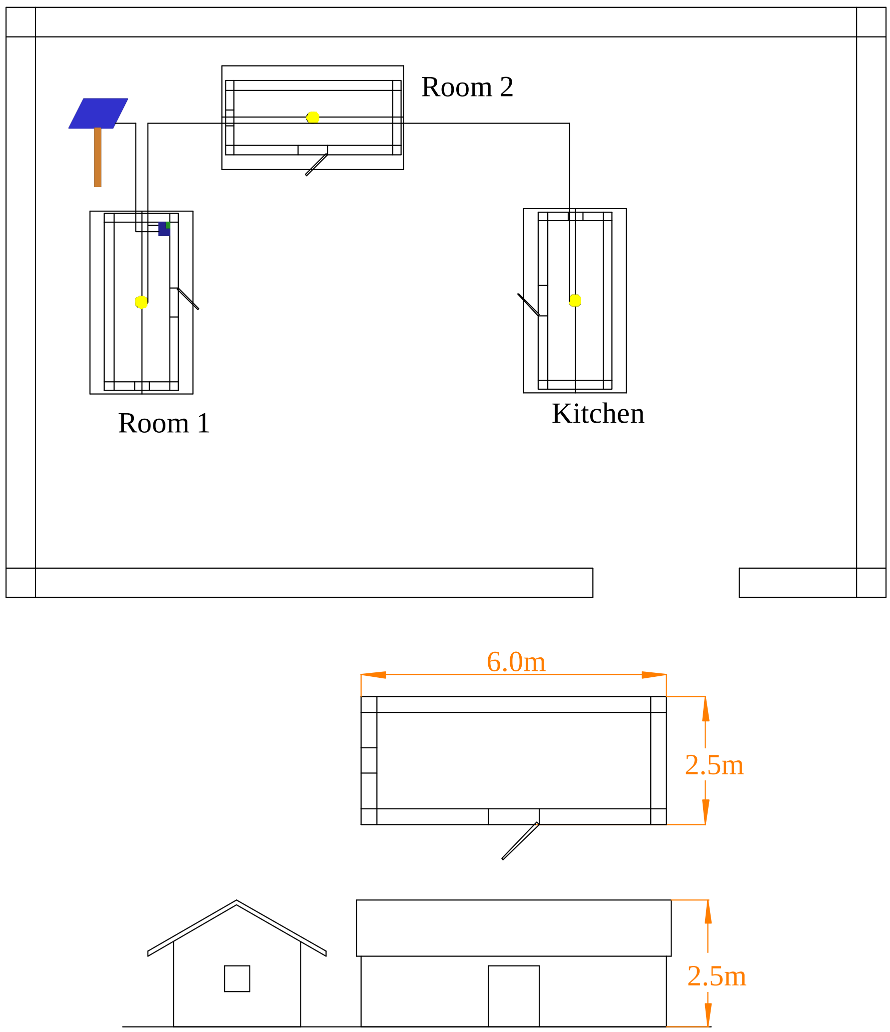


Fig. III-1.5.1-3 Example of Household and Wiring (Sun Juan)

Photo III-1.5.1-1 Household Made by Stone

Photo III-1.5.1-2 Household Made by Bricks of Sun-dried Mud

Photo III-1.5.1-3 Household at the Center of Village

III-1.5.2 Design of SHS

1. Power Demand

The table below shows power demand of a household that consists of three house buildings under the condition of minimum monthly irradiation. LED is applied as night light or outside light. Power demand of radio is 4 hours at minimum irradiation month, and demand of TV is not considered. However, it is possible to use radio for longer time when solar irradiation is strong and the household that does not need much energy for lighting. Table III-1.5.2-1 shows power demand.

Table III-1.5.2-1 Power Demand

Demand	Rated power (W)	Hours (hours/day)	Power consumption (Wh/day)
Room 1: Fluorescent Light (1)	12	3	36
Room 2: Fluorescent Light (2)	12	3	36
Kitchen: Fluorescent Light (3)	12	2	24
LED	2	8	16
Radio	10	4	40
			152
System voltage	12	V	
Total Demand	**12.7**	**Ah/day**	

2. Estimated Power Output

The table below shows estimated monthly power output from 50 Wp of SHS at Sun Juan. For the design of PV system, power output was estimated based on the solar irradiation in January. Therefore, there is surplus power output in the other months. It is possible to use radio or black-white TV (20 W) by the surplus power output

Table III-1.5.2-2 Estimated Power Output (50 Wp)

Month	Irradiation (kWh/m^2-day)	Power Output (kWh/day)	Power Output (Ah/day)	Monthly Output (kWh/Mo)
Jan	4.8	0.18	15.0	5.6
Feb	5.1	0.19	15.9	5.3
Mar	5.2	0.20	16.3	6.0
Apr	5.5	0.21	17.1	6.2
May	5.2	0.19	16.1	6.0
Jun	5.1	0.19	15.8	5.7
Jul	5.3	0.20	16.3	6.1
Aug	5.5	0.21	17.1	6.4
Sep	5.8	0.22	17.9	6.5
Oct	6.0	0.22	18.6	6.9
Nov	5.7	0.21	17.9	6.4
Dec	5.2	0.20	16.3	6.1
Average	**5.4**	**0.20**	**16.7**	**6.1**

Annual: 73.1 (kWh/year)

Power output (kWh/day) = PV capacity (Wp) × K × Solar irradiation (kWh/m^2-day)

(K = K1 × K2 × K3 × K4 × K5 × K6)

Design loss

K1:	Temperature correction coefficient	(10°C)	1.08
K2:	Module derating factor	normally 0.9~0.95	0.9
K3:	Power loss (PV module to battery)	normally 0.95	0.95
K4:	Controller		0.95
K5:	Battery Charge/discharge		0.9
K6:	Power loss (Battery to demand)		0.95

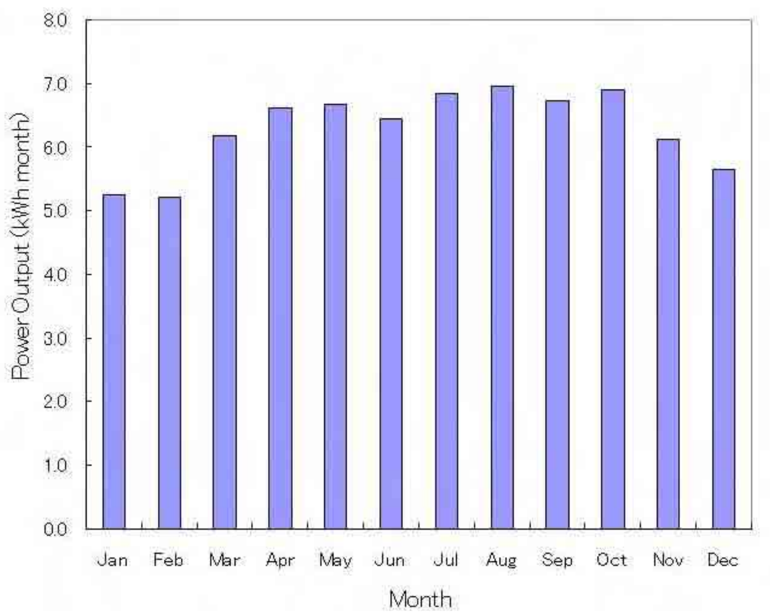


Fig. III-1.5.2-1 Estimated Power Output

3. System Design

Battery Capacity

Cu = (Autonomous day +1) (Daily consume) / PD max

= 95 Ah ≒ 100 Ah

Autonomous day	:	2 days
PD max	:	40%
Daily consume	:	13.4 Ah/day

Summary of system

PV module	:	50 Wp
Controller	:	10 A
Battery	:	100 Ah
Fluorescent Light	:	12 W × 3
LED	:	2 W × 1
DC/DC converter	:	input 12 V - output 1.5 V, 3 V, 4.5 V, 6 V, 9 V

III-1.5.3 Design of BCS

1. Power Demand

BCS is the facility that user bring their own battery to charge. The users bring back the charged battery to home then use in their houses. The amount of electrical consumption by BCS is smaller than that of SHS users due to no power station at their houses. And, the amount of power consumption increases with the capacity of battery. For the design of BCS, use of car battery is considered because it is easy to obtain. The battery is heavy; the weight is around 25 kg at 70 Ah. In rural areas, many old people are living and in most of the cases there are no transportation method except walking. The table below shows power demand of the battery with capacity of 70 Ah.

Table III-1.5.3-1 Power Demand (70 Ah)

Demand	Rated power (W)	Hours (hours/day)	Power consumption (Wh/day)
Fluorescent Light (1)	12	3	36
Fluorescent Light (2)	12	1.5	18
LED	2	10	20
Radio	10	1	10
Total			**84**

System voltage : 12 V

Demand (Ah) : 7.0 Ah/day

Charging interval : 4 days

Solar Insolation : 4.8 h/day (January)

Necessary current I_N (Ah) = Battery capacity (70 Ah) × K6 / (K1 × K2 × K3 × K4 × K5)

= 47.9 Ah/day

K1:	Temperature correction coefficient	1.08
K2:	Module derating factor	0.90
K3:	Power loss (PV module to battery)	0.95
K4:	Controller	0.95
K5:	Battery Charge/discharge	0.90
K6:	Depth of discharge	40%

2. Generation System

The number of necessary PV modules for charging different capacity of battery is calculated based on the power demand and minimum monthly solar irradiation. The following table shows PV module and current at maximum power point for the calculation.

Number of PV module N = I_N / (I_{pmax} × Solar insolation × K1 × K2 × K3 × K4 × K5)

Table III-1.5.3-2   Current at Maximum Power Point

PV module (Wp)	I_{pmax} (A)
50	3.0
80	4.6
130	7.4

The following table shows the necessary number of PV modules and the cost for 70 Ah and 50 Ah battery users. For a battery charging station, two of 130 Wp PV modules are used for a battery charging system due to high solar irradiation potential in Sun Juan.

Table III-1.5.3-3   Necessary Number PV Module for Battery Charging

PV module		Battery (50 Ah)		Battery (70 Ah)	
Capacity (Wp)	Unit price (US$)	Necessary number of PV module	Price of PV array	Necessary number of PV module	Price of PV array
50	320	3	960	4	1,280
80	480	2	960	3	1,440
130	600	1	600	2	1,200

Power output (kWh/day) = PV capacity (Wp) × K × Solar irradiation (kWh/m^2-day)
= 878 Wh/day = 73 Ah/day
(K = K1 × K2 × K3 × K4 × K5 × K6)

3. System Design

Summary of System (BCS)

Household	:	4 households / system
PV module	:	130 Wp × 2 modules
Controller	:	20 A

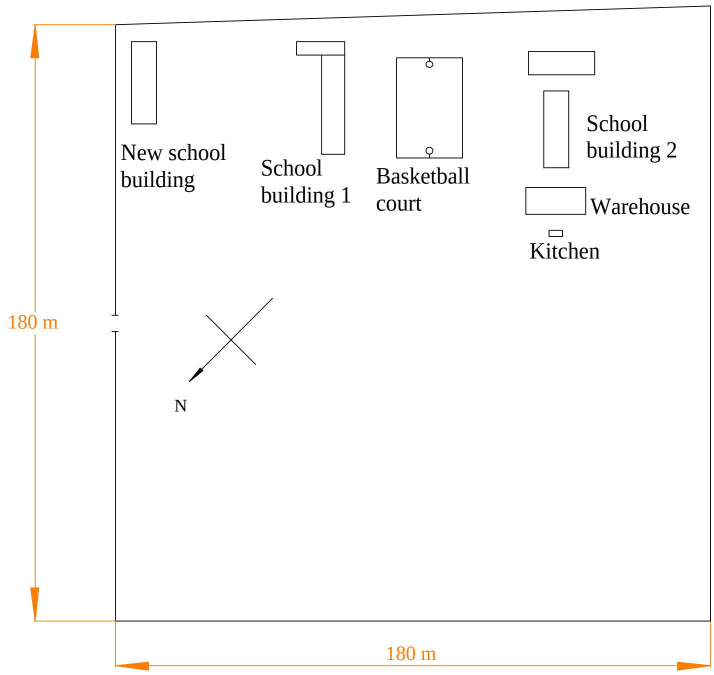
Household

Battery	:	50 Ah, 70 Ah
Fluorescent Light	:	12 W × 3
LED	:	2 W
DC/DC converter	:	input 12 V - output 1.5 V, 3 V, 4.5 V, 6 V, 9 V
Voltage meter	:	DC

III-1.5.4 Design of Rural School

1. Power Demand

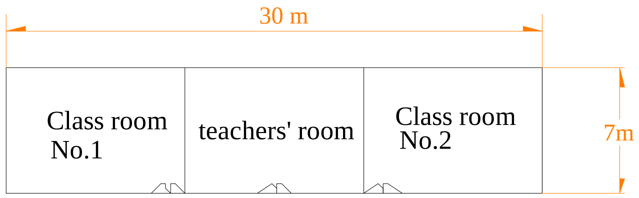
In Sun Juan, a school with a large area is located at the center of village. The following picture shows the school. There are five buildings in the school area. School buildings 1 and 2 are being used for education when the study was carried out. The area is large enough to install PV system near the school buildings.



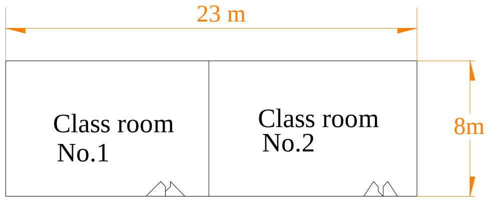
New school building

School building being used: building 1 (front), 2 (back)

Fig. III-1.5.4-1 Rural School in Sun Juan



School building 1



School building 2

Fig. III-1.5.4-2 Classroom

The power demand is estimated based on the class rooms currently being used. Installation of lights is necessary in four class rooms and one teacher's room. Totally 20 lights, four lights by five rooms, are estimated. And also, there are no classes in the evening, so the using hours are estimated as four hours. The number of PC is estimated as three and using for three hours.

Table III-1.5.4-1 Power Demand for Rural School (4 class room + 1 teacher's room)

Demand	Rated power (W)	No.	Hours (hours/day)	Power consumption (Wh/day)
FC-light	12	20	5	1,200
PC	300	3	3	2,700
Printer	300	1	1	300
TV	60	1	4	240
DVD	40	1	1	40
Inverter – self consumption	7.5	1	10	75
				4,555
Inverter efficiency	90%			
Total power demand	5,061	Wh/day		
System voltage	48	V		
Total demand	**105.4**	**Ah/day**		

2. Estimated Power Output

The table below shows the estimated monthly power output for PV system at the rural school. For the design of PV system, the power output was estimated based on the solar irradiation in January. Therefore, there is surplus the power output in the other months. It is possible to use for battery charge or some tool machines by the surplus power output.

Table III-1.5.4-2 Estimated Power Output (Rural School)

Month	Irradiation (kWh/m^2-day)	Power Output (kWh/day)	Power Output (Ah/day)	Monthly Output (kWh/Mo)
Jan	4.8	5.41	112.6	167.6
Feb	5.1	5.71	119.0	159.9
Mar	5.2	5.85	121.9	181.4
Apr	5.5	6.16	128.3	184.8
May	5.2	5.80	120.9	179.9
Jun	5.1	5.68	118.4	170.5
Jul	5.3	5.89	122.6	182.4
Aug	5.5	6.16	128.4	191.0
Sep	5.8	6.45	134.4	193.5
Oct	6.0	6.71	139.7	207.9
Nov	5.7	6.43	134.0	193.0
Dec	5.2	5.88	122.5	182.3
Average	**5.4**	**6.01**	**125.2**	**182.9**

Annual: 2,194.3 (kWh/year)

Power output (kWh/day) = PV capacity (Wp) × K × Solar irradiation (kWh/m^2-day)
(K = K1 × K2 × K3 × K4 × K5 × K6 × K7)

K1:	Temperature correction coefficient		1.08
K2:	Module derating factor	normally 0.9~0.95	0.9
K3:	Power loss (PV module to battery)	normally 0.95	0.95
K4:	Controller		0.95
K5:	Battery Charge/discharge		0.9
K6:	Power loss (Battery to demand)		0.95
K7:	Inverter		0.9

System voltage 48 V

3. System Design

Battery capacity

Cu = (Autonomous day +1) (Daily consume) / PD max
= 791 Ah ≒ 800 Ah

Autonomous day : 2 days
PD max : 40%
Daily consume : 105.4 Ah/day

Summary of system (rural school)

PV module : 1.5 kWp (130 Wp 3 × 4)
Controller : DC 48 V, 40 A
Battery : 48 V, 800 Ah (800 Ah, 2 V × 24)
Inverter : 2,500 W
Fluorescent Light : 12 W × 20
Computer : 300 W × 3
Printer : 300 W × 1
TV : 60 W × 3
DVD : 40 W × 1

III-1.5.5 Design of Rural Health Clinic

1. Power Demand

There are two types of electrical demand at the rural health clinic, DC and AC. Vaccine refrigerators operated by DC power from PV system are already developed and widely used in developing countries thorough activity of WHO and so on. Operation of refrigerator by AC power in PV system is not suitable due to inrush power from the motor. Also, communications radio can be operated by DC power. The other equipments will be operated by AC power.

Table III-1.5.5-1 Power Demand (DC)

Demand	Rated power (W)	No.	Hours (hours/day)	Power consumption (Wh/day)
Vaccine refrigerator	60	1	12	720
Communication radio : stand-by	2	1	12	24
: transmitting	30	1	1	30
Total				**774**

Table III-1.5.5-2 Power Demand (AC)

Demand	Rated power (W)	No.	Hours (hours/day)	Power consumption (Wh/day)
FC-light	12	8	6	576
PC	300	1	4	1,200
Printer	300	1	1	300
TV	60	1	5	300
DVD	40	1	1	40
Inverter-operation	7.5	1	8	60
Total				**2,416**

Total : 3,190 (Wh/day)

2. Estimated Power Output

The table below shows the estimated monthly power output for PV system at the rural health clinic. For the design of PV system, the power output was estimated based on the solar irradiation in January. Therefore, there is surplus power output in the other months. It is possible to use for battery charge or some tool machines by the surplus power output.

Table III-1.5.5-3 Estimated Power Output (Rural health clinic)

Month	Irradiation (kWh/m^2-day)	Power Output (kWh/day)	Power Output (Ah/day)	Monthly Output (kWh/Mo)
Jan	4.8	3.60	75.1	111.7
Feb	5.1	3.81	79.3	106.6
Mar	5.2	3.90	81.3	120.9
Apr	5.5	4.11	85.6	123.2
May	5.2	3.87	80.6	119.9
Jun	5.1	3.79	78.9	113.7
Jul	5.3	3.92	81.7	121.6
Aug	5.5	4.11	85.6	127.3
Sep	5.8	4.30	89.6	129.0
Oct	6.0	4.47	93.1	138.6
Nov	5.7	4.29	89.3	128.7
Dec	5.2	3.92	81.7	121.5
Average	**5.36**	**4.01**	**83.5**	**121.9**

Annual: 1,462.8 (kWh/year)

Power output (kWh/day) = PV capacity (Wp) × K × Solar irradiation (kWh/m^2-day)
(K = K1 × K2 × K3 × K4 × K5 × K6 × K7)

K1:	Temperature correction coefficient		1.08
K2:	Module derating factor	normally 0.9~0.95	0.9
K3:	Power loss (PV module to battery)	normally 0.95	0.95
K4:	Controller		0.95
K5:	Battery Charge/discharge		0.9
K6:	Power loss (Battery to demand)		0.95
K7:	Inverter		0.9

System voltage 48 V

3. System Design

Battery Capacity

Cu = (Autonomous day +1) (Daily consume) / PD max
= 540 Ah ≒ 600 Ah

Autonomous day	:	2 days
PD max	:	40%
Daily consume	:	72.1 Ah/day

Summary of system (Rural health clinic)

PV module	:	1.0 kWp (130 Wp 3 × 3)
Controller	:	DC 48 V, 40 A
Battery	:	48 V, 600 Ah (600 Ah, 2 V × 24)
Inverter	:	1,000 W
Fluorescent Light	:	12 W × 8
Computer	:	300 W × 1
Printer	:	300 W × 1
TV	:	60 W × 1
DVD	:	40 W × 1
Vaccine refrigerator	:	600 W × 1 (DC 12 V)
Communications radio	:	30 W (DC 12 V)

III-1.5.6 Cost

1. Cost of Equipment

SHS: for 50 households

Table III-1.5.6-1 System Cost (SHS)

Item			No.	Unit	Price (US$)
PV panel	50	Wp	1	250	250
Controller	10	A	1	40	40
Battery*1	100	Ah	1	110	110
FC-light	12	W	3	20	60
LED	2	W	1	20	20
DC-DC converter	12	V	1	15	15
Accessories (wire, pole etc.)	1	set			125
Installation & Transportation	10	%			62
Total					**682**

*1: Battery is Deep-Cycle Battery (made in Bolivia)

BCS: for 20 households

Table III-1.5.6-2 System Cost (BCS)

Item			No.	Unit	Price (US$)
PV module	130	Wp	10	600	6,000
Controller:	20	A	5	80	400
Accessories (wire, pole etc.)	8	%	1	125	512
Installation & Transportation	10	%	1	62	640
Total					**7,552**

Table III-1.5.6-3 System Cost (BCS: wiring work in households)

Item			No.	Unit	Price (US$)
Battery:	70	Ah	1	100	100
Fluorescent Light:	12	W	2	20	40
LED:	2	W	1	20	20
DC/DC converter:	12	V	1	15	15
Voltage meter:	DC 12 V		1	10	10
Accessories (wire, pole etc.)	8	%			15
Installation & Transportation	10	%			19
Total					**219**

Rural school:

Table III-1.5.6-4 System Cost (rural school)

Item			No.	Unit	Price (US$)
PV module: (130 Wp × 12)	1.5	kWp	12	600	7,200
Controller: (48 V)	60	A	1	500	500
Battery: (48 V)	700	Ah	24	320	7,680
Inverter:	2,500	W	1	2,000	2,000
Fluorescent Light:(AC)	12	W	15	7	105
Computer:	300	W	3	540	1,620
Printer:	300	W	1	100	100
TV:	60	W	1	180	180
DVD:	40	W	1	60	60
Grounding materials	100	Ω	1	600	600
Accessories Cost: (wire, etc.)	8	%			1,604
Installation & Transportation	10	%			2,005
Total					**23,653**

Rural health clinic:

Table III-1.5.6-5 System Cost (rural health clinic)

Item			No.	Unit	Price (US$)
PV module:(130 Wp × 9)	1	kWp	9	600	5,400
Controller: (48 V)	60	A	1	500	500
Battery: (48 V)	600	Ah	24	300	7,200
Inverter:	1,000	W	1	1,000	1,000
Fluorescent Light:	12	W	8	7	56
Computer:	300	W	1	540	540
Printer:	300	W	1	100	100
TV:	60	W	1	180	180
DVD:	40	W	1	60	60
Vaccine refrigerator	600	W	1	2,500	2,500
Communication radio	30	W	1	2,000	2,000
Grounding materials	100	Ω	1	600	600
Accessories Cost: (wire, etc.)	8	%			1,611
Installation & Transportation	10	%			2,014
Total					**23,760**

Total:

Table III-1.5.6-6 System Cost (Total)

Item	No.	Unit	Price (US$)
SHS	50	682	34,100
BCS	1	7,552	7,552
BCS for each house	20	219	4,380
Rural School	1		23,653
Rural Health Clinic	1		23,760
Total			**93,445**

2. O & M

In components of PV system, some consumable parts such as battery and controller should be replaced every few years. On the other hand, the life span of PV module and LED are as long as around 20 years and basically replacement of every few years is not necessary. The life span of controller is around 10 years. In this system, deep cycle battery made in Bolivia is chosen. Therefore, the lifespan of battery in SHS becomes around 5 to 7 years. On the other hand, for BCS, use of car battery is considered because users own a battery and it is easy to obtain. The life span of fluorescent light is estimated 2 to 3 years and that of inverter is estimated 10 years. The following table shows the life span of components of SHS.

Table III-1.5.6-7 Life Span of PV System Component

Item	Lifetime (years)
PV module	20
Controller	10
Battery (deep cycle)	5 to 7
Battery (car)	2 to 3
Fluorescent Light	2 to 3
LED	20
Inverter	10

O&M cost: Annual O&M cost is estimated 2% of initial investment.

III-1.6 Organization of Construction, Operation and Management and Cost

As the structure is simple, it can be set up with the cooperation of village people under supervision of experts of university or NGOs, etc.

Operation will be done by selected and trained villagers as a form of micro enterprise. The micro enterprise will be registered legally

Those who assume the work of the enterprise will be publicly selected from villagers who are willing to undertake the business. As the revenue size of the enterprise is small, the operators of the enterprise will be in principle two; one commercial manager and one technical staff[2].

Before selection, around 10 candidates will be selected from the village who expresses interests in undertaking the operation and management, and all of them will be trained equally. By doing such, back up staff can be secured and if the final selected members will not continue, the remaining people can substitute.

2 If the service coverage size or revenue is very small, it could be single operator assuming both commercial side and technical side.

The training will be held on site in principle. It is scheduled to have initial villagers sensitization, two times of equipment training, and three times of management training. So both technical and administration training will be held. After starting operation, within 6 months, it is scheduled to have back-stop training for those undertaking the business. In addition, in order to secure sustainability it should have at least three times of monitoring (acompaniamiento) by the trainers after operation.

In order to secure corporate governance (Gobernabilidad de la empresa), the enterprise must record accounts with revenues and expenditures. An user organization (junta de usuarios) will be created, and the enterprise shall be responsible for periodical reporting of their operation to the user organization. With this, the enterprise will be defined as open enterprise to users and at the same time, the users will be able to monitor each other, as the enterprise can only be sustained with users' equal participation and assuming responsibility.

The microenterprise will make a contract with the ownership holder (propietario) in order to undertake the public service. It is a kind of concession contract (sesion en uso). In addition, the enterprise will make contracts with users in order to provide service. By binding contracts, rights and obligations of the enterprise will be secured together with those of users. The users will pay according to the tariff set among them.

The costs needed are shown below. The cost necessary for power generation including spare parts are excluded

Initial investment	:	US$	500
Project assistance and monitoring	:	US$	25,000
Annual operation and management	:	N Soles	1,000

III-1.7 Economic and Social Evaluation

III-1.7.1 Evaluation Method

In this master plan study, the analysis method established by SNIP will be applied on the condition that public finance will be used to implement the projects.

In the methodology of SNIP, a financial analysis comparing the costs and benefits using the market price is called economic analysis (Análisis Económico), while an economic analysis comparing them using the economic price is called social analysis (Análisis Social). In order to have consistency with the Peruvian system, the SNIP terms will be used in this report.

The basic flow of the analysis is as follows:

1. Economic Analysis

In Economic Analysis, the expected amount of net benefit will be calculated with the estimates of costs and benefits, using the market price.

- Estimation of costs at market price
- Preparation of a cash flow for capital investment
- Preparation of a cash flow for O&M cost
- Calculation of incremental costs in comparison with “without project”
- Estimation of benefits at market price
- Calculation of incremental benefits in comparison with “without project”.
- Calculation of net benefit (Net Present Value)

2. Social Analysis

In Social Analysis, the expected amount of net benefit will be calculated with the estimates of costs and benefits, using the social price which excludes the distorted factors due to economic policy such as taxes and subsidies.

- Estimation of costs at social price
- Preparation of a cash flow for capital investment
- Preparation of a cash flow for O&M cost
- Calculation of incremental costs in comparison with “without project”
- Estimation of benefits at social price
- Calculation of incremental benefits in comparison with “without project”
- Calculation of net benefit (Social Net Present Value)

3. Sensitivity Analysis

Sensitivity analysis tests the impact on the project in the case of varying important input items such as investment amount, electricity tariff, benefit, etc.

III-1.7.2 Assumptions

The following assumptions are used for evaluating the projects:

1. Discount Rate

- Economic analysis 12%
- Social analysis 11%

2. Conversion Factor

Market price is considered to be distorted due to several economic policies such as taxes or tariff duty. In order to obtain real price, i.e. social price, conversion factors are used.

- Equipment 1.08
- Pole 1.00
- Domestic equipment 1.00
- Study, power purchase 1.00

- Transportation 1.00
- Imported equipment 0.90
- Skilled labors 0.87
- Unskilled labors 0.41 (Sierra)
- IGV 0.00

3. Service Life

The service life of each facility shall be as follows:

Item	Period (years)
Solar panel	20
Battery (deep cycle)	7
Battery (car)	3
Controller	10
Inverter	10
Electromechanical equipment transmission/distribution lines	20

4. Evaluation Period

The evaluation period for the project shall be 20 years.

5. Alternative Project

Alternative projects to supply electricity to San Juan shall be as follows:

Item	Contents
Alternative 1	Electrification with solar panel
Alternative 2	Electrification with extension of grid

6. Electrification of School and Medical Post

In comparison of the alternatives for the purpose of selection of electrification method, electrification of school and medial post will not be considered as a part of the project. Such electrification will be implemented as a demonstration project, therefore, the analysis is limited to the calculation of the amount to cover the operation and maintenance cost.

III-1.7.3 Project Cost and Benefit of Alternative 1 (Solar Power Project)

1. Construction Cost

The construction cost of the project is estimated at US$65,705 as follows:

Table III-1.7.3-1 Initial Investment

(unit: US$)

Item	SHS	BCS (1)	BCS (2)*	Total
PV Panel	250	0	0	-
PV Module	0	6,000	0	-
Controller	40	400	0	-
Battery	110	0	100	-
FC-light	60	0	40	-
LED	20	0	20	-
DC-DC converter	15	0	15	-
Voltage meter	0	0	10	-
Accessories	125	512	15	-
Installation & Transportation	62	640	19	-
Sub-total/unit	682	7,552	218	-
number	50	1	20	-
Sub-total	34,100	7,552	4,360	46,012
IGV, etc	14,595	3,232	1,866	19,693
Total	**48,695**	**10,784**	**6,226**	**65,705**

* Note: unit cost for each household.

2. O&M Cost

The annual operation and maintenance cost is calculated tentatively as follows:.

Item	Annual Cost	Remarks
Operational O&M cost	US$345	S/.1,000 per year
Technical O&M cost	US$1,314	US$65,705 × 2%
Total	**US$1,659**	

3. Power Demand

As to the power demand, the following values in the Chapter III-1.5.2 were adopted:

	Daily Demand (Wh/day)
SHS	152
BCS	84
School	4,555
Medical post	3,190

4. Benefit

(1) Economic Benefit

The economic benefit is electricity sale revenue. Unit rate of 18 Soles (=US$6.21) /month for SHS and 1.5 Soles (=US$0.52; one charge per four days) for BCS is used to estimate the annual benefit.

Item	Unit rate	Annual Income
SHS	US$6.21/month	6.21 × 12 months × 50 HH = US$3,724
BCS	US$0.52/charge	0.52 × 7.5 charges × 12 months × 20 HH = US$ 931

(2) Social Benefit

The social benefit is taken from the date of “Beneficios Económicos de la Electricidad en Areas Rurales del Perú” (NRECA, 1999). 80% of the following values are adopted.

Area	Sierra
Illumination	US$ 158.40/year × 0.8 = 126.72
Radio & TV	US$ 60.48/year × 0.8 = 48.38

III-1.7.4 Alternative 2 (Grid Extension Project)

1. Initial Investment

The breakdown of the cost of transmission and distribution lines required for grid extension is as follows:

(Unit: US$)

Item	Total	Linea Primaria	Red Primaria	Red Secundaria
Materials	79,023	48,804	5,588	24,631
Installation	61,948	50,082	1,394	10,471
Transportation	7,701	4,185	218	3,298
IGV, etc.	28,247	19,538	1,368	7,296
Total	**176,918**	**122,654**	**8,568**	**45,696**

2. O&M Cost

The technical operation and maintenance cost is calculated using the percentage as follows:

Item	Factor (%)	Remarks
Transmission/distribution	2.0~2.5	1st~20th year

The unit rate calculated from the electricity tariff parameter for mid voltage (MT-2) dated February 1, 2008, Pliego Azangaro Rural, by ElectroPuno, which serves Puno was used to calculate the cost of electricity purchase.

Weighted Price of Bar Energy at Middle Voltage – February 2008		
Peak Time Power	S/./kW-month	23.68
Peak Time Energy	ctm. S/./kWh	10.29
Off Peak Time Energy	ctm. S/./kWh	9.22
Weighting Factor		0.304
Weighted Price of bar energy equivalent to Middle Voltage	ctm. S/./kWh	**9.54**
	US$	0.0329

(Price including IGV: 0.0391)

3. Energy Demand

The same demand volume was used as the Alternative 1.

4. Benefit

(1) Economic Benefit

The unit rate calculated from the electricity tariff for low voltage residence (BTB5) dated February 1, 2008, Pliego Azángaro Rural, by ElectroPuno, which serves Puno was used to calculate economic benefit.

	Unit rate
Power charge	1.30 Soles/month
Energy charge	0.452 Soles/kWh

(2) Social Benefit

The same benefit was used as the Alternative 1.

III-1.7.5 Evaluation

It is found out that the larger benefit is expected with the electrification by a solar power project than the grid extension, and surpasses the criteria of IRR = 11%, established by SNIP, for social evaluation. Therefore, the solar power project shall be implemented in San Juan.

(US$)

	Alternative 1	Alternative 2
NPV(IRR)	–57,847 (–6.1%)	–234,577 (n.a.)
SNPV(IRR)	5,609 (12.3%)	–87,342 (0.9%)

III-1.7.6 Sensitivity Analysis

As to the sensitivity analysis, the following items are tested to see the variation of net present value of the project.

Item	Contents
(1) Investment cost	10% increase, 10% decrease
(2) Revenue	10% increase, 10% decrease
(3) Social benefit	10% increase, 10% decrease

1. Investment Cost

(US$)

	Alternative 1	
	NPV	SNPV
10%	–65,686	–1,701
Base Case 0%	–57,847	5,609
–10%	–50,008	12,919

2. Power Sales Revenue

(US$)

	Alternative 1	
	NPV	SNPV
10%	–53,605	5,609
Base Case 0%	–57,847	5,609
–10%	–61,950	5,609

3. Social Benefit

(US$)

	Alternative 1	
	NPV	SNPV
10%	–57,847	15,370
Base Case 0%	–57,847	5,609
–10%	–57,847	–4,152

As a result of the sensitivity analysis, it has been revealed that the change in investment cost has a greater impact than in power sale revenue as to the NPV. On the other hand, SNPV is more sensitive in change of social benefit than that of investment cost. Therefore, it is important to have more accurate estimation of investment cost, as well as social benefit in the following stage of the study.

Table III-1.7-1 Incremental Costs to Each Alternative (Private Cost) - Alternative 1

ITEM	PERIODO																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																					
1. Estudios	5,000																				
2. Construcción																					
(1) SFD	48,695																				
1) Suministro de Equipos, Materiales y Servidumbre	31,000																				
Paneles solares	12,500																				
Baterias	5,500							5,500							5,500						
Equipos de iluminación	4,000																				
controladores / convertidor	2,750										2,750										
coductores	3,750																				
Soportes y postes	2,500																				
2) Instalación	1,240																				
M.O. Calificado	620																				
M.O. No Calificado	620																				
3) Transporte	1,860																				
4) Gastos Generales [12% C.D.]	4,092																				
5) Utilidades [8% C.D.]	2,728																				
6) IGV [19%]	7,775																				
7) Subtotal SFD	48,695	0	0	0	0	0	0	5,500	0	0	2,750	0	0	0	5,500	0	0	0	0	0	0
(2) ERB																					
1) Suministro de Equipos, Materiales y Servidumbre	10,902																				
Paneles solares	6,000																				
Baterias	2,000			2,000			2,000			2,000			2,000			2,000			2,000		
Equipos de iluminación	1,200																				
controladores / convertidor	700										700										
Conductores y cajas conexiones	802																				
Soportes y postes	200																				
2) Instalación	404																				
M.O. Calificado	202																				
M.O. No Calificado	202																				
3) Transporte	606																				
4) Gastos Generales [12% C.D.]	1,429																				
5) Utilidades [8% C.D.]	953																				
6) IGV [19%]	2,716																				
7) Subtotal ERB	17,010	0	0	2,000	0	0	2,000	0	0	2,000	700	0	2,000	0	0	2,000	0	0	2,000	0	0
SUBTOTAL	70,705	0	0	2,000	0	0	2,000	5,500	0	2,000	3,450	0	2,000	0	5,500	2,000	0	0	2,000	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO	500	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659
C) TOTAL COSTOS CON PROYECTO	71,205	1,659	1,659	3,659	1,659	1,659	3,659	7,159	1,659	3,659	5,109	1,659	3,659	1,659	7,159	3,659	1,659	1,659	3,659	1,659	1,659
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES	71,205	1,659	1,659	3,659	1,659	1,659	3,659	7,159	1,659	3,659	5,109	1,659	3,659	1,659	7,159	3,659	1,659	1,659	3,659	1,659	1,659

Table III-1.7-2 Incremental Costs to Each Alternative (Social Price) - Alternative 1

ITEM	Factor	P E R I O D O																				
	Correc.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																						
1. Estudios	1.00	5000																				
2. Construcción																						
(1) SFD																						
1) Suministro de Equipos, Materiales y Servidumbre		33,280																				
Paneles solares	1.08	13,500																				
Baterias	1.08	5,940							5,940							5,940						
Equipos de iluminación	1.08	4,320																				
controladores / convertidor	1.08	2,970										2,970										
conductores	1.08	4,050																				
Soportes y postes	1.00	2,500																				
2) Instalación		794																				
M.O. Calificado	0.87	539																				
M.O. No Calificado	0.41	254																				
3) Transporte	1.00	1,860																				
4) Gastos Generales [12% C.D.]	1.00	4,092																				
5) Utilidades [8% C.D.]	1.00	2,728																				
6) IGV [19%]	0.00	0																				
7) Subtotal SFD		42,754	0	0	0	0	0	0	5,940	0	0	2,970	0	0	0	5,940	0	0	0	0	0	0
(2) ERB																						
1) Suministro de Equipos, Materiales y Servidumbre		11,758																				
Paneles solares	1.08	6,480																				
Baterías	1.08	2,160			2,160			2,160			2,160			2,160			2,160			2,160		
Equipos de iluminación	1.08	1,296																				
controladores / convertidor	1.08	756										756										
Conductores y cajas conexiones	1.08	866																				
Soportes y postes	1.00	200																				
2) Instalación		259																				
M.O. Calificado	0.87	176																				
M.O. No Calificado	0.41	83																				
3) Transporte	1.00	606																				
4) Gastos Generales [12% C.D.]	1.00	1,429																				
5) Utilidades [8% C.D.]	1.00	953																				
6) IGV [19%]	0.00	0																				
7) Subtotal ERB		15,005	0	0	2,160	0	0	2,160	0	0	2,160	756	0	2,160	0	0	2,160	0	0	2,160	0	0
3. SUBTOTAL		62,759	0	0	2,160	0	0	2,160	5,940	0	2,160	3,726	0	2,160	0	5,940	2,160	0	0	2,160	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO	1.00	500	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659	1,659
C) TOTAL COSTOS CON PROYECTO		68,259	1,659	1,659	3,819	1,659	1,659	3,819	7,599	1,659	3,819	5,385	1,659	3,819	1,659	7,599	3,819	1,659	1,659	3,819	1,659	1,659
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES		68,259	1,659	1,659	3,819	1,659	1,659	3,819	7,599	1,659	3,819	5,385	1,659	3,819	1,659	7,599	3,819	1,659	1,659	3,819	1,659	1,659

Table III-1.7-3 Incremental Costs to Each Alternative (Private Price) - Alternative 2

RUBRO	PERIODO																				
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
A) COSTOS DE INVERSION																					
Estudios/Supervision/Preinversion (17%)	**30,076**																				
Instalación de Líneas Primarias	**122,654**																				
Suministro de Equipos, Materiales y Servidumbre	**48,804**																				
Origen Nacional	14,641																				
Origen Importado	34,163																				
Montaje Electromecánico de Líneas Primarias	50,082																				
M.O. Calificada	35,058																				
M.O. No Calificada	15,025																				
Transporte	4,185																				
IGV (19%)	**19,583**																				
Instalación de Redes Primarias	**8,568**																				
Suministro de Equipos, Materiales y Servidumbre	**5,588**																				
Origen Nacional	2,682																				
Origen Importado	2,906																				
Montaje Electromecánico de Redes Primarias	1,394																				
M.O. Calificada	976																				
M.O. No Calificada	418																				
Transporte	218																				
IGV (19%)	**1,368**																				
Instalación de Redes Secundarias	**45,696**																				
Suministro de Equipos y Materiales	**24,631**																				
Origen Nacional	10,345																				
Origen Importado	14,286																				
Montaje Electromecánico	10,471																				
M.O. Calificada	7,330																				
M.O. No Calificada	3,141																				
Transporte	3,298																				
IGV (19%)	**7,296**																				
Subtotal costos de inversión	**206,995**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACIÓN Y MANTENIMIENTO																					
1. Compra de energía		146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146	146
2. Costos de operación y mantenimiento		4,140	4,189	4,238	4,288	4,339	4,390	4,442	4,495	4,548	4,601	4,656	4,711	4,766	4,823	4,880	4,937	4,996	5,055	5,114	5,175
C) TOTAL COSTOS CON PROYECTO (A + B)	206,995	4,286	4,335	4,384	4,434	4,485	4,536	4,588	4,640	4,694	4,747	4,802	4,857	4,912	4,969	5,026	5,083	5,142	5,201	5,260	5,321
D) COSTOS DE OPERACIÓN Y MANTENIMIENTO SIN PROYECTO	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES (C - D)	206,995	4,286	4,335	4,384	4,434	4,485	4,536	4,588	4,640	4,694	4,747	4,802	4,857	4,912	4,969	5,026	5,083	5,142	5,201	5,260	5,321

Table III-1.7-4 Incremental Costs to Each Alternative (Social Price) - Alternative 2

RUBRO		PERIODO																				
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTOS DE INVERSION																						
Estudios/Supervision/Preinversion (17%)	1.00	30,076																				
Instalación de Líneas Primarias		86,233																				
Suministro de Equipos, Materiales y Servidumbre		45,388																				
Origen Nacional	1.00	14,641																				
Origen Importado	0.90	30,747																				
Montaje Electromecánico de Líneas Primarias		36,660																				
M.O. Calificada	0.87	30,500																				
M.O. No Calificada	0.41	6,160																				
Transporte	1.00	4,185																				
IGV (19%)	0.00	0																				
Instalación de Redes Primarias		6,536																				
Suministro de Equipos, Materiales y Servidumbre		5,297																				
Origen Nacional	1.00	2,682																				
Origen Importado	0.90	2,615																				
Montaje Electromecánico de Redes Primarias		1,021																				
M.O. Calificada	0.87	849																				
M.O. No Calificada	0.41	172																				
Transporte	1.00	218																				
IGV (19%)	0.00	0																				
Instalación de Redes Secundarias		34,165																				
Suministro de Equipos y Materiales		23,202																				
Origen Nacional	1.00	10,345																				
Origen Importado	0.90	12,857																				
Montaje Electromecánico		7,665																				
M.O. Calificada	0.87	6,377																				
M.O. No Calificada	0.41	1,288																				
Transporte	1.00	3,298																				
IGV (19%)	0.00	0																				
Subtotal costos de inversión		157,010	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACIÓN Y MANTENIMIENTO																						
1. Compra de energía	1.00	0	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123	123
2. Costos de operación y mantenimiento	1.00	0	3,140	3,177	3,215	3,253	3,291	3,330	3,369	3,409	3,450	3,490	3,532	3,573	3,615	3,658	3,701	3,745	3,789	3,834	3,879	3,925
C) TOTAL COSTOS CON PROYECTO (A + B)		157,010	3,263	3,300	3,337	3,375	3,414	3,453	3,492	3,532	3,572	3,613	3,654	3,696	3,738	3,781	3,824	3,868	3,912	3,957	4,002	4,048
D) COSTOS DE OPERACIÓN Y MANTENIMIENTO SIN PROYECTO		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES (C - D)		157,010	3,263	3,300	3,337	3,375	3,414	3,453	3,492	3,532	3,572	3,613	3,654	3,696	3,738	3,781	3,824	3,868	3,912	3,957	4,002	4,048

Table III-1.7-5 General Analysis of the Demand

a) Variables importantes / Important variables		Supuesto/Assumption		Fuentes de Información / Source
Crecimiento anual de la población / Annual increase of the population	:	**0.0%**		Misión / Mission
Crecimiento anual de la población electrificada / Annual increase of electrified population	:	**0.0%**		Misión / Mission
Porcentaje de abonados domésticos / Percemtage of domestic consumers	:	**100%**		Misión / Mission
Consumo unitario mensual de SFD / Monthly unit consumption of SHS	:	**152**	Wh/ abonado	Misión / Mission
Consumo unitario mensual de ERB / Monthly unit consumption of BCR		**84**	Wh/ abonado	Misión / Mission
Tasa de Crecimiento del Consumo unitario anual / Increase rate of annual unit consumption	:	**0.0%**		Misión / Mission
Porcentaje de pérdidas de energía (en BT y MT) / Percentage of energy loss (LV & MV)	:	**10%**		Osinerg
Factor de carga (Load factor)	:	**25%**		Registros CONCESIONARIAS y ADINELSA Registration

b) Proyección / Projection

	AÑOS / YEARS																				
UNIDADES / UNIT	**0**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
Número de hogares / Number of houses		70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70	70
Número de conexiones domesticas (SFD) (Number of domestic connection - SHS)		50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50	50
Número de abonados (ERB) (Number of customers - BCS)		20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
Consumo anual por SFD (Annual consumption by SHS)		55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55	55
Consumo anual por ERB (Annual consumption by BCS)		31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31
Consumo anual de SFD Annual consupmtion of SHS)		2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774	2,774
Consumo anual de ERB (Annual consumption of BCS)		613	613	613	613	613	613	613	613	613	613	613	613	613	613	613	613	613	613	613	613
Consumo total / Total consumption (KWh)		3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387
Pérdidas de energía (MT y BT) (Energy loss (MV & LV)		339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339	339
Energía al ingreso del sistema (KWh) (Energy input from the system (kWh))		3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726	3,726
Factor de carga (Load factor)		25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Potencia al ingreso del sistema (KW) (Pow er input from the system (kW))		**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**	**1.70**

Table III-1.7-6 Incremental Benefits to Each Alternative (Private Price) - Alternative 1

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto / With Project																					
Income from montly tariff																					
Ingresos por cuotas mensuales reguladas	0	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655
- SFD / SHS	0	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724	3,724
- ERB / BCS	0	931	931	931	931	931	931	931	931	931	931	931	931	931	931	931	931	931	931	931	931
2.- Situación sin Proyecto / Without Project																					
Beneficios sin proyecto / Benefit w/o project	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2)																					
Income from monthly tariff																					
Ingresos por cuotas mensuales reguladas	**0**	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655

Important variable	Value		Information source						
Variables importantes:	**Valoración**	**100%**	**Fuente de información:**						
Cuota mensual por abonado / Monthly tariff	Soles		meses	total	Vivienda	Soles	TC	dolares	
- SFD / SHS	**18.00**	/mes(month) /vivienda (HH)	12	216	50	10,800	2.9	3,724	/año (year)
- ERB / BCS	**1.50**	/recarga (charge)	90	135	20	2,700	2.9	931	/año (year)
Período de reposición / Replacement period			months	total	HH	Soles	Ex.rate	dollar	
- activos generales / General assets:	**20**	años (years)							
- baterías para SFD / Battery for SHS:	**7**	años (years)							
- baterías para ERB / Battery for BCS:	**3**	años (years)							
- controladores / Controllers:	**10**	años (years)							
Tasa de impuesto a la renta / Income Tax rate	30%								

Estado de pérdidas y ganancias:	PERIODO / PERIOD																				
Profit and Loss Statement	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Total cuotas de servicio /Total tariff icome		4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655
2. Costos de OyM / O&M cost		-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659	-1,659
3. Depreciación / Depreciation																					
- Activos generales / General assets		-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288	-1,288
- Baterías / Battary		-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983	-1,983
- Controladores / Controllers		-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471	-471
6. Utilidad antes de impuestos / Income before tax		-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745	-745
7. Impuesto a la renta (solamente cuando hay incremento de utilidades) / Income tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table III-1.7-7 Incremental Benefit to Each Alternative (Private Price) - Alternative 2

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyect - With Project																					
Venta de energia total / total energy sales	0	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904
Venta de energia domesticos / domestic sales		904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904
2.- Situación sin Proyecto / Without Project																					
Beneficios sin proyecto / Benefit without project		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) / Incremental Benefit																					
Ingresos por vena de energia (Revenue by energy sales)		904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904

Variables importantes: (Important Variables)	Potencia (Power)		Energia (Energy)	
Tarifa de la energia / Electricity tariff	1.3	/abonado (consumer)	0.4520	/kWh
Viviendas (Houses)	70	SFD (SHS)	2,774.00	kWh/ano (year)
meses (months)	12	ERB (BCS)	613.20	kWh/ano (year)
Soles	1092	/año (year)	1,531	/año (year)
TC (Ex.rate)	2.9	dolar/soles	2.9	dolar/soles
US$	377	/año (year)	528	/año (year)

Tasa de impuesto a la renta / tax rate 30%

Estado de pérdidas y ganancias (Profit and Loss statement)	**PERIODO / PERIOD**																				
	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
1. Total cuotas de servicio (total fee for service)		904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904
2. Costos de OyM (O&M cost)		-4,140	-4,189	-4,238	-4,288	-4,339	-4,390	-4,442	-4,495	-4,548	-4,601	-4,656	-4,711	-4,766	-4,823	-4,880	-4,937	-4,996	-5,055	-5,114	-5,175
3. Compra de energia (Energy purchase)		-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146	-146
4. Depreciación (Depreciation)		-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951	-3,951
7. Utilidad antes de impuestos (Profit before tax)		-7,332	-7,381	-7,431	-7,481	-7,532	-7,583	-7,635	-7,687	-7,740	-7,794	-7,848	-7,903	-7,959	-8,015	-8,072	-8,130	-8,188	-8,247	-8,307	-8,367
8. Impuesto a la renta (solamente cuando hay incremento de utilidades) Income Tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table III-1.7-8 Incremental Benefit to Each Alternative (Social Price) - Alternative 1 and 2

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto / With Project																					
Beneficio económico iluminación (Economic benefits of lighting)		8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870	8,870
Voluntad de pago por radio y televisión (Willingness to pay for radio and TV)		3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387	3,387
Voluntad de pago por otros (Other WtP)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub total beneficios económicos (Sub total of economic benefits)		12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257
2.- Situación sin Proyecto / Without Project																					
Beneficio económico sin proyecto (Economic benefit without project)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) / Incremental Benefits																					
Beneficios económicos incrementales (Incremental economic benefits)		12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257

Table III-1.7-9 Actual Value of Benefits to Each Alternative (Private Price)

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Beneficios Incrementales - Privados / Incremental Benefit - Private																					
ALTERNATIVA 1	0	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655	4,655
ALTERNATIVA 2	0	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904	904
2.- Costos Incrementales - Privados/ Incremental Costs - Private																					
ALTERNATIVA 1	71,205	1,659	1,659	3,659	1,659	1,659	3,659	7,159	1,659	3,659	5,109	1,659	3,659	1,659	7,159	3,659	1,659	1,659	3,659	1,659	1,659
ALTERNATIVA 2	206,995	4,286	4,335	4,384	4,434	4,485	4,536	4,588	4,640	4,694	4,747	4,802	4,857	4,912	4,969	5,026	5,083	5,142	5,201	5,260	5,321
3.- Beneficios Netos Totales - Privados / Total Net Benefit - Private																					
ALTERNATIVA 1	-71,205	2,996	2,996	996	2,996	2,996	996	-2,504	2,996	996	-454	2,996	996	2,996	-2,504	996	2,996	2,996	996	2,996	2,996
ALTERNATIVA 2	-206,995	-3,381	-3,430	-3,480	-3,530	-3,580	-3,632	-3,684	-3,736	-3,789	-3,843	-3,897	-3,952	-4,008	-4,064	-4,121	-4,179	-4,237	-4,296	-4,356	-4,416

	NPV	IRR
ALTERNATIVAS	**VAN (12%)**	**TIR**
ALTERNATIVA 1	-57,847	-6.1%
ALTERNATIVA 2	-234,577	#DIV/0!

Table III-1.7-10 Actual Value of Benefits to Each Alternative (Social Price)

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Beneficios Incrementales / Incremental Benefits																					
ALTERNATIVA 1	0	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257
ALTERNATIVA 2	0	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257	12,257
2.- Costos Incrementales / Incremental Costs																					
ALTERNATIVA 1	68,259	1,659	1,659	3,819	1,659	1,659	3,819	7,599	1,659	3,819	5,385	1,659	3,819	1,659	7,599	3,819	1,659	1,659	3,819	1,659	1,659
ALTERNATIVA 2	157,010	3,263	3,300	3,337	3,375	3,414	3,453	3,492	3,532	3,572	3,613	3,654	3,696	3,738	3,781	3,824	3,868	3,912	3,957	4,002	4,048
3.- Beneficios Netos Totales / Total Net Benefits																					
ALTERNATIVA 1	-68,259	10,598	10,598	8,438	10,598	10,598	8,438	4,658	10,598	8,438	6,872	10,598	8,438	10,598	4,658	8,438	10,598	10,598	8,438	10,598	10,598
ALTERNATIVA 2	-157,010	8,995	8,957	8,920	8,882	8,843	8,805	8,765	8,725	8,685	8,644	8,603	8,561	8,519	8,477	8,433	8,390	8,345	8,301	8,255	8,209

	NPV	IRR
ALTERNATIVAS	**VAN (11%)**	**TIR**
ALTERNATIVA 1	5,609	12.3%
ALTERNATIVA 2	-87,342	0.9%

III-1.7.7 Electrification of School and Medical Post

The investment cost required for electrification of school and medical post, according to Table III-1.5.6-4 and Table III-1.5.6-5 is as follows:

(unit: US$)

Item	School	Medical post
Investment cost	23,653	23,760
IGV, etc.	10,124	10,170
Total	**33,777**	**33,930**

2% of the investment cost is estimated as annual operation and maintenance cost. The average cost of annual requirement including replacement of the equipment is estimated as follows. It is important to decide beforehand which organization to bear such cost:

	O&M cost (US$/year)	Replacement during 20 years (US$)	Annual average cost (US$)
School	676	26,668	2,009
Medical Post	679	29,745	2,166

III-1.8 Electricity Tariff Setting and Fund Mechanism

1. Electricity Tariff Setting

There are two types of electricity tariff system: one is the metered rate system; the other is the flat-rate system. In the former case, the following actions are made: installation of electricity meter, periodical meter inspection, submission of electricity bill according to the energy consumption. For these activities, a person in charge of inspection and tariff calculation is required. Thus, it would be a time-consuming and less-effective job especially in a low population area. On the other hand, the flat-rate system does not involve such fiddly procedure, and an electricity bill with a constant price will be issued to the consumers. This would save much cost in paperwork.

Item	Advantage	Disadvantage
Metered rate system	Fair in cost sharing	Fiddly for meter inspection
Flat-rate system	No need for meter inspection	Unfair to the small consumer

Especially, there is little variation in energy consumption by each household, in the case of solar power project. Therefore, an advantage of the flat-rate system can be expected. From this viewpoint, examination was made on the condition that the flat-rate system would be adopted for this project.

<Items for Examination and Conditions>

In order to examine the level of electricity tariff, the following items will be referred. Basically, the tariff should cover the operation and maintenance cost from a viewpoint of sustainability. It also should be set at an affordable level to the most of the local people. In the case that the tariff rate thus calculated is expensive in comparison with the level of current tariff rate level, application of a certain subsidiary system should be considered.

(1) O&M cost
(2) Current level of electricity tariff
(3) Willingness to pay

Each item is examined as follows:

(1) O&M Cost

Operation and maintenance cost is tentatively estimated as 2% of the investment, thus the annual cost is calculated as US$1,659.

(2) Current Level of Electricity Tariff

A unit rate of 18 Soles/month is applied for SHS in GEF Project. 1.5 Soles/charge is applied for BCS. These amounts shall be used as a reference.

(3) Willingness to Pay

A willingness to pay mentioned here refers to the value of the current energy expenditure, obtained by an inquiry conducted for local people as a part of social study. It is not the value obtained as "willingness to pay" in the inquiries.

Table III-1.8-1 Willingness to Pay: San Juan

(Nuevos Soles)

Max	80.0
Min	0.0
Average	20.0
Median	17.2

Next, a tentative calculation of electricity tariff required to recover the cost for electricity service, with the following conditions:

1) Micro-enterprise does not earn any profit.
2) Operation cost is 2% of the initial investment cost
3) Replacement of equipment is the responsibility of a micro-enterprise
4) Charging cost at BCS varies in proportion to the tariff of SHS. The lowest price shall be 1.5 Soles.

<Result of Examination>

As a result, the level of electricity tariff was calculated as follows:

No subsidy to initial investment	25.30 Soles
100% subsidy to initial investment	11.53 Soles

A tariff to cover the operation and maintenance cost, including the replacement cost for this project is calculated as 25.30 Soles/month for SHS and 2.11 Soles for BCS. As to the rate for SHS, it exceeds some 7 Soles as compared to the tariff of 18 Soles applied in GEF Project. From a viewpoint of willingness to pay, more than a quarter of 50 households can afford to pay.

In order to minimize the amount of subsidy, the operation cost of the micro enterprise to be established by the local people requires further examination, including self-help efforts by local people.

Under the condition that the initial investment is totally subsidized, the subsidy level to recover the O&M cost was calculated for the following cases:

1) GEF Project tariff : 18.0 Soles
2) 80% of the willingness to pay : 9.5 Soles
3) Grid tariff (incl. FOSE) : 2.88 Soles ([1.3 + 0.242 × 55.48 / 12] × 1.19)

(unit: Nuevos Soles)

Unit rate/month	Subsidy amount	Annual amount	Remarks
18.00	0.00	0	GEF tariff
11.53	0.00	0	Base tariff
9.50	2.03	1,218	2.03 × 50 HH × 12
2.88	8.65	5,190	8.65 × 50 HH × 12

2. Fund Mechanism

(1) Construction Cost

The initial investment cost required for the project shall be procured from the SPERAR Fund, as well as the fund of the local government (e.g. CANON).

(2) Training Cost

The cost required for providing training for project management shall be procured form the SPERAR fund.

(3) Operation and Maintenance Cost

The operation and maintenance cost shall basically be borne by the consumer as an electricity tariff. The operation cost of a micro-enterprise to be established by local people shall also be covered with this fund.

(4) Subsidy

Subsidy is indispensable in order to secure stably a certain level of revenue. At least, it is desirable to set the electricity tariff at a similar level with the neighboring area electrified with a grid. For this purpose, it is important for a micro-enterprise to register as an electricity serving company in MEM, and apply to OSINERGMIN for a provision of cross subsidy based on FOSE.

III-1.9 Social and Environmental Consideration

The following table shows the result of evaluation and measures to the environmental factors that are supposed to give impact on natural and social environment in San Juan.

Table III-1.9-1 Summary of Evaluation of Environmental Elements

Items	Rat-ing	Result of the survey	Measures
Misdistribution of benefit and damage Local conflicts of interest	C	People with lower income in the community will not be able to use the electrical service after the PV system is introduced. It is anticipated that misdistribution of benefit will be occur among inhabitants.	(1) The master plan proposes that MEM/DPR should establish the financial supporting system in order that the poor people can use electricity. (2) The master plan plans to introduce BCS, whose charge is lower than that of SHS, for the poor people.
Gender	C	As women may be difficult to participate in the dissemination, training and management organization that the master plan proposes to give to inhabitants, it is anticipated that electrification fixes the inequity between both genders relating to social development.	The master plan proposes that the implementer should recommend and support inhabitants that women must be given dissemination and training as well as have possibility of candidate of the management organization.
Solid wastes	C	At national level, quality and capacity of treatment and recycle of used battery is limited now. As the number of project sites increases, recycling will be difficult. As result, it is anticipated that water pollution and air pollution will occur by acid and lead due to inappropriate treatment in the small scale factories.	The master plan proposes to establish the battery recycling system (the batteries used for the PV system will be collected, treated by private companies and re-used by PV users). Also, it suggests that MEM/DPR should take initiative of giving administrative directives, in collaboration with Ministry of Production who are in charge of solid waste treatment and Ministry of Health in charge of industrial health, to the factories that discharge pollution through battery treatment and recycling.

Note: Evaluation classification
A: Serious impact is expected.
B: Impact is expected to a certain extent.
C: Not strong impact is expected but impact sometimes occurs.
D: Low level impact may happen. More minute investigation and evaluation are required at the FS.
Source: JICA study team, 2008

III-2 PV System (Tarapoto in Loreto Region)

III-2.1 Natural Conditions

Tarapoto village is located 2 hours from Iquitos city by boat. The village is located on a river side. Annual average temperature of Iquios is as high as around 26°C. The annual precipitation is as large as 2,800 mm, around double of that of Tokyo. Therefore, it can be said that the feature of climate at Tarapoto is rainforest climate, high temperature with much humidity. The annual ambient temperature, precipitation and sunshine duration are shown in Table III-2.1-1.

Table III-2.1-2 shows monthly average of solar irradiation in Iquitos. The average of annual solar irradiation is 3.7 kWh/m^2. It is obviously that solar irradiation in Iquitos is as high as that of Tokyo at 3.5 kWh/m^2. Maximum monthly average of solar irradiation was recorded in September at 4.7 kWh/m^2 and that of minimum is recorded in May at 3.0 kWh/m^2.

Table III-2.1-1 Monthly Average of Temperature, Precipitation and Sunshine Duration

Month	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Ambient Temperature (°C)	28.3	27.8	28.0	27.7	27.0	26.0	26.4	27.2	27.9	28.1	27.7	27.7	27.5
Precipitation (mm)	103.2	151.5	353.2	156.9	282.6	285.6	161.6	178.8	101.4	139.2	218.5	247.6	198.3
Sunshine Duration (hours)	176.4	134.3	105.0	116.4	114.6	68.7	92.6	180.5	125.5	136.6	146.6	128.5	127.1

Source: SENAMHI 2004

Table III-2.1-2 Monthly Average of Solar Irradiation (Iquitos)

Month	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Irradiation (kWh/m^2)	3.4	3.7	3.5	3.7	3.0	3.1	3.7	4.2	4.7	3.8	4.2	3.8	3.7

Source: Generacion de Electricidad a pequeña escala con Energia Solar Fotovoltaica, CENERGIA and ECOFYS

III-2.2 Social and Economic Conditions and Gender Issues

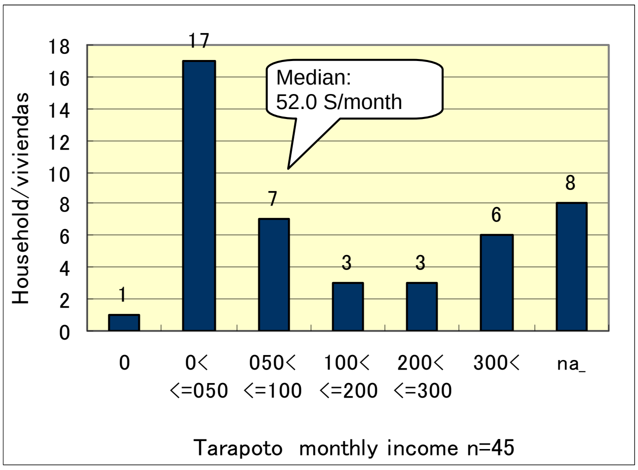
1. Community (Localidad) and Population

- Tarapoto lies along the Rio Nanay, about 16 km west to the Regional Government office of Loreto in Iquitos City in the line of the crow.
- The number of households in Tarapoto is 83 (source: MEM database) but many people are supposed to live in the forest far from the centre of the village. Result of the latest national census executed on 21st October 2007 should be collected at the FS stage.
- There is one primary school in the community.

2. Industry and Main Income Sources

Located in tropical forest being near to Iquitos city, inhabitants of Tarapoto receive richer agriculture products and have more marketing opportunity than inhabitants in San Juan.

- Agriculture as well as forestry and fishery are income sources. More than 90% of the interviewed households plant banana, cassava and around 70+% cultivate maize.
- Inhabitants get income mainly by selling banana, cassava and maize. These crops are consumed for domestic use as staple food. Also, timber and carbon are other income sources for several households.
- Monthly income on median is 52.0 Soles by estimate of the amount of product sales, based on the community survey by MEM/DPR. It may be estimated lower if their affordability is considered. Income distribution of Tarapoto is shown in Fig. III-2.2-1.



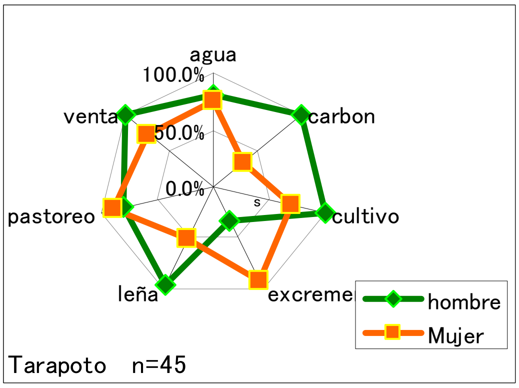
Note: data is estimated by accumulation of product sales and possibly less than the real income.
Source: JICA study team, 2008

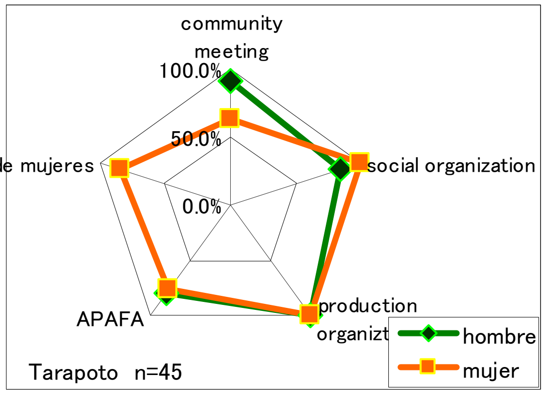
Fig. III-2.2-1 Income Distribution in Tarapoto

3. Gender

Comparing with San Juan, stronger division of labour between women and men is found in daily livelihood activities: carbon making, collection of firewood, cultivation as well as sale of products are considered as men's work while collection of excrement (for fuel) are women's work. Both women and men attend social organizations but, like San Juan, more men participate in community meeting than women. It may be supposed that women have less control of the family budget because they are less in charge of sale of products.

Difference between women and men in daily and livelihood activities and social activities is shown in Fig. III-2.2-2.





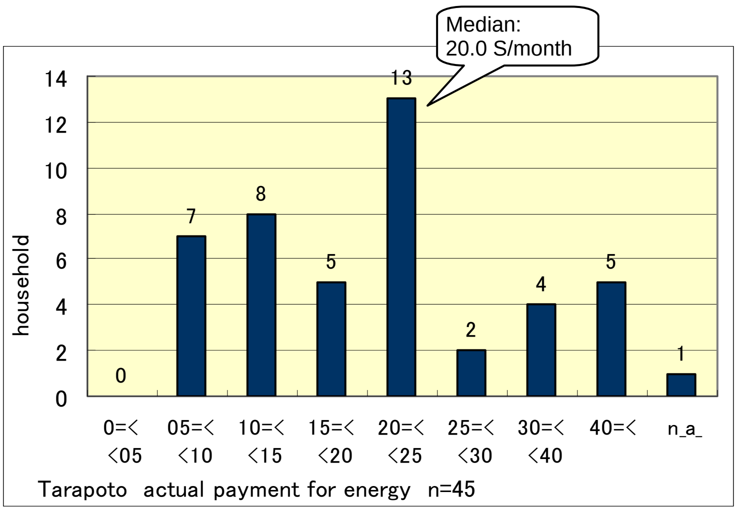
Source: JICA study team 2008

Fig. III-2.2-2 Gender Distribution in Daily Livelihood Activity (left) and Social Activity (right)

III-2.3 Demand of Electricity and Affordability

1. Actual Energy Use

- Kerosene lamp is used as main lighting for almost all the interviewed houses. Battery torch is used supplementary.
- Actually one household possesses a black and white TV using battery and 20 households (44.4%) possess radio.
- Monthly payment for energy is 20.0 Soles on median at present. Nine households say that they can afford more than 30 Soles.



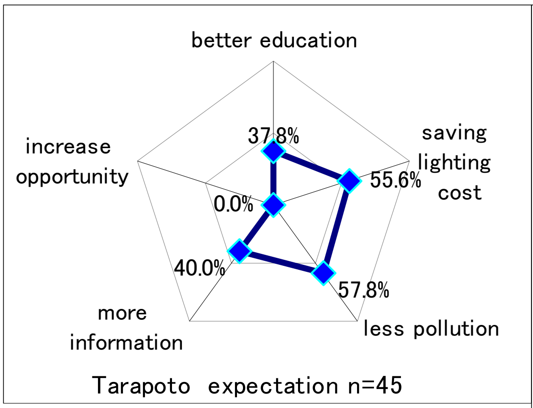
Source: JICA study team 2008

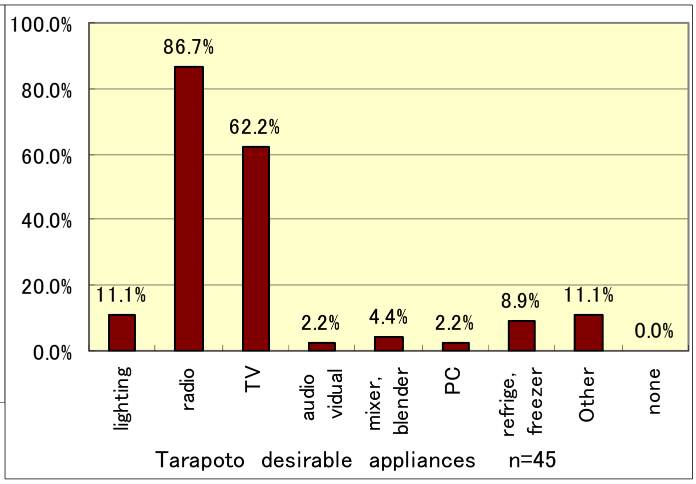
Fig. III-2.3-1 Actual Payment for Energy

2. Intention of Electrification

- Social survey did not mention particular intention or obstacle of electrification Project.

- 86.7% of the interviewed people replied that they knew what renewable energy (PV system) was. It may be because there are several communities in Iquitos area that are equipped by PV system and inhabitants of Tarapoto had seen them.
- Not more than 60% of the respondents show their expectation of electricity of a particular item, around a half of which want to improve air pollution and to reduce payment for lighting. Different from other sites, radio is the most demanded appliance that they want to buy after electrification.



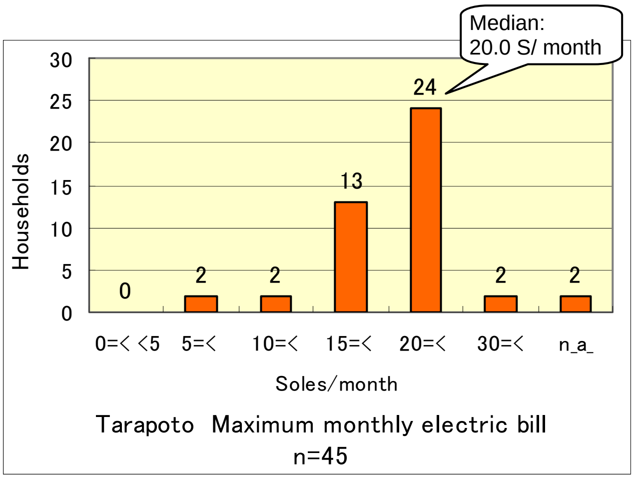


Source: JICA study team, 2008

Fig. III-2.3-2 Expectation of Electrification (left) and Desirable Electric Appliances (right)

3. Affordability

- The result of the community survey shows that the most frequent answers are 15 Soles and 20 Soles per month and the median is 20 Soles. This amount is much higher than other Pre-FS sites. It is necessary for the implementer to confirm it when he/she holds public hearing about the project implementation for avoiding negative impact.
- More than 80% of the respondents say that monthly payment is most preferable.



Source: JICA study team, 2008

Fig. III-2.3-3 Maximum Affordable Monthly Electric Bill

III-2.4 Comparison of Initial Investment Amount by Electrification Method

The team studied the electrification method most suitable to the location, taking the number of the households as parameter. The assumption is as follows;

<Assumption>

[Village Information]	Number of Localidad	:	1
	Number of User	:	45 (Tentative)
	Connecting Rate	:	0.8
[Grid Extension]	Length of Linea Primarias from end of Existing Grid	:	3 (km)
	Linea Primarias	:	5,100 (US$/km)
	Redes Primarias	:	110 (US$/User)
	Redes Secundaria	:	220 (US$/User)
[Photovoltaic]	PV	:	780 (US$/User)

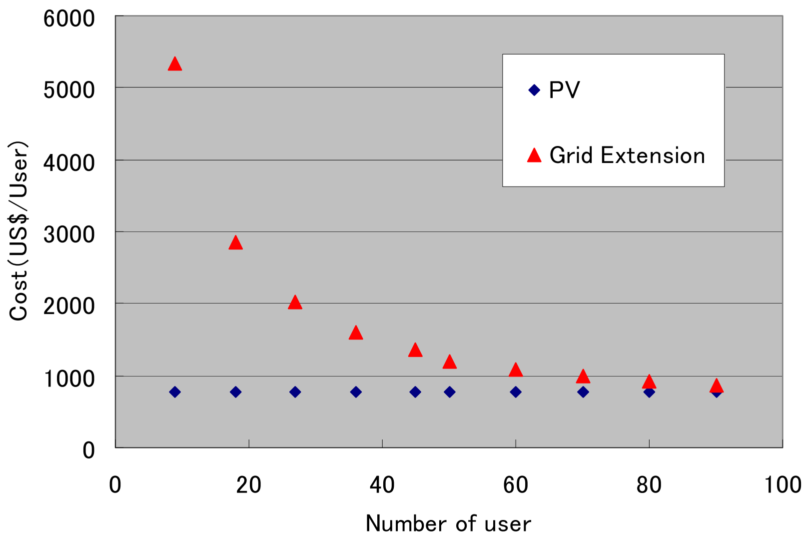


Fig. III-2.4-1 Comparison of Initial Investment Amount by Electrification Method (2)

The number of the households targeted to be electrified at this location is 36 (Household: 45, Target rate: 0.8). As Fig. III-2.4-1 shows, PV is more preferable to grid extension for electrification method in terms of initial investment amount.

Furthermore, not only initial investment amount but operation & maintenance expense, future power usage expected in a productive manner, and future socio- economic development at this location should be studied to decide the most appropriate method of electrification.

III-2.5 Design and Cost

1. Result of Household Survey

Household survey was carried out for 45 households out of 83 households in Tarapoto. The results are shown in the tables below. In Tarapoto, 22 soles are being paid for the basic energy consumption such as kerosene lamp and candle for lighting, dry cell battery for radio. The average of lighting hours is 4 hours 30 minutes and that of radio is 3 hours 36 minutes. On the other hand, affordability of payment for electricity is as small at 17.5 soles per month. Most of the households require more than 2 lights after electrified. Around 75% of the households answered that they expected use of radio and 40% of the respondents use of television after electrified. Around 88% of the respondents are expecting power supply by pay for service, 5% of the respondents are expecting battery charging station. In Tarapoto, most of the households are located near the river. The interviewed households are located within 1.5 km × 2.5 km as shown Fig. III-2.5-1.

Monthly expenditure for energy

(sol/Mo.)

Lighting	14.0
Dry-cell battery	8.0
Lighting + Dry cell battery	22.0

Average of energy consumption hours for lighting and radio

Lighting	4 hr. 30 min.
Radio	3 hr. 36 min.

Expecting power consumption hours after electrified

	hours	household
Room 1	3 hr. 13 min.	100%
Room 2	3 hr. 10 min.	63%
Room 3	3 hr. 46 min.	23%
Outside	-	-
Radio	2 hr. 48 min.	75%
TV	2 hr. 22 min.	40%

System for payment

System owner (US$750 cash)	0%
System owner (US$750 loan)	8%
Fee for service 18 (s/mo.)	88%
Battery charge 1.5 (s/charge)	5%

In Tarapoto, demand for SHS is larger than that of the other systems, so that SHS is designed in the field study at pre-feasibility level.

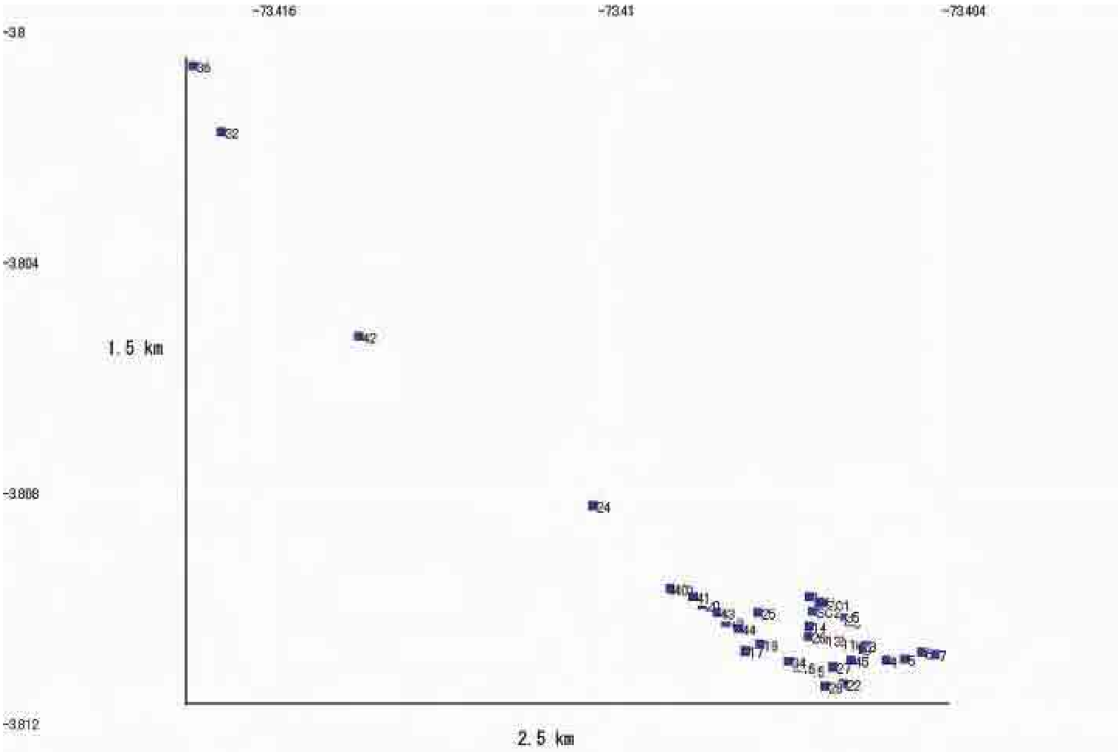


Fig. III-2.5-1 Location of Interviewed Households

2. Potential of Solar Irradiation

The capacity of PV system is designed based on the smallest monthly solar irradiation in May. For the design of PV system, the tilting angle of PV module in smallest irradiation month was calculated to make larger irradiation value from the latitude and longitude with the globe model. Fig. III-2.5-2 shows the relation between tilting angle and surface irradiation at Iquitos. The result shows the optimum tilting angle in Iquitos is 10 degrees.

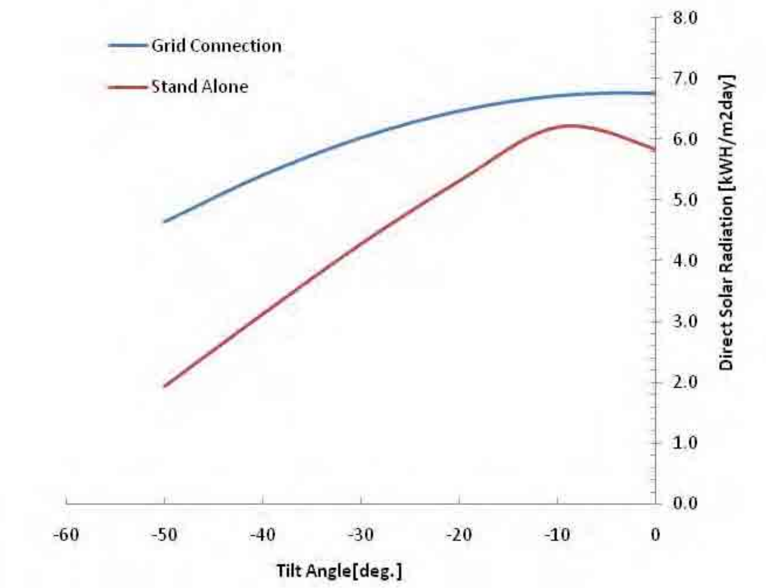


Fig. III-2.5-2 Solar Irradiation vs. Tilting Angle (Iquitos)

Table III-2.5-1 Monthly Irradiation (horizontal, tilting angle 10 deg.)

Month	Jan	Feb.	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Horizontal Irradiation (kWh/m^2)	3.4	3.7	3.5	3.7	3.0	3.1	3.7	4.2	4.7	3.8	4.2	3.8	3.7
Irradiation tilt angle 20 deg. (kWh/m^3)	3.09	3.49	3.45	3.83	3.23	3.4	4.03	4.43	4.74	3.65	3.86	3.41	3.7

Source: JICA study team

3. Structure of Household

The following drawing shows a typical household in Tarapoto. Almost all of the houses are made by woods, and the roof is made by straw or galvanized iron. Most of the houses have a kitchen room near to the main house. The ambient temperature in Tarapoto is high, so the construction of the house is open for blowing natural wind into house building. Most of the houses have wide space of a living room without walls between rooms. The rooms in the house have no ceiling but only divided by walls. The numbers of rooms are depending on the size of household as around 2 to 4.

It is necessary to install lights at a living room and kitchen by power supply from SHS. Many people answered that, even if there are some rooms in a house, only one light could cover all of the rooms since there is no ceiling. In general, the kitchen is built to the next of main house building and the floor is connected. The following picture shows the drawing on wiring.

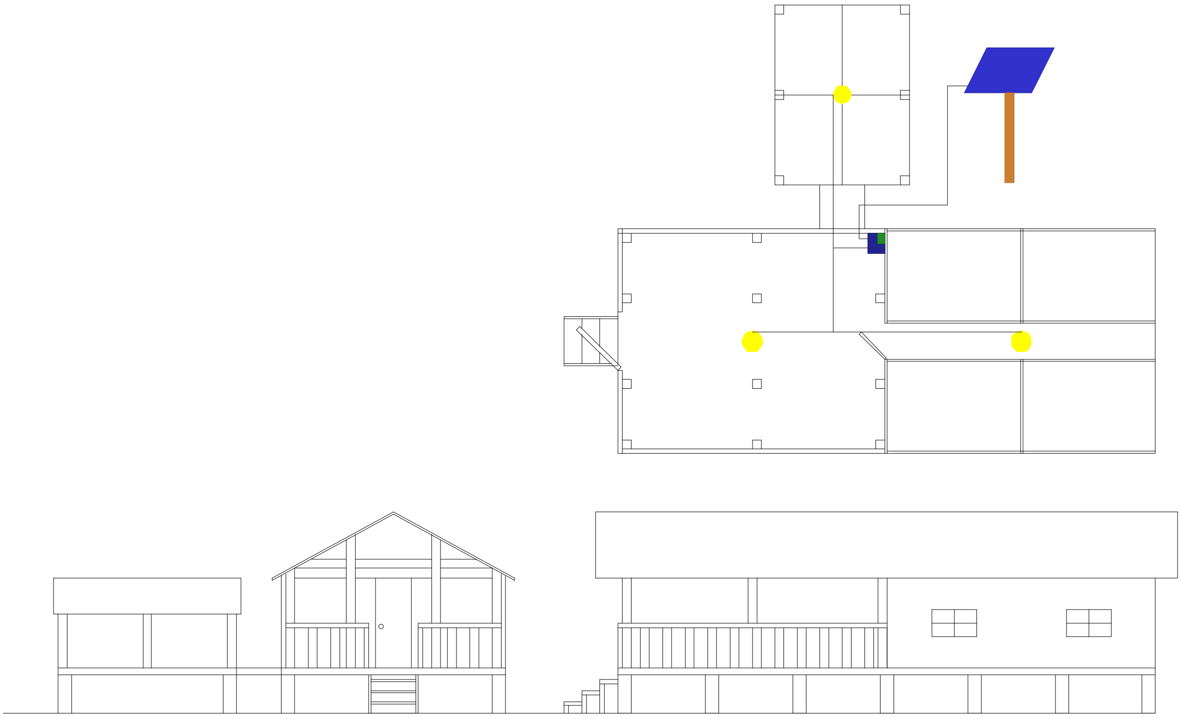


Fig. III-2.5-3   Example of Household and Wiring (Tarapoto)

Photo III-2.5-1 Interviewed Household (Tarapoto)

Photo III-2.5-2 UNDP Project (Aucayo)

Photo III-2.5-3 Open Structure of Typical Household

III-2.5.1 Design of SHS

1. Power Demand

The table below shows power demand of a household with a room and a kitchen. The result of household interview shows that the number of households requesting multiple lights is small. The ratio of households expecting two lights is 63%, and that of three lights is as small as 23%. The household with a small number of rooms requires light only at the living room and kitchen because the construction of house is widely open. There is demand for night light, especially for the purpose of taking care of infant. For this purpose, use of LED is considered in the system. Power demand of radio is 2.5 hours at minimum irradiation month, and demand of TV is not considered. However, it is possible to use radio for longer time when solar irradiation is strong and the household that does not need much energy for lighting. Table III-2.5.1-1 shows power demand.

Table III-2.5.1-1 Power Demand

Demand	Rated power (W)	Hours (hours/day)	Power consumption (Wh/day)
Room: Fluorescent Light	12	3	36
Kitchen: Fluorescent Light	12	2	24
LED	2	8	16
Radio	10	3	30
			106
System voltage	12	V	
Total Demand	**8.8**	**Ah/day**	

2. Estimated Power Output

The table below shows estimated monthly power output from 50 Wp of SHS at Tarapoto. For the design of PV system, the power output was estimated based on the solar irradiation in January. Therefore, there is surplus power output in the other months. It is possible to use radio or black-white TV (20 W) by the surplus power output.

Table III-2.5.1-2 Estimated Power Output (50 Wp)

Month	Irradiation (kWh/m^2-day)	Power Output (kWh/day)	Power Output (Ah/day)	Monthly Output (kWh/Mo)
Jan	3.1	0.11	8.9	3.3
Feb	3.5	0.12	10.1	3.4
Mar	3.5	0.12	10.0	3.7
Apr	3.8	0.13	11.1	4.0
May	3.2	0.11	9.3	3.5
Jun	3.4	0.12	9.8	3.5
Jul	4.0	0.14	11.7	4.3
Aug	4.4	0.15	12.8	4.8
Sep	4.7	0.16	13.7	4.9
Oct	3.7	0.13	10.6	3.9
Nov	3.9	0.13	11.2	4.0
Dec	3.4	0.12	9.9	3.7
Average	**3.7**	**0.13**	**10.8**	**3.9**

Annual: 47.1 (kWh/year)

Power output (kWh/day) = PV capacity (Wp) × K × Solar irradiation (kWh/m^2-day)
(K = K1 × K2 × K3 × K4 × K5 × K6)

Design loss

K1:	Temperature correction coefficient	(25°C)	1.00
K2:	Module derating factor	normally 0.9~0.95	0.9
K3:	Power loss (PV module to battery)	normally 0.95	0.95
K4:	Controller		0.95
K5:	Battery Charge/discharge		0.9
K6:	Power loss (Battery to demand)		0.95

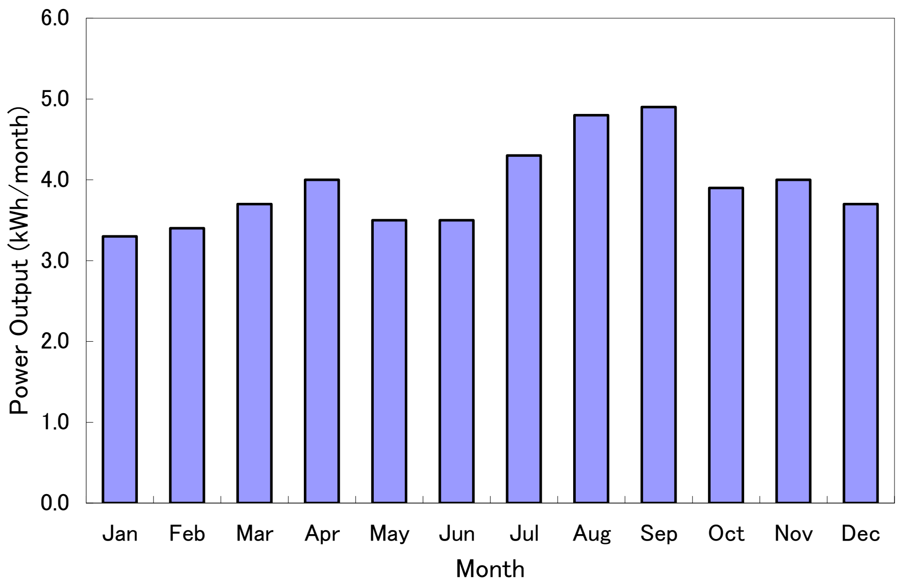


Fig. III-2.5.1-1 Estimated Monthly Power Output

3. Battery Capacity

Cu = (Autonomous day +1) (Daily consume) / PD max

= 88 Ah ≒ 100 Ah

Autonomous day : 3 days

PD max : 40%

Daily consume : 8.8 Ah/day

4. Summary of System

System

PV module : 50 Wp

Controller : 10 A

Battery : 100 Ah

Fluorescent Light : 12 W × 2

LED : 2 W × 1

DC/DC converter : input 12 V - output 1.5 V, 3 V, 4.5 V, 6 V, 9 V

III-2.5.2 Cost

1. Cost of Equipment

SHS: for 45 households

Table III-2.5.2-1 System Cost (SHS)

Item			No.	Unit	Price (US$)
PV panel	50	Wp	1	250	250
Controller	10	A	1	40	40
Battery*1	100	Ah	1	110	110
FC-light	12	W	3	20	60
LED	2	W	1	20	20
DC-DC converter	12	V	1	15	15
Accessories (wire, pole etc.)	1	set	1	125	125
Installation & Transportation	10	%	1	62	62
Total					**682**

*1: Battery is Deep-Cycle Battery (made in Bolivia)

2. O & M

In components of PV system, some consumable parts such as battery and controller should be replaced every few years. On the other hand, the life span of PV module and LED are as long as around 20 years and basically replacement of every few years is not necessary. The life span of controller is around 10 years. In this system, deep cycle battery made in Bolivia is chosen. Therefore, the lifespan of battery in SHS becomes around 5 to 7 years. On the other hand, for BCS, use of car battery is considered because users own a battery and it is easy to obtain. The life span of fluorescent light is estimated 2 to 3 years and that of inverter is estimated 10 years. The following table shows the life span of components of SHS.

Table III-2.5.2-2 Life Span of PV System Component

Item	Lifetime (years)
PV module	20
Controller	10
Battery (deep cycle)	5 to 7
Battery (car)	2 to 3
Fluorescent Light	2 to 3
LED	20
Inverter	10

O&M cost: Annual O&M cost is estimated 2% of initial investment.

III-2.6 Organization of Construction, Operation and Management and Cost

As the structure is simple, it can be set up with the cooperation of village people under supervision of experts of university or NGO, etc.

Operation will be done by selected and trained villagers as a form of micro enterprise. The micro enterprise will be registered legally.

Those who assume the work of the enterprise will be publicly selected from villagers who are willing to undertake the business. As the revenue size of the enterprise is small, the operators of the enterprise will be in principle two; one commercial manager and one technical staff[3].

Before selection, around 10 candidates will be selected from the village who express interests in undertaking the operation and management, and all of them will be trained equally. By doing such, back up staff can be secured and if the final selected members will not continue, the remaining people can substitute.

The training will be held on site in principle. It is scheduled to have initial villagers sensitization, two times of equipment training, and three times of management training. So both technical and administration training will be held. After starting operation, within 6 months, it is scheduled to have back-stop training for those undertaking the business. In addition, in order to secure sustainability it should have at least three times of monitoring (acompaniamiento) by the trainers after operation.

In order to secure corporate governance, the enterprise must record accounts with revenues and expenditures. User organization (junta de usuarios) will be created and the enterprise shall be

[3] If the service coverage size or revenue is very small, it could be single operator assuming both commercial side and technical side.

responsible for periodical reporting of their operation to the user organization. With this, the enterprise will be defined as open enterprise to users and at the same time, users will be able to monitor each other, as the enterprise can only be sustained with users' equal participation and assuming responsibility.

The micro enterprise will make a contract with ownership holder (propietario) in order to undertake the public service. It is a kind of concession contract (sesion en uso). In addition, the enterprise will make contracts with users in order to provide service. By binding contracts, rights and obligations of the enterprise will be secured together with those of users. Users will pay according to the tariff set among them

The costs needed are shown below. The cost necessary for power generation including spare parts are excluded.

Initial investment	:	US$	500
Project assistance and monitoring	:	US$	25,000
Annual operation and management	:	N Soles	1,000

III-2.7 Economic and Social Evaluation

III-2.7.1 Evaluation Method

In this Master Plan study, the analysis method established by SNIP will be applied on the condition that public finance will be used to implement the projects.

In the methodology of SNIP, a financial analysis comparing the costs and benefits using the market price is called economic analysis (Análisis Económico), while an economic analysis comparing them using the economic price is called social analysis (Análisis Social). In order to have consistency with the Peruvian system, the SNIP terms will be used in this report.

The basic flow of the analysis is as follows:

1. Economic Analysis

In Economic Analysis, the expected amount of net benefit will be calculated with the estimates of costs and benefits, using the market price.

- Estimation of costs at market price
- Preparation of a cash flow for capital investment
- Preparation of a cash flow for O&M cost
- Calculation of incremental costs in comparison with "without project"
- Estimation of benefits at market price
- Calculation of incremental benefits in comparison with "without project".
- Calculation of net benefit (Social Net Present Value)

2. Social Analysis

In Social Analysis, the expected amount of net benefit will be calculated with the estimates of costs and benefits, using the social price which excludes the distorted factors due to economic policy such as taxes and subsidies.

- Estimation of costs at social price
- Preparation of a cash flow for capital investment
- Preparation of a cash flow for O&M cost
- Calculation of incremental costs in comparison with "without project"
- Estimation of benefits at social price
- Calculation of incremental benefits in comparison with "without project"
- Calculation of net benefit (Social Net Present Value)

3. Sensitivity Analysis

Sensitivity analysis tests the impact on the project in the case of varying important input items such as investment amount, electricity tariff, benefit, etc.

III-2.7.2 Assumptions

The following assumptions are used for evaluating the projects:

1. Discount Rate

- Economic analysis 12%
- Social analysis 11%

2. Conversion Factor

Market price is considered to be distorted due to several economic policies such as taxes or tariff duty. In order to obtain real price, i.e. social price, conversion factors are used.

- Equipment 1.08
- Pole 1.00
- Domestic equipment 1.00
- Study/power purchase 1.00
- Transportation 1.00
- Imported equipment 0.90
- Skilled labors 0.87
- Unskilled labors 0.49 (Selva)
- IGV 0.00

3. Service Life

Service life of each facility shall be as follows:

Item	Period (years)
Solar panel	20
Battery (deep cycle)	7
Battery (car)	3
Controller	10
Inverter	10
Electromechanical equipment transmission/distribution lines	20

4. Evaluation Period

The evaluation period for the project shall be 20 years.

5. Alternative Project

Alternative projects to supply electricity to San Juan shall be as follows:

Item	Contents
Alternative 1	Electrification with solar panel
Alternative 2	Electrification with extension of grid

III-2.7.3 Project Cost and Benefit of Alternative 1 (Solar Power Project)

1. Construction Cost

The construction cost of the Project is estimated at US$43,825 as follows:

Table III-2.7.3-1 Initial Investment

(unit: US$)

Item	SHS	Number	Total
PV Panel	250	45	11,250
Controller	40	45	1,800
Battery	110	45	4,950
FC-light	60	45	2,700
LED	20	45	900
DC-DC converter	15	45	675
Accessories	125	45	5,625
Installation/Transportation	62	45	2,790
Sub-total	682	45	30,690
IGV, etc	292	45	13,135
Total	**974**	**45**	**43,825**

2. O&M Cost

The annual operation and maintenance cost is calculated tentatively as two percent of the investment cost.

Item	Annual cost (US$)	Remarks
Operational O&M cost Technical O&M cost	345 877	S/.1,000 per year US$43,825 × 2%
Total	**1,222**	

3. Power Demand

As to the power demand, the following value in the Chapter III-2.5.2 was adopted:

Item	Daily Demand	Annual Demand
SHS	106 Wh/day	38.69 kWh/year

4. Benefit

(1) Economic Benefit

The economic benefit is electricity sale revenue. Unit rate of 18 Soles (=US$6.21) /month is used to estimate the annual benefit.

Item	Unit rate	Annual Income
SHS BCS	US$6.21/month US$0.52/charge	6.21 × 12 months × 50 HH = US$3,724 0.52 × 7.5 charges × 12 months × 20 HH = US$ 931

(2) Social Benefit

The social benefit is taken from the date of "Beneficios Económicos de la Electricidad en Areas Rurales del Perú" (NRECA, 1999). 80% of the following values are adopted.

Area	Selva
Illumination Radio & TV	US$ 102.24/year × 0.8 = 81.79 US$ 57.96/year × 0.8 = 46.37

III-2.7.4 Alternative 2 (Grid Extension Project)

1. Initial Investment

The breakdown of the cost of transmission and distribution lines required for grid extension is as follows:

Table III-2.7.4-1 Initial Investment

(Unit: US$)

Item	Total	Linea Primaria	Red Primaria	Red Secundaria
Materials	36,832	25,734	3,494	7,603
Installation	19,992	16,832	1,177	1,984
Transportation	2,651	2,059	280	313
IGV, etc.	11,300	8,479	941	1,881
Total	**70,775**	**53,104**	**5,891**	**11,781**

2. O&M Cost

The technical operation and maintenance cost is calculated using the percentage as follows:

Item	Factor (%)	Remarks
Transmission/distribution	2.0~2.5	1st~20th year

The unit rate calculated from the electricity tariff parameter for mid voltage (MT-2) dated February 1, 2008, Pliego Iquitos Rural, by ElectroOriente, which serves Loreto, was used to calculate the cost of electricity purchase.

Weighted Price of Bar Energy at Middle Voltage – February 2008		
Peak Time Power	S/./kW-month	25.75
Peak Time Energy	ctm. S/./kWh	19.48
Off Peak Time Energy	ctm. S/./kWh	19.48
Weighting Factor		0.273
Weighted Price of bar energy equivalent to Middle Voltage	ctm. S/./kWh	**19.48**
	US$	0.0672

(Price including IGV: 0.0800)

3. Energy Demand

The same demand volume was used as the Alternative 1.

4. Benefit

(1) Economic Benefit

The unit rate calculated from the electricity tariff for low voltage residence (BTB5) dated February 1, 2008, Pliego Iquitos Rural (E4), by ElectroOriente, which serves Loreto, was used to calculate economic benefit.

	Unit rate
Power charge	1.25 Soles/month
Energy charge	0.4936 Soles/kWh

(2) Social Benefit

The same benefit was used as the Alternative 1.

III-2.7.5 Evaluation

It is found out that the larger benefit is expected with the electrification by the solar power project than the grid extension. However, both cases have lower IRR, as compared to the criteria of 11% established by SNIP.

(US$)

	Alternative 1	Alternative 2
NPV (IRR)	–41,963 (–4.9%)	–91,367 (n.a.)
SNPV (IRR)	–12,081 (6.3%)	–30,330 (2.7%)

III-2.7.6 Sensitivity Analysis

As to the sensitivity analysis, the following items are tested to see the variation of net present value of the project.

Item	Contents
(1) Investment cost	10% increase, 10% decrease
(2) Revenue	10% increase, 10% decrease
(3) Social benefit	25% increase (=NRECA 100%) 10% increase, 10% decrease

1. Investment Cost

(US$)

		Alternative 1	
		NPV	SNPV
	10%	–46,851	–16,598
Base Case	0%	–41,963	–12,081
	–10%	–37,074	–7,563

2. Power Sales Revenue

(US$)

		Alternative 1	
		NPV	SNPV
	10%	–39,459	–12,081
Base Case	0%	–41,963	–12,081
	–10%	–44,466	–12,081

3. Social Benefit

(US$)

		Alternative 1	
		NPV	SNPV
	25%	–41,963	–599
	10%	–41,963	–7,488
Base Case	0%	–41,963	–12,081
	–10%	–41,963	–16,673

As a result of the sensitivity analysis, it has been revealed that the change in investment cost has a greater impact than in power sale revenue as to the NPV. On the other hand, impact by change in social benefit and investment cost is almost the same.

However, SNPV and NPV show negative value in all cases. The reason comes from the level of the general social benefit in Selva based on NRECA study used here, and the small number of target households. Therefore, it is not wise to reject the implementation of the project only with this study, but it is important to estimate the social benefit based on more accurate study at Tarapoto in the following stage of the study.

Table III-2.7-1 Incremental Costs to Each Alternative (Private Cost) - Alternative 1

ITEM	PERIODO																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																					
1. Estudios	5,000																				
2. Construccion																					
(1) SFD	43,825																				
1) Suministro de Equipos, Materiales, etc.	27,900																				
Paneles solares	11,250																				
Baterias	4,950							4,950							4,950						
Equipos de iluminacion	3,600																				
controladores / convertidor	2,475										2,475										
coductores	3,375																				
Soportes y postes	2,250																				
2) Instalacion	1,116																				
M.O. Calificado	558																				
M.O. No Calificado	558																				
3) Transporte	1,674																				
4) Gastos Generales [12% C.D.]	3,683																				
5) Utilidades [8% C.D.]	2,455																				
6) IGV [19%]	6,997																				
7) Subtotal SHS	43,825	0	0	0	0	0	0	4,950	0	0	2,475	0	0	0	4,950	0	0	0	0	0	0
SUBTOTAL	48,825	0	0	0	0	0	0	4,950	0	0	2,475	0	0	0	4,950	0	0	0	0	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO COSTO DE APOYO AL PROYECTO	0	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222
C) TOTAL COSTOS CON PROYECTO	53,825	1,222	1,222	1,222	1,222	1,222	1,222	6,172	1,222	1,222	3,697	1,222	1,222	1,222	6,172	1,222	1,222	1,222	1,222	1,222	1,222
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES	53,825	1,222	1,222	1,222	1,222	1,222	1,222	6,172	1,222	1,222	3,697	1,222	1,222	1,222	6,172	1,222	1,222	1,222	1,222	1,222	1,222

Table III-2.7-2 Incremental Costs to Each Alternative (Social Price) - Alternative 1

ITEM	Factor	P E R I O D O																				
	Correc.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																						
1. Estudios	1.00	5,000																				
2. Construccion																						
(1) SFD		0																				
1) Suministro de Equipos, Materiales, etc.		29,952																				
Paneles solares	1.08	12,150																				
Baterias	1.08	5,346							5,346							5,346						
Equipos de iluminacion	1.08	3,888																				
controladores / convertidor	1.08	2,673										2,673										
conductores	1.08	3,645																				
Soportes y postes	1.00	2,250																				
2) Instalacion		759																				
M.O. Calificado	0.87	485																				
M.O. No Calificado	0.49	273																				
3) Transporte	1.00	1,674																				
4) Gastos Generales [12% C.D.]	1.00	3,683																				
5) Utilidades [8% C.D.]	1.00	2,455																				
6) IGV [19%]	0.00	0																				
7) Subtotal SHS		38,523																				
SUBTOTAL		38,523	0	0	0	0	0	0	5,346	0	0	2,673	0	0	0	5,346	0	0	0	0	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO	1.00	0	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222	1,222
C) TOTAL COSTOS CON PROYECTO		43,523	1,222	1,222	1,222	1,222	1,222	1,222	6,568	1,222	1,222	3,895	1,222	1,222	1,222	6,568	1,222	1,222	1,222	1,222	1,222	1,222
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES		43,523	1,222	1,222	1,222	1,222	1,222	1,222	6,568	1,222	1,222	3,895	1,222	1,222	1,222	6,568	1,222	1,222	1,222	1,222	1,222	1,222

Table III-2.7-3 Incremental Costs to Each Alternative (Private Price) - Alternative 2

RUBRO	PERIODO																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTOS DE INVERSION																					
Estudios/Supervision/Preinversion (17%)	**12,032**																				
Instalación de Líneas Primarias	**53,104**																				
Suministro de Equipos, Materiales y Servidumbre	**25,734**																				
Origen Nacional	7,720																				
Origen Importado	18,014																				
Montaje Electromecánico de Líneas Primarias	16,832																				
M.O. Calificada	11,782																				
M.O. No Calificada	5,050																				
Transporte	2,059																				
IGV (19%)	**8,479**																				
Instalación de Redes Primarias	**5,891**																				
Suministro de Equipos, Materiales y Servidumbre	**3,494**																				
Origen Nacional	1,677																				
Origen Importado	1,817																				
Montaje Electromecánico de Redes Primarias	1,177																				
M.O. Calificada	824																				
M.O. No Calificada	353																				
Transporte	280																				
IGV (19%)	**941**																				
Instalación de Redes Secundarias	**11,781**																				
Suministro de Equipos y Materiales	**7,603**																				
Origen Nacional	3,193																				
Origen Importado	4,410																				
Montaje Electromecánico	1,984																				
M.O. Calificada	1,389																				
M.O. No Calificada	595																				
Transporte	313																				
IGV (19%)	**1,881**																				
Subtotal costos de inversión	**82,807**	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACIÓN Y MANTENIMIENTO																					
1. Compra de energía		153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153	153
2. Costos de operación y mantenimiento		1,416	1,432	1,449	1,466	1,484	1,501	1,519	1,537	1,555	1,573	1,592	1,611	1,630	1,649	1,668	1,688	1,708	1,728	1,749	1,769
C) TOTAL COSTOS CON PROYECTO (A + B)	82,807	1,569	1,585	1,602	1,619	1,637	1,654	1,672	1,690	1,708	1,726	1,745	1,764	1,783	1,802	1,822	1,841	1,861	1,881	1,902	1,923
D) COSTOS DE OPERACIÓN Y MANTENIMIENTO SIN PROYECTO	-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES (C - D)	82,807	1,569	1,585	1,602	1,619	1,637	1,654	1,672	1,690	1,708	1,726	1,745	1,764	1,783	1,802	1,822	1,841	1,861	1,881	1,902	1,923

Table III-2.7-4 Incremental Costs to Each Alternative (Social Price) - Alternative 2

RUBRO		PERIODO																				
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTOS DE INVERSION																						
Estudios/Supervision/Preinversion (17%)	1.00	12,032																				
Instalación de Líneas Primarias		38,717																				
Suministro de Equipos, Materiales y Servidumbre		23,933																				
Origen Nacional	1.00	7,720																				
Origen Importado	0.90	16,213																				
Montaje Electromecánico de Líneas Primarias		12,725																				
M.O. Calificada	0.87	10,251																				
M.O. No Calificada	0.49	2,474																				
Transporte	1.00	2,059																				
IGV (19%)	0.00	0																				
Instalación de Redes Primarias		4,481																				
Suministro de Equipos, Materiales y Servidumbre		3,312																				
Origen Nacional	1.00	1,677																				
Origen Importado	0.90	1,635																				
Montaje Electromecánico de Redes Primarias		890																				
M.O. Calificada	0.87	717																				
M.O. No Calificada	0.49	173																				
Transporte	1.00	280																				
IGV (19%)	0.00	0																				
Instalación de Redes Secundarias		8,975																				
Suministro de Equipos y Materiales		7,162																				
Origen Nacional	1.00	3,193																				
Origen Importado	0.90	3,969																				
Montaje Electromecánico		1,500																				
M.O. Calificada	0.87	1,208																				
M.O. No Calificada	0.49	292																				
Transporte	1.00	313																				
IGV (19%)	0.00	0																				
Subtotal costos de inversión		64,205	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACIÓN Y MANTENIMIENTO																						
1. Compra de energía	1.00	0	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129	129
2. Costos de operación y mantenimiento	1.00	0	1,284	1,299	1,315	1,330	1,346	1,362	1,378	1,394	1,411	1,427	1,444	1,461	1,478	1,496	1,514	1,531	1,550	1,568	1,586	1,605
C) TOTAL COSTOS CON PROYECTO (A + B)		64,205	1,413	1,428	1,443	1,459	1,475	1,490	1,507	1,523	1,539	1,556	1,573	1,590	1,607	1,625	1,642	1,660	1,678	1,697	1,715	1,734
D) COSTOS DE OPERACIÓN Y MANTENIMIENTO SIN PROYECTO		-	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES (C - D)		64,205	1,413	1,428	1,443	1,459	1,475	1,490	1,507	1,523	1,539	1,556	1,573	1,590	1,607	1,625	1,642	1,660	1,678	1,697	1,715	1,734

Table III-2.7-5 General Analysis of the Demand

a) Variables importantes (Important Variables)		Supuesto (Assumption)	Fuentes de Información (Source)
Crecimiento anual de la población (Annual population increase)	:	**0.0%**	Misión
Crecimiento anual de la población electrificada (Annual increase of electriried population	:	**0.0%**	Misión
Porcentaje de abonados domésticos (Percentage of domestic clients)	:	**100%**	Misión
Tasa de Crecimiento del Consumo unitario anual (Increase rate of annual unit consumptio	:	**0.0%**	Misión
Porcentaje de pérdidas de energía en BT y MT (Energy loss rate in Low & Middle voltage	:	**10%**	Osinergmin
Factor de carga (Load factor)	:	**25%**	Registros CONCESIONARIAS Y ADINELSA

b) Proyección (Projection)

UNIDADES (Units)	AÑOS (YEAR)																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Número de hogares (Number of households)		45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Número de conexiones domesticas (SFD) (Number of domestic connection - SHS)		45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45	45
Consumo anual por SFD (Annual consumption by SHS)		39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39	39
Consumo anual SFD (Annual consumption by SHS)		1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741
Consumo total (kWh) (Total consumption)		1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741	1,741
Pérdidas de energía (MT y BT) (Energy loss)		174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174	174
Energía al ingreso del sistema (kWh) (Energy from grid)		1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915	1,915
Factor de carga (Load factor)		25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Potencia al ingreso del sistema (kW) (Power from grid)		**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**	**0.87**

Table III-2.7-6 Incremental Benefits to Each Alternative (Private Price) - Alternative 1

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto / With Project																					
Incom from montly tariff																					
Ingresos por cuotas mensuales reguladas	0	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352
- SFD / SHS	0	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352
2.- Situación sin Proyecto / Without Project																					
Beneficios sin proyecto / Benefit w /o project		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2)																					
Income from monthly tariff																					
Ingresos por cuotas mensuales reguladas		3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352

Important variables	Value								
Variables importantes:	**Valoración**	**100%**							
Cuota mensual por abonado/ Monthly tariff:	Soles		meses	Anual	Vivienda	Soles	TC	dolares	
- SFD / SHS	**18.00**	/mes(month) /vivienda (HH)	12	216	45	9,720	2.9	3,352	/año (year)
Período de reposición / Replacement period			months	Annual	HH	Soles	Exc. Rate	dollars	
- activos generales / General assets:	**20**	años (years)							
- baterías / Battery:	**7**	años (years)							
- controladores / Controllers:	**10**	años (years)							
Tasa de impuesto a la renta / Income Tax rate	30%								

Estado de pérdidas y ganancias:	PERIODO (Period)																				
(Profit and Loss Statement)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Total cuotas de servicio (Total fee from the service)		3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352
2. Costos de operación y mantenimiento (Fee for operation and maintenance)		-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222	-1,222
3. Depreciación activos generales (Depreciation for general assets)		-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844	-844
4. Depreciación baterías (Depreciation for batteries)		-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965	-965
5. Depreciación controladores (Depreciation for controllers)		-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338	-338
6. Utilidad antes de impuestos (Profit before tax)		-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17	-17
7. Impuesto a la renta (income tax)		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table III-2.7-7 Incremental Benefit to Each Alternative (Private Price) - Alternative 2

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyect - With Project																					
Venta de energia total / total energy sales	0	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529
Venta de energia domestica / domestic sales		529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529
2.- Situación sin Proyecto / Without Project																					
Beneficios sin proyecto / Benefit w ithout project		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) / Incremental Benefit																					
Ingresos por vena de energia (Revenue by energy sales)		529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529

Variables importantes:	**carga**		**energia**		**Total**	
(Important Variables)	Pow er		Energy			
Tarifa de la energia / Electricity tariff	1.25		0.4936			
	45	Viviendas (HH)	1,741.05	kWh/ano (year)		
	12	meses (months)				
Soles	675	/ano (year)	859.38	/ano (year)		
1US$=S/.	2.9		2.9			
US$	232.76	/ano (year)	296.34	/ano (year)	529.10	/ano (year)

Tasa de impuesto a la renta / tax rate 30%

Estado de pérdidas y ganancias (Profit and Loss statement)	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Total cuotas de servicio (total fee for service)		529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529
2. Costos de OyM (O&M cost)		-1,416	-1,432	-1,449	-1,466	-1,484	-1,501	-1,519	-1,537	-1,555	-1,573	-1,592	-1,611	-1,630	-1,649	-1,668	-1,688	-1,708	-1,728	-1,749	-1,769
3. Compra de energia (Energy purchase)		-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153	-153
4. Depreciación (Depreciation)		-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842	-1,842
7. Utilidad antes de impuestos (Profit before tax)		-2,881	-2,898	-2,915	-2,932	-2,949	-2,967	-2,984	-3,002	-3,021	-3,039	-3,058	-3,076	-3,095	-3,115	-3,134	-3,154	-3,174	-3,194	-3,214	-3,235
8. Impuesto a la renta (solamente cuando hay incremento de utilidades) Tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table III-2.7-8 Incremental Benefit to Each Alternative (Social Price) - Alternative 1 and 2

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto / With Project																					
Beneficio económico iluminación (Economic benefits of lighting)		3,681	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253	4,253
Voluntad de pago por radio y televisión (Willingness to pay for radio and TV)		2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087	2,087
Voluntad de pago por otros (Other WtP)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sub total beneficios económicos (Sub total of economic benefits)		5,767	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340
2.- Situación sin Proyecto / Without Project																					
Beneficio económico sin proyecto (Economic benefit without project)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) / Incremental Benefits																					
Beneficios económicos incrementales (Incremental economic benefits)		5,767	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340	6,340

Table III-2.7-9 Actual Value of Benefits to Each Alternative (Private Price)

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Beneficios Incrementales - Privados / Incremental Benefit - Private																					
ALTERNATIVA 1	0	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352	3,352
ALTERNATIVA 2	0	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529	529
2.- Costos Incrementales - Privados/ Incremental Costs - Private																					
ALTERNATIVA 1	53,825	1,222	1,222	1,222	1,222	1,222	1,222	6,172	1,222	1,222	3,697	1,222	1,222	1,222	6,172	1,222	1,222	1,222	1,222	1,222	1,222
ALTERNATIVA 2	82,807	1,569	1,585	1,602	1,619	1,637	1,654	1,672	1,690	1,708	1,726	1,745	1,764	1,783	1,802	1,822	1,841	1,861	1,881	1,902	1,923
3.- Beneficios Netos Totales - Privados / Total Net Benefit - Private																					
ALTERNATIVA 1	-53,825	2,130	2,130	2,130	2,130	2,130	2,130	-2,820	2,130	2,130	-345	2,130	2,130	2,130	-2,820	2,130	2,130	2,130	2,130	2,130	2,130
ALTERNATIVA 2	-82,807	-1,040	-1,056	-1,073	-1,090	-1,108	-1,125	-1,143	-1,161	-1,179	-1,197	-1,216	-1,235	-1,254	-1,273	-1,293	-1,312	-1,332	-1,352	-1,373	-1,393

	NPV	IRR
ALTERNATIVAS	**VAN (12%)**	**TIR**
ALTERNATIVA 1	-41,963	-4.9%
ALTERNATIVA 2	-91,367	#DIV/0!

Table III-2.7-10 Actual Value of Benefits to Each Alternative (Social Price)

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Beneficios Incrementales / Incremental Benefits																					
ALTERNATIVA 1	0	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767
ALTERNATIVA 2	0	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767	5,767
2.- Costos Incrementales / Incremental Costs																					
ALTERNATIVA 1	43,523	1,222	1,222	1,222	1,222	1,222	1,222	6,568	1,222	1,222	3,895	1,222	1,222	1,222	6,568	1,222	1,222	1,222	1,222	1,222	1,222
ALTERNATIVA 2	64,205	1,413	1,428	1,443	1,459	1,475	1,490	1,507	1,523	1,539	1,556	1,573	1,590	1,607	1,625	1,642	1,660	1,678	1,697	1,715	1,734
3.- Beneficios Netos Totales / Total Net Benefits																					
ALTERNATIVA 1	-43,523	4,546	4,546	4,546	4,546	4,546	4,546	-800	4,546	4,546	1,873	4,546	4,546	4,546	-800	4,546	4,546	4,546	4,546	4,546	4,546
ALTERNATIVA 2	-64,205	4,354	4,339	4,324	4,308	4,293	4,277	4,261	4,244	4,228	4,211	4,194	4,177	4,160	4,143	4,125	4,107	4,089	4,071	4,052	4,033

	NPV	IRR
ALTERNATIVAS	**VAN (11%)**	**TIR**
ALTERNATIVA 1	-12,081	6.3%
ALTERNATIVA 2	-30,330	2.7%

III-2.8 Electricity Tariff Setting and Fund Mechanism

III-2.8.1 Electricity Tariff Setting

There are two types of electricity tariff system: one is the metered rate system; the other is the flat-rate system. In the former case, the following actions are made: installation of electricity meter, periodical meter inspection, submission of electricity bill according to the energy consumption. For these activities, a person in charge of inspection and tariff calculation is required. Thus, it would be a time-consuming and less-effective job especially in a low population area. On the other hand, the flat-rate system does not involve such fiddly procedure, and an electricity bill with a constant price will be issued to the consumers. This would save much cost in paperwork.

Item	Advantage	Disadvantage
Metered rate system	Fair in cost sharing	Fiddly for meter inspection
Flat-rate system	No need for meter inspection	Unfair to the small consumer

Especially, there is little variation in energy consumption by each household, in the case of solar power project. Therefore, an advantage of the flat-rate system can be expected. From this viewpoint, examination was made on the condition that the flat-rate system would be adopted for this project.

1. Items for Examination and Conditions

In order to examine the level of electricity tariff, the following items will be referred. Basically, the tariff should cover the operation and maintenance cost from a viewpoint of sustainability. It also should be set at an affordable level to the most of the local people. In the case that the tariff rate thus calculated is expensive in comparison with the level of current tariff rate level, application of a certain subsidiary system should be considered.

(1) O&M cost
(2) Current level of electricity tariff
(3) Willingness to pay

Each item is examined as follows:

(1) O&M Cost

The operation and maintenance cost is tentatively estimated as 2% of the investment, thus annual cost is calculated as US$1,222.

(2) Current Level of Electricity Tariff

A unit rate of 18 Soles/month, applied for SHS in GEF Project, shall be used as a reference.

(3) Willingness to Pay

A willingness to pay mentioned here refers to the value of the current energy expenditure, obtained by an inquiry conducted for local people as a part of social study. It is not the value obtained as "willingness to pay" in the inquiries.

Table III-2.8.1-1 Willingness to Pay: Tarapoto

(Nuevos Soles)

Max	68.0
Min	8.0
Average	21.3
Median	20.0

2. Result of Examination

Next, a tentative calculation of electricity tariff required to recover the cost for electricity service, with the following conditions:

- Micro-enterprise does not earn any profit.
- Operation cost of is 2% of the initial investment cost
- Replacement of equipment is the responsibility of a micro-enterprise

As a result, the level of electricity tariff was calculated as follows:

No subsidy to initial investment	24.34 Soles
100% subsidy to initial investment	9.89 Soles

A tariff to cover the operation and maintenance cost, including the replacement cost for this project, is calculated as 24.34 Soles/month for SHS. As to the rate for SHS, it exceeds some 6 Soles as compared to the tariff of 18 Soles applied in GEF Project. From a viewpoint of willingness to pay, about a half of 45 households can afford to pay.

In order to minimize the amount of subsidy, the operation cost of the micro-enterprise to be established by the local people requires further examination, including self-help efforts by local people.

Under the condition that the initial investment is totally subsidized, the subsidy level to recover the O&M cost was calculated for the following cases:

- GEF Project tariff : 18.0 Soles
- 80% of the willingness to pay : 10.0 Soles
- Grid tariff (incl. FOSE) : 2.43 Soles(= $1.25 + 0.2468 \times 38.69 / 12 \times 1.19$)

(unit: Nuevos Soles)

Unit rate/month	Subsidy amount	Annual amount	Remarks
18.00	0.00	0.0	GEF tariff
10.00	0.00	0.0	80% coverage
9.89	0.00	0.0	Base rate
2.43	7.46	4,028.4	7.46 × 45 HH × 12

III-2.8.2 Fund Mechanism

1. Construction Cost

The initial investment cost required for the project shall be procured from the SPERAR Fund, as well as the fund of the local government (e.g. CANON).

2. Training Cost

The cost required for providing training for project management shall be procured form the SPERAR fund.

3. Operation and Maintenance Cost

The operation and maintenance cost shall basically be borne by the consumer as an electricity tariff. The operation cost of a micro-enterprise to be established by local people shall also be covered with this fund.

4. Subsidy

Subsidy is indispensable in order to secure stably a certain level of revenue. At least, it is desirable to set the electricity tariff at a similar level with the neighboring area electrified with a grid. For this purpose, it is important for a micro-enterprise to register as an electricity serving company in MEM, and apply to OSINERGMIN for a provision of cross subsidy based on FOSE.

III-2.9 Social and Environmental Consideration

The following table shows the result of evaluation and measure to the environmental factors that are supposed to give impact on natural and social environment in Tarapoto.

Table III-2.9-1 Result of Environmental Survey and Measures

<table>
<tr><th>Items</th><th>Rat-
ing</th><th>Result of the survey</th><th>Measures</th></tr>
<tr><td>Misdistribution of benefit and damage</td><td rowspan="2">C</td><td rowspan="2">People with lower income in the community will not be able to use the electrical service after the PV system is introduced. It is anticipated that misdistribution of benefit will be occur among inhabitants.</td><td rowspan="2">(1) The master plan proposes that MEM/DPR should establish the financial supporting system in order that the poor people can use electricity.
(2) The master plan plans to introduce BCS, whose charge is lower than that of SHS, for the poor people.</td></tr>
<tr><td>Local conflicts of interest</td></tr>
</table>

Items	Rat-ing	Result of the survey	Measures
Gender	C	As women may be difficult to participate in the dissemination, training and management organization that the master plan proposes to give to inhabitants, it is anticipated that electrification fixes the inequity between both genders relating to social development.	The master plan proposes that the implementer should recommend and support inhabitants that women must be given dissemination and training as well as have possibility of candidate of the management organization.
Solid wastes	C	At national level, quality and capacity of treatment and recycle of used battery is limited now. As the number of project sites increases, recycling will be difficult. As result, it is anticipated that water pollution and air pollution will occur by acid and lead due to inappropriate treatment in the small scale factories.	The master plan proposes to establish the battery recycling system (the batteries used for the PV system will be collected, treated by private companies and re-used by PV users). Also, it suggests that MEM/DPR should take initiative of giving administrative directives, in collaboration with Ministry of Production who are in charge of solid waste treatment and Ministry of Health in charge of industrial health, to the factories that discharge pollution through batter treatment and recycling.

Note: Evaluation classification
A: Serious impact is expected.
B: Impact is expected to a certain extent.
C: Not strong impact is expected but impact sometimes occurs.
D: Low level impact may happen. More minute investigation and evaluation are required at the FS.
Source: JICA study team, 2008

III-3 Mini/Micro Hydropower (Yerba Buena in Cajamarca Region)

III-3.1 Natural Conditions

The project site is San Juan Yerba Buena which is located in the southeast of Cajamarca region. Yerba Buena is located approximately 30 km northeast from Cajamarca city, from where the site can be accessed approximate 2 hours by car (refer to Table III-3.1-1). Although the access roads have already been asphalt-paved from Cajamarca to Encañada on the way to Yerba Buena, unpaved road continues to the project site beyond that place. The project site is located at a height of 3,500 m above sea level, where it belongs to a mountain area 1,000 m higher than Cajamarca city.

Table III-3.1-1 Project Site

Region	: Cajamarca
Province	: Cajamarca
District	: Encañada
Village	: San Juan Yerba Buena Grande

III-3.2 Social and Economic Conditions and Gender Issues

1. Community (Localidad) and Population

- Twelve communities are chosen as the target by Pre-FS, which may be under different *centro poblados*. They are located in the catchment area of Rio Challuagon and its three tributaries, but some communities may be located beyond the boundary of the catchment area.
- Total population of these communities is 582 (source: Health Post of Yerba Buena Grande & DPR database).

Yerba Buena Grande 76
San Luis..............................41 (DPR)
Chancas ....50 (DPR)
Guagayo ....45 (DPR)
Yerba Buena Chica...........102
Toldopata............................70
Quinua Pampa ....39 (DPR)
Porvenir Encañada.....................50
San Nicolas de Challuaguún......44
Yerba Buena Alta 26
Santa Rosa de Yerba Buena 19
Santa Rosa de Milpo..................20 (DPR)

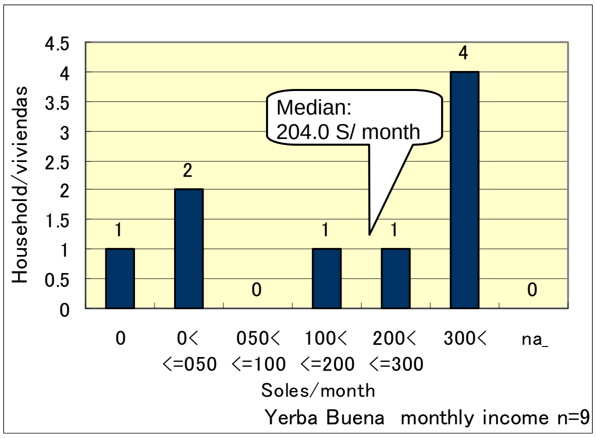
- There are primary school, secondary school, health post and satellite phone using solar panel in San Juan Yerba Buena Grande (the main village). Some of the other communities have primary school but data was not given in the Pre-FS period as the target communities had not been decided.
- Houses are scattered from river side (3,500 m) to hill top (3,800 m).
- Fields are mainly used for cow grazing and cultivated land is small.

- Comparing with other Pre/Fs sites, Yerba Buena is located relatively near to the big city (Cajamarca, the capital of the region), about two hours by car (25km in the line of the crow), and inhabitants frequently go there for purchase of daily necessities.

2. Industry and Main Income Sources

This area is located in the *suni* zone (chilly upland), where agriculture (maize, potato) and cow raising meet.

- Main income source is selling milk to two large milk companies, Nestle and Gloria. Both companies buy fresh milk every day at 0.55 Soles/liter and pay for it every 15 days. One cow produces 3 litters of milk a day and a household who has one cow gains approximately 50 Soles monthly.
- The survey shows that a household owns 3.8 heads of cow in average, but the number might be more. Households who do not own cows gain income by crop sales or wage labour but their income is rather small. The number of cows means the degree of wealth of the family.
- Income distribution of Yerba Buena Grande (interview result) is shown in Fig. III-3.2-1. Even though the number of interviews is limited, the median of monthly income is higher compared with two Pre-FS sites of the solar system.

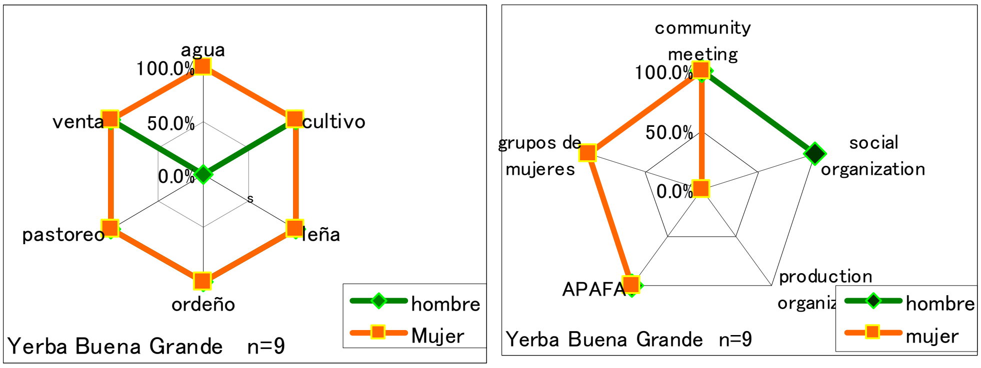


Note: The data estimated by sales amounts of products. Probably, estimated lower than the actual income.
Source: JICA study team, 2008

Fig. III-3.2-1 Income distribution in Yerba Buena Grande

3. Gender

In this area, each of women and men organize own traditional, communal organization *ronda* and have social authority. Though the number of respondents is limited, the result of the community survey shows that women and men share daily works except water drawing as well as participate in social activities except social institution. Thus, women's participation in Yerba Buena is the highest among the four sites of pre feasibility study level.



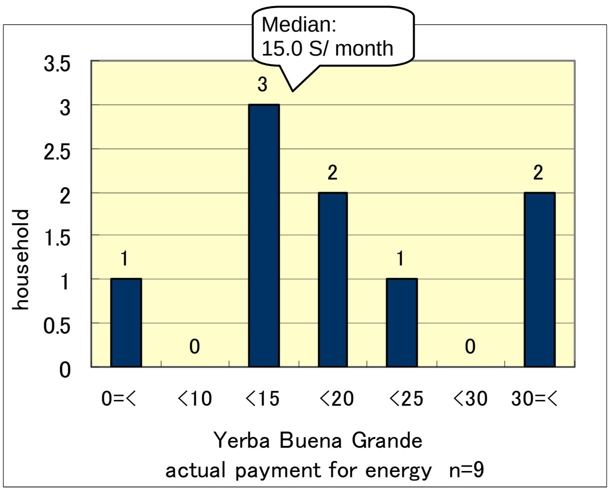
Source: JICA study team 2008

Fig. III-3.2-2 Gender Distribution in Daily Livelihood Activity (left) and Social Activity (right)

III-3.3 Demand of Electricity and Affordability

1. Actual Energy Use

- Candle and matches are main energy sources and kerosene lamp follows but not used so often. Actual monthly payment for energy is 15.0 Soles in median.
- Many households possess radio, some have TV and mobile phones.
- Secondary school has a computer using solar panel donated by mining company in 2001. It is used for learning.
- Mobile phone is used by many inhabitants.
- So, inhabitants are accustomed to 'civilized or modernized life' to a certain extent.

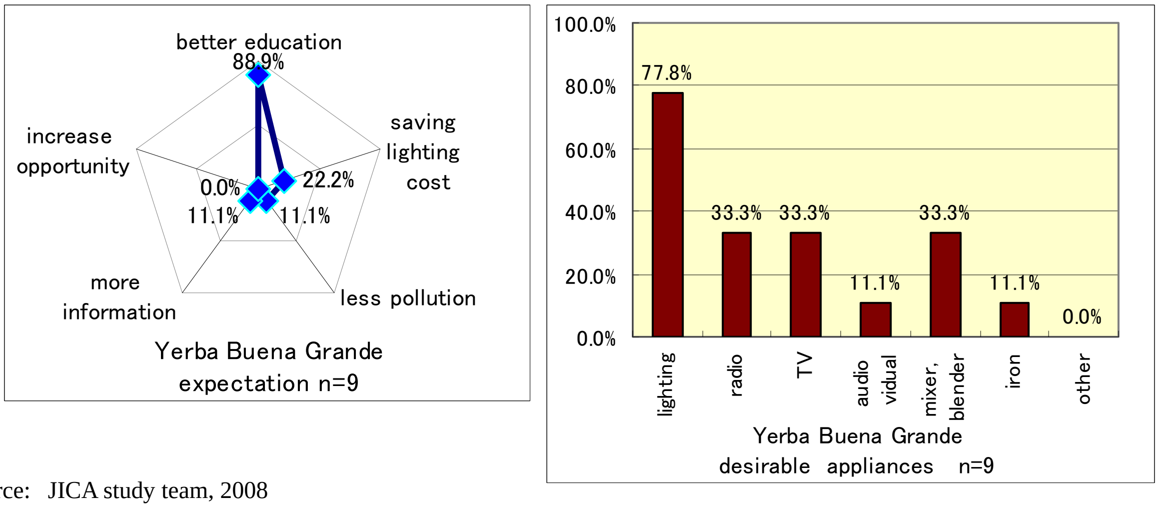


Source: JICA study team 2008

Fig. III-3.3-1 Actual Payment for Energy

2. Intention of Electrification

- Six communities among twelve were included in the PAFE III of JBIC (SNIP No. 8195). However, the mayor of Encañada District requested to the JICA study team to execute Pre-FS (and implement) by mini/micro hydropower system.
- Three private micro hydropower generators work in San Juan Yerba Buena Grande. Users paid 500 Soles as initial cost and 5 soles as monthly cost to the owner of the generator. Other inhabitants know well this and want to use electricity. However, only 22% of the interviewed people know the renewable energy.
- The most expectation after electrification is to improve education condition by light and computer and the most desirable electric appliance is lighting (bulb.)



Source: JICA study team, 2008

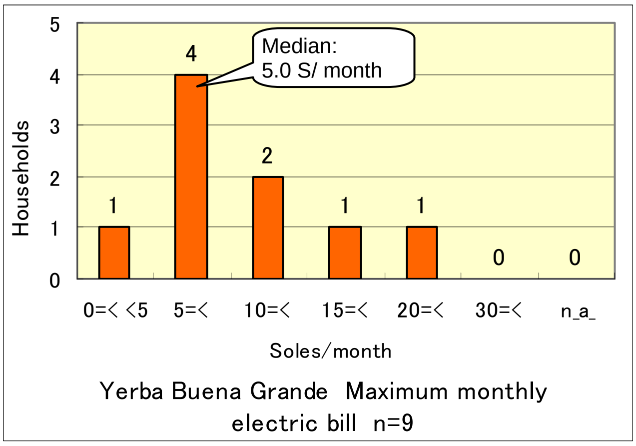
Fig. III-3.3-2 Expectation of Electrification (left) and Desirable Electric Appliances (right)

- As same as Catilluc (an electrified community in the region of Cajamarca where the community survey was carried out), the main income source of Yerba Buena is milk sale. Catilluc has a milk refrigerator using electricity. However, neither community officials nor interviewed inhabitants showed intention of productive use of electricity.

3. Affordability

- The amount of maximum affordable payment for electricity is 5 Soles a month according to the result of community survey. It is far less than the estimated necessary amount, supposedly because inhabitants well know that the users of actual hydropower system pay this amount every month. Respondents of the survey forget or ignore that the actual electricity service using micro hydropower requires users to pay initial cost (500 Soles).
- On the other hand, some households show an intention to pay more than 15 Soles.

- As the median monthly income of Yerba Buena Grande is rather high in the surveyed communities, it may be possible for inhabitants to pay more. However, the implementer needs to explain the project and reach agreement of all inhabitants.
- Two-thirds of the respondents say that they prefer to pay the electricity bill every month, while 22.2% of them say that they prefer to pay every half a year.



Source: JICA study team, 2008

Fig. III-3.3-3 Maximum Affordable Monthly Electricity Bill

III-3.4 Comparison of Initial Investment Amount by Electrification Method

The team studied the electrification method most suitable to the location, taking the number of the households as parameter. The assumption is as follows:

<Assumption>

[Village Information]	Number of Localidad	:	12
	Number of User	:	557
	Connecting Rate	:	0.8
[Hydro Power]	Linea Primarias	:	5,800 (US$/km)
	Redes Primarias	:	290 (US$/User)
	Redes Secundaria	:	490 (US$/User)
	Hydro Power (Electric)	:	1,000 (US$/kW)
	Hydro Power (Civil)	:	2,000 (US$/kW)
	Length of Linea Primarias	:	23.75 (km)
[Photovoltaic]	PV	:	780 (US$/User)
[Grid Extension]	Length of Linea Primarias from end of Existing Grid	:	7.2 (km)

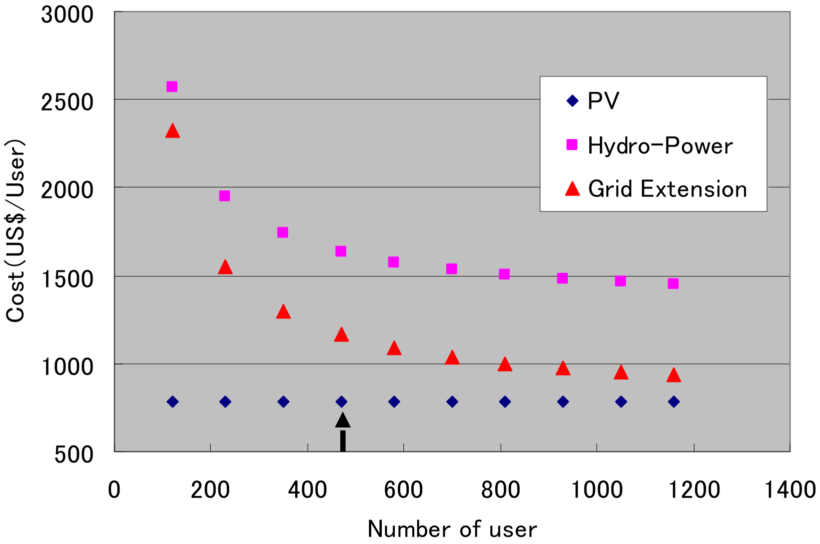


Fig. III-3.4-1　Comparison of Initial Investment Amount by Electrification Method (3)

The number of the households targeted to be electrified at this location is 465 (Household: 557, Target rate: 0.8). As Fig. III-3.4-1 shows, PV is more preferable to grid extension or hydropower for electrification method in terms of initial investment amount.

Furthermore, not only initial investment amount but operation & maintenance expense, future power usage expected in a productive manner, and future socio- economic development at this location should be studied to decide the most appropriate method of electrification.

III-3.5　Design and Cost

III-3.5.1　Design

1.　Target Villages

The target villages are mainly San Yuan Yerba Buena Grande and its surrounding 11 villages which do not have any grid extension plans.　The target villages and the number of households are shown in Table III-3.5.1-1.　The data regarding the number of households come from GIS data in DPR and the health post data in 2006 from the site survey in Table III-3.5.1-1.　The prior data is the latter one and the former one is adopted in the case of no data in the latter one.　In addition, 25 households served by the existing mini hydropower are excluded as shown in Table III-3.5.1-1.

Table III-3.5.1-1 Target Villages and Number of Households

No.	ID	Region	Province	District	Villages	Household	
						DEP(GIS)	Health Post 2006
1	0601050034	Cajamarca	Cajamarca	Encañada	Yerba Buena Grande	71	**76**
2	0601050033	Cajamarca	Cajamarca	Encañada	Yerba Buena Chica (la Torre)	101	**102**
3	0601050023	Cajamarca	Cajamarca	Encañada	San Nicolas De Challuagun	38	**44**
4	0601050032	Cajamarca	Cajamarca	Encañada	San Luis	**41**	-
5	0601050029	Cajamarca	Cajamarca	Encañada	Toldopata (Toldo Pata)	53	**70**
6	0601050027	Cajamarca	Cajamarca	Encañada	Yerba Buena Alta	18	**26**
7	0601050035	Cajamarca	Cajamarca	Encañada	Chancas	**50**	-
8	0601050024	Cajamarca	Cajamarca	Encañada	Quinua Pampa	**39**	-
9	0601050036	Cajamarca	Cajamarca	Encañada	Santa Rosa de Yerba Buena	14	**19**
10	0601050028	Cajamarca	Cajamarca	Encañada	Guaguayo	**45**	-
11	0601050025	Cajamarca	Cajamarca	Encañada	Porvenir Encaðada	45	**50**
12	0601050026	Cajamarca	Cajamarca	Encañada	Santa Rosa De Milpo	**20**	-
					Subtotal	**582**	
					Total	**582 – 25 = 557**	

2. Project Parameters

This project is so designed that a weir and intake will be installed in Challuagon river, river water will be conveyed from the intake to 1.3 km downstream approximately and then electric power will be generated by use of about 100 m height. The project parameters are shown in Table III-3.5.1-2.

Table III-3.5.1-2 Project Parameters

Catchment Area	: 23.0 km^2
Name of River	: Challuagon
Length of Canal	: 1.3 km
Length of Penstock	: 210 m
Intake	: E.L 3,530 m
Tailrace	: E.L 3,430 m
Gross Head (Effective Head)	: 100 m (97.0 m)
Discharge	: 0.112 m^3/s
Installed Capacity	: 80 kW

3. Electricity Demand

(1) General Demand

Electricity demand for this project was estimated under the following conditions. At first, it was assumed that electricity demand /month /household will be 15 kWh, and then business demand like restaurants, stores and small industries and public illuminations were allocated by a rate based on the household demand (15 kWh/month /household). This value is equal to 40 W light × 2 (6 hours), 20 W radio × 1 (4 hours) in one day equivalent. The growth rate of population for 20 years from this time was assumed to be 1.5%/year, the connection rate to distribution lines was also assumed to be 80% in consideration of existing households far from distribution lines. In addition, the plant factor was assumed to be 25% corresponding to 6 hours/day because peak demand in the near term is expected for lights and radio use during the night time.

Table III-3.5.1-3 Estimate Condition of Electricity Demand

(a) Number of household	: 557
(b) Electricity demand /household	: 15 kWh/month
(c) Business demand (Restaurant, store, etc.)	: 10% of total household electricity demand
(d) Small industries demand	: 10% of total household electricity demand
(e) Public illuminations	: 5% of total household electricity demand
(f) Others (Public facilities)	: 10% of total household electricity demand
(g) Backup	: 15% of total household electricity demand
(h) Transmission and distribution loss	: 10% of [(c) + (d) + (e) + (f) + (g)]
(i) Growth rate of population (20 years)	: 1.5%
(j) Connection rate (Peak)	: 80%
(k) Plant factor	: 25%

Necessary capacity was estimated as shown in the following table based on the above conditions.

Table III-3.5.1-4 Estimation of Necessary Capacity

(a) Number of target households (after 20 years)	: $0.8 \times 557 \times (1 + 0.015)^{20} \cong$ 600 users
(b) Total household electricity demand (kW)	: $P = \dfrac{E}{t \times f_c} = \dfrac{15 \times 600 \times 12}{8{,}760 \times 0.25} = 49.3$ $E = P \times t \times f_c$ E = Energy, t = Time, f_c =charge factor
(c) Business demand (Restaurant, store, etc.) (kW)	: $P \times 0.10 = 49.3 \times 0.10 = 4.93$
(d) Small industries demand (kW)	: $P \times 0.10 = 49.3 \times 0.10 = 4.93$
(e) Public illuminations (kW)	: $P \times 0.05 = 49.3 \times 0.05 = 2.47$
(f) Others (kW)	: $P \times 0.10 = 49.3 \times 0.10 = 4.93$
(g) Backup (kW)	: $P \times 0.15 = 49.3 \times 0.15 = 7.40$
(h) Subtotal (kW)	: (b) + (c) + (d) + (e) + (f) + (g) = 73.96
(i) Transmission and distribution loss (kW)	: $(h) \times 0.10 = 73.96 \times 0.10 = 7.40$
Total	: (b) + (c) + (d) + (e) + (f) + (g) + (i) = 81.36 ≒ **80 kW**

(2) Productive Demand

In this study, there is room for demand during the daytime because the peak demand is assumed as general demand for the night time. Therefore, productive demands in the future will be able to consider public facilities like a school, hospital and agriculture like an irrigation, milling, converted timber, milk pump, etc. depending on intended use as shown in Fig. III-3.5.1-1.

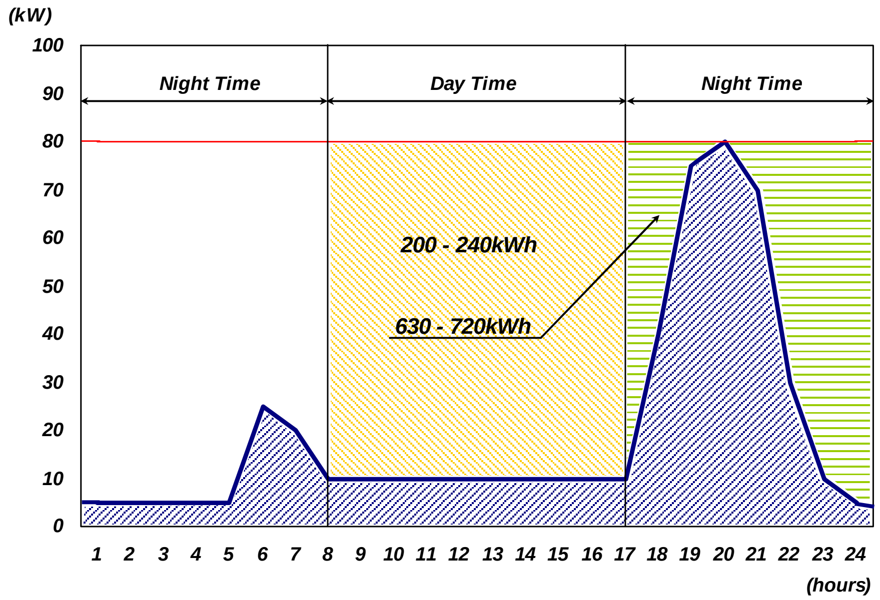


Fig. III-3.5.1-1 Pattern Diagram of Electricity Demand

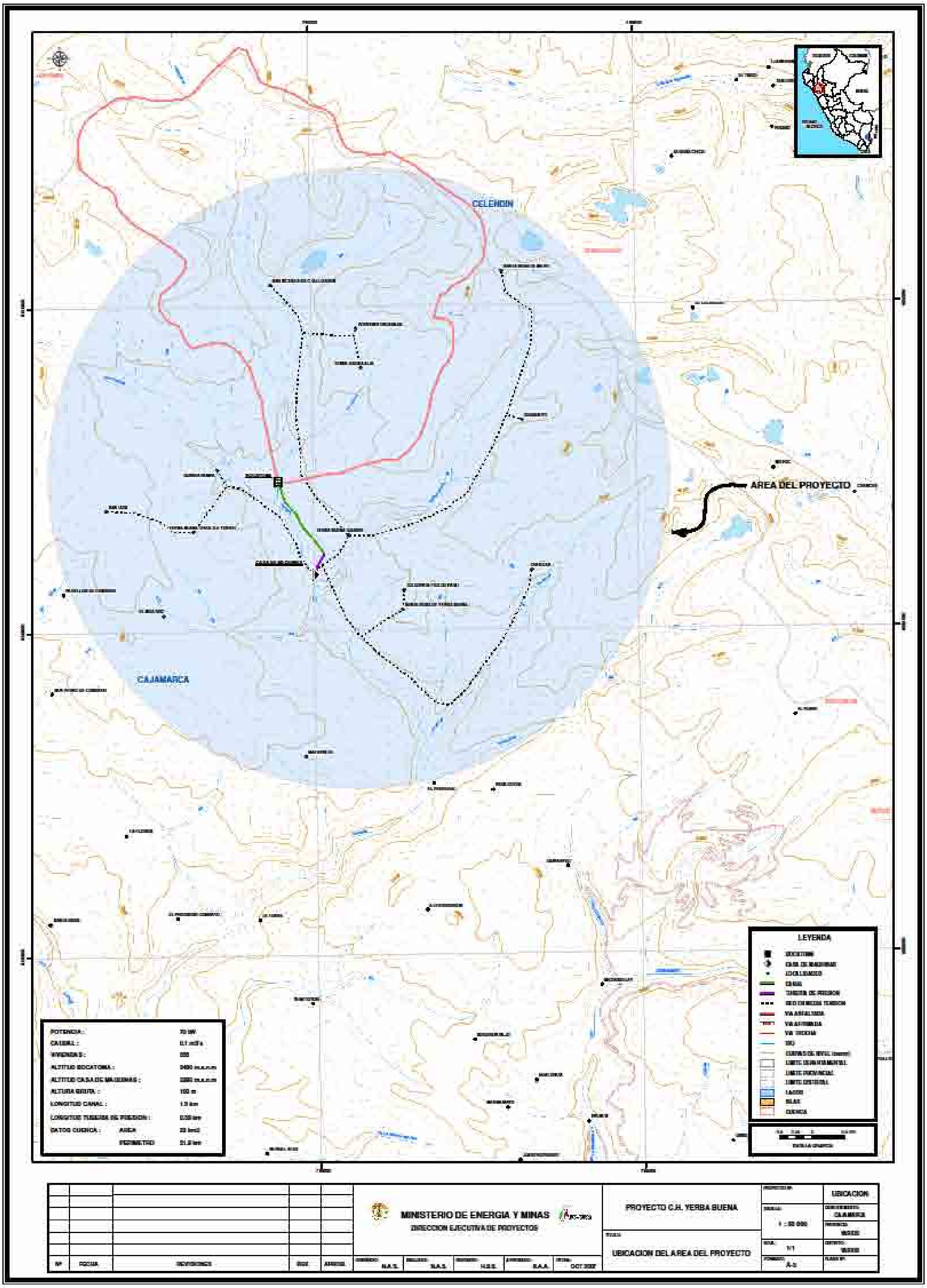


Fig. III-3.5.1-2   Planned Location of Power Station

4. Site Survey

(1) Surrounding Topography and Geology

This site is located in the altitude of 3,000 to 4,000 m, where relatively deep V-shaped ravines of 10 to 100 m height are formed in a river located at a high altitude. Consequently, rough terrains are formed around Yerba Buena.

Although rock outcrops can be seen from place to place in the river, cracks on those rocks are also found here and there. However, these seem to be relatively stable because there is little evidence of break and fall recently. A lot of gravels can be seen in the river bed near the planned location of intake, those grain diameters are several to dozens of centimeter (cm). Although fine-grain sand can be seen between gravels, few sedimentation problems are expected relatively because there is little sedimentation in the upstream and downstream river.

Photo III-3.5.1-1 Distant Prospect of Yerba Buena

Photo III-3.5.1-2 Condition of River and Ravine

Photo III-3.5.1-3 Condition of River Bed

Photo III-3.5.1-4 Rock Outcrop at Stream Bank

(2) Simplified Location Survey

The simplified location survey was carried out by using GPS (Geographic Positioning System) in the site survey and approximate locations of main structures like an intake, headrace and powerhouse, etc. were grasped. Those results are shown in Table III-3.5.1-5.

Although the distance between the intake planned site and the head tank is about 1.3 km, the headrace in this section can be partially using the existing irrigation channel with 600 m length (1.2 m width × 0.6 m height). In addition, the head between the planned intake site and the powerhouse of about 100 m can be secured. Generally, its accuracy about the altitude is sometimes a problem in the use of GPS but there are few problems in the use of the relative altitude.

(3) Simplified Measurement for River Discharge

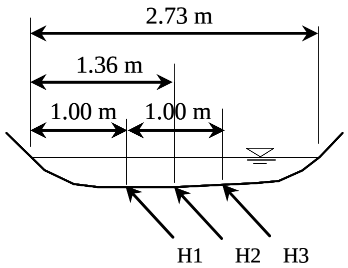
It is one of the most important factors to grasp the river discharge in hydropower planning. Measurements for several years should be carried out and accumulated discharge data in a project river at the stage of actual planning. These data are not prepared in Peru; therefore there are a lot of problems at the stage of planning. If discharge measurement is carried out in a near river which is not the actual target, the actual discharge will be able to be easily estimated by comparison of the catchment areas between the measured and the projected rivers. However, the above method has a problem of application for micro hydropower cases, which will make use of a small river with a catchment area several km^2 because a river with its discharge data usually has a large catchment area with 100 to 1,000 km^2 and the difference between those catchment areas is too much. On the other hand, in the case without measured data in a project river, a method can be used: a model of hydrological balance and mathematics by using existing precipitation data, etc. These methods have limited application to estimation of a discharge in the case without data, consequently, a project river discharge should be essentially obtained from measured data.

Table III-3.5.1-5 Results of Simplified Location Survey

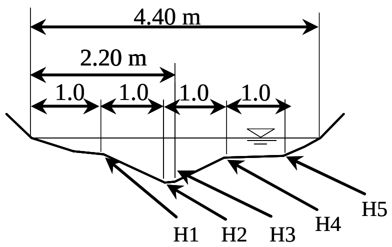
Location	Longitude and Latitude	Altitude (m)	Interval Distance (m)	Cumulative Distance (m)
Planning Location of Intake	S 06 58’ 48.4” W 078 22’ 44.8”	3,524	0	0
Existing Canal_1	S 06 58’ 54.4” W 078 22’ 47.9”	-	210	210
Existing Canal_2	S 06 58’ 55.9” W 078 22’ 47.5”	-	50	260
Existing Canal_3	S 06 58’ 58.8” W 078 22’ 47.8”	-	80	340
Existing Canal_4	S 06 59’ 01.8” W 078 22’ 47.9”	-	100	430
Existing Canal_5	S 06 59’ 05.1” W 078 22’ 47.5”	3,521	110	540
End of Existing Canal	S 06 59’ 07.2” W 078 22’ 48.7”	3,516	70	610
Planning Location of Head Tank	S 06 59’ 23.9” W 078 22’ 37.3”	3,523	620	1,230
Planning Location of Powerhouse	S 06 59’ 29.2” W 078 22’ 41.2”	3,423	200	1,430

In this study at first appropriate data were investigated regarding rivers near the project but no data were found.

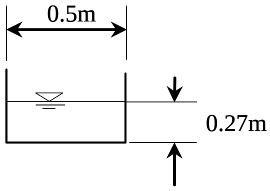
Therefore, a discharge measurement was implemented at Yerba Buena site in the second site survey. July, when the second site survey was carried out, is a dry season in Peru and it is appropriate time in order to obtain minimum discharge that should be basic data for planning of micro hydropower. In addition, measurement for daily water level in the project river was requested to local residents until the end of September in order to grasp its discharge fluctuation in the dry season. These results are shown below. As well, a measurement of discharge for the existing irrigation channel was carried out.

<table>
<tr><th colspan="2">[Site ST.1] Location of Staff Gauge
(The result of measurement for river crossing and current velocity)</th></tr>
<tr><td>Location</td><td>S: 06°58’45.8”, W: 078°22’44.0” (Altitude=3,523 m)</td></tr>
<tr><td>Velocity (No. 1)</td><td>V_1 = 3 m / 7.54 sec = 0.398 m/sec</td></tr>
<tr><td>Velocity (No. 2)</td><td>V_2 = 3 m / 6.37 sec = 0.471 m/sec</td></tr>
<tr><td>Velocity (No. 3)</td><td>V_3 = 3 m / 7.64 sec = 0.393 m/sec</td></tr>
<tr><td>Average Velocity</td><td>V = 0.421 m/sec</td></tr>
<tr><td>Staff Gauge</td><td>30 cm (July 9, 2007)</td></tr>
<tr><td>River section</td><td>


H1 = 0.24 m
H2 = 0.21 m
H3 = 0.10 m
Average = 0.18 m
A = 2.73 × 0.18 = 0.491 m^2</td></tr>
<tr><td>Calculated discharge</td><td>Q = A × V = 0.491 × 0.421 × 0.8 = 0.165 m^3/s</td></tr>
</table>

<table>
<tr><th colspan="2">[Site ST.2] Location of Staff Gauge
(The result of measurement for river crossing and current velocity)</th></tr>
<tr><td>Location</td><td>S: 06°58’46.2”, W: 078°22’44.4” (Altitude=3,522 m)</td></tr>
<tr><td>Velocity (No. 1)</td><td>V_1 = 5 m / 15.89 sec = 0.315 m/sec</td></tr>
<tr><td>Velocity (No. 2)</td><td>V_2 = 5 m / 18.86 sec = 0.265 m/sec</td></tr>
<tr><td>Velocity (No. 3)</td><td>V_3 = 5 m / 18.82 sec = 0.266 m/sec</td></tr>
<tr><td>Average Velocity</td><td>V = 0.282 m/sec</td></tr>
<tr><td>Staff Gauge</td><td>17 cm (July 9, 2007)</td></tr>
<tr><td>River section</td><td>


H1 = 0.10 m
H2 = 0.16 m
H3 = 0.15 m
H4 = 0.09 m
H5 = 0.08 m
Average = 0.12 m
A = 4.4 × 0.12 = 0.528 m^2</td></tr>
<tr><td>Calculated discharge</td><td>Q = A × V = 0.528 × 0.282 × 0.8 = 0.119 m^3/sec</td></tr>
</table>

[Site Irrigation Channel] The result of measurement for river crossing and current velocity	
Location	S: 06°58’51.9”, W: 078°22’46.7” (Altitude=3,523 m)
Velocity (No. 1)	V_1 = 10 m / 25 sec = 0.400 m/sec
Velocity (No. 2)	V_2 = 10 m / 32 sec = 0.313 m/sec
Velocity (No. 3)	V_3 = 10 m / 30 sec = 0.333 m/sec
Average Velocity	V = 0.349 m/sec
River section	 A = 0.5 × 0.27 = 0.135 m^2
Calculated discharge	Q = A × V = 0.135 × 0.349 × 0.8= **0.038 m^3/sec**

Discharge measurements were carried out at the above 2 sites (ST.1 and 2) and the existing irrigation channel. In addition, simplified staff gauges are installed. ST.1 covers the whole cross section of this river and ST.2 covers a part of section, the distance between ST.1 and 2 is 10 m approximately. Water level was 30 cm on the staff gauge of ST.1 and 17 cm on the staff gauge of ST.2 when those were installed. JICA study team requested to record daily water level using staff gauges to local residents and obtained the results as shown in Table III-3.5.1-6 and Table III-3.5.1-7.

Fluctuations with several cm were seen depending on weather for the observation period, that was for 2 months approximately from July 9 to September 1, 2007, the resulting average value was each 30.3 cm and 17.7 cm. Therefore, the river discharge was estimated to be mostly constant after the second site survey. There is little vegetation around this site; therefore, it seems that the soil here has a problem about water retentivity. However, the discharge in dry season seems to be securable stably by existence of the lake (Challuagon) in an upstream of the river.

Photo III-3.5.1-5 Lake Challuagon (Upstream of the Site)

Table III-3.5.1-6 Result of Water Level Measurement (ST.1)

Name of River : Challuagon
Village : Yerba Buena Grande
Province : Encanada
Region : Cajamarca
Station No. : 1

Date	Time 8:00:00 (cm)	12:00:00 (cm)	17:00:00 (cm)	Weather	Remarks
09-Jul-07	-	-	30.0	clear	
10-Jul-07	30.0	-	-	cloudy	
11-Jul-07	30.0	-	-	clear	
12-Jul-07	30.0	-	-	clear	
13-Jul-07	30.0	-	-	clear	
14-Jul-07	30.0	-	-	clear	
15-Jul-07	30.0	-	-	cloudy	
16-Jul-07	30.0	-	-	clear	
17-Jul-07	31.0	-	-	cloudy	
18-Jul-07	31.0	-	-	rainy	
19-Jul-07	30.0	-	-	clear	
20-Jul-07	30.0	-	-	cloudy	
21-Jul-07	30.0	-	-	clear	
22-Jul-07	30.0	-	-	clear	
23-Jul-07	30.0	-	-	clear	
24-Jul-07	-	-	-	-	No data
25-Jul-07	-	-	-	-	No data
26-Jul-07	31.0	-	-	cloudy	
27-Jul-07	32.0	-	-	rainy	
28-Jul-07	30.0	-	-	clear	
29-Jul-07	31.0	-	-	clear	
30-Jul-07	31.0	-	-	clear	
31-Jul-07	30.0	-	-	clear	
01-Aug-07	30.0	-	-	clear	
02-Aug-07	30.0	-	-	clear	
03-Aug-07	31.0	-	-	clear	
04-Aug-07	31.0	-	-	clear	
05-Aug-07	30.0	-	-	clear	
06-Aug-07	30.0	-	-	clear	
07-Aug-07	31.0	-	-	clear	
08-Aug-07	31.0	-	-	clear	
09-Aug-07	31.0	-	-	rainy	
10-Aug-07	30.0	-	-	cloudy	
11-Aug-07	30.0	-	-	cloudy	
12-Aug-07	30.0	-	-	cloudy	
13-Aug-07	30.0	-	-	clear	
14-Aug-07	30.0	-	-	clear	
15-Aug-07	30.0	-	-	cloudy	
16-Aug-07	31.0	-	-	cloudy	
17-Aug-07	30.0	-	-	clear	
18-Aug-07	30.0	-	-	clear	
19-Aug-07	30.0	-	-	clear	
20-Aug-07	30.0	-	-	cloudy	
21-Aug-07	30.0	-	-	cloudy	
22-Aug-07	30.0	-	-	clear	
23-Aug-07	30.0	-	-	cloudy	
24-Aug-07	30.0	-	-	clear	
25-Aug-07	30.0	-	-	clear	
26-Aug-07	30.0	-	-	clear	
27-Aug-07	30.0	-	-	clear	
28-Aug-07	30.0	-	-	cloudy	
29-Aug-07	31.0	-	-	rainy	
30-Aug-07	32.0	-	-	rainy	
31-Aug-07	32.0	-	-	cloudy	
01-Sep-07	30.0	-	-	clear	

Average= 30.3 cm

Table III-3.5.1-7 Result of Water Level Measurement (ST.2)

Name of River : Challuagon
Village : Yerba Buena Grande
Province : Encanada
Region : Cajamarca
Station No. : 2

Date	Time 8:00:00 (cm)	12:00:00 (cm)	17:00:00 (cm)	Weather	Remarks
09-Jul-07	-	-	17.0	clear	
10-Jul-07	17.0	-	-	cloudy	
11-Jul-07	17.0	-	-	clear	
12-Jul-07	16.0	-	-	clear	
13-Jul-07	16.0	-	-	clear	
14-Jul-07	16.0	-	-	clear	
15-Jul-07	17.0	-	-	cloudy	
16-Jul-07	17.0	-	-	clear	
17-Jul-07	18.0	-	-	cloudy	
18-Jul-07	18.0	-	-	rainy	
19-Jul-07	17.0	-	-	clear	
20-Jul-07	17.0	-	-	cloudy	
21-Jul-07	17.0	-	-	clear	
22-Jul-07	17.0	-	-	clear	
23-Jul-07	17.0	-	-	clear	
24-Jul-07	-	-	-	-	No data
25-Jul-07	-	-	-	-	No data
26-Jul-07	17.0	-	-	cloudy	
27-Jul-07	18.0	-	-	rainy	
28-Jul-07	18.0	-	-	clear	
29-Jul-07	18.0	-	-	clear	
30-Jul-07	16.0	-	-	clear	
31-Jul-07	16.0	-	-	clear	
01-Aug-07	17.0	-	-	clear	
02-Aug-07	16.0	-	-	clear	
03-Aug-07	17.0	-	-	clear	
04-Aug-07	17.0	-	-	clear	
05-Aug-07	16.0	-	-	clear	
06-Aug-07	16.0	-	-	clear	
07-Aug-07	17.0	-	-	clear	
08-Aug-07	17.0	-	-	clear	
09-Aug-07	18.0	-	-	rainy	
10-Aug-07	20.0	-	-	cloudy	
11-Aug-07	20.0	-	-	cloudy	
12-Aug-07	19.0	-	-	cloudy	
13-Aug-07	19.0	-	-	clear	
14-Aug-07	19.0	-	-	clear	
15-Aug-07	18.0	-	-	cloudy	
16-Aug-07	19.0	-	-	cloudy	
17-Aug-07	19.0	-	-	clear	
18-Aug-07	19.0	-	-	clear	
19-Aug-07	18.0	-	-	clear	
20-Aug-07	18.0	-	-	cloudy	
21-Aug-07	18.0	-	-	cloudy	
22-Aug-07	19.0	-	-	clear	
23-Aug-07	19.0	-	-	cloudy	
24-Aug-07	19.0	-	-	clear	
25-Aug-07	19.0	-	-	clear	
26-Aug-07	17.0	-	-	clear	
27-Aug-07	17.0	-	-	clear	
28-Aug-07	18.0	-	-	cloudy	
29-Aug-07	19.0	-	-	rainy	
30-Aug-07	20.0	-	-	rainy	
31-Aug-07	20.0	-	-	cloudy	
01-Sep-07	19.0	-	-	clear	

Average= 17.7 cm

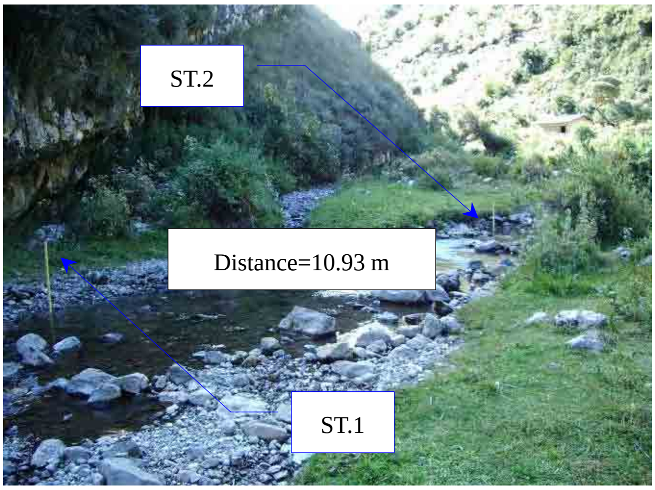


Photo III-3.5.1-6 Location of Staff Gauge

Photo III-3.5.1-7 Situation of Staff Gauge Installation

Photo III-3.5.1-8 Ditto

Photo III-3.5.1-9 after Installation of Staff Gauge (ST.1)

Photo III-3.5.1-10 Situation of Measurement River Section

Photo III-3.5.1-11 Discharge Measurement at Irrigation Channel

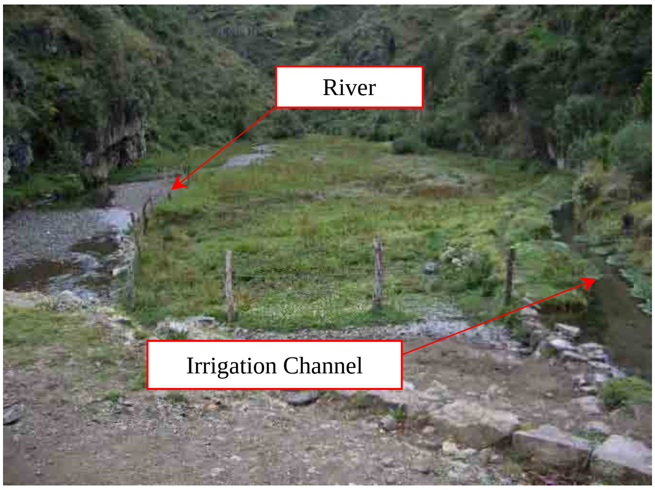


Photo III-3.5.1-12 River and Irrigation Channel

Photo III-3.5.1-13 Transfer of Measurement Instruments

Photo III-3.5.1-14 Explanation of Water Level Measurement

5. Civil Design

(1) Design Condition

<Estimation of Usable Discharge>

1) Results of Site Survey

The river discharge in dry season (minimum discharge), discharge for irrigation and usable discharge for electric power generation are expected as shown in Table III-3.5.1-8 from the results of the simplified measurement mentioned above.

Table III-3.5.1-8 Estimated Discharge

(a) River discharge in dry season	: **0.165 m^3/s**	(Minimum discharge)
(b) Discharge for irrigation	: 0.038 m^3/s	(Actual consumption is 50-60% approximately: **0.025 m^3/s**)
(c) Usable discharge for power generation	: (a) – (b) = 0.165 – 0.025 = **0.14 m^3/s**	

However, this site survey was carried out for only one season (dry season). As mentioned in the Master Plan, site survey for several years or existing data are necessary for estimation of river discharge. For this reason, the site survey and collecting data without interruption are necessary for final determination of river discharge.

2) Hydrological Analysis

The river discharge was studied by using analytical method from monthly average precipitation and temperature data in addition of site survey results. The monthly average precipitation and temperature data come from the data of Encañada, that is the nearest from the project site among existing data (SENAMHI). The precipitation data for 9 years from 1998 to 2006 and temperature data for 4 years from 2003 to 2006 were adopted as the latest one that can be obtained.

The monthly average precipitation and temperature is shown in Fig. III-3.5.1-3 and Table III-3.5.1-9. From this figure and table it is presumed that the dry season in this area is from May to September. The change of average temperature is from 2 to 3°C; this difference is not so much throughout the year. The total average precipitation/year is 980 mm approximately.

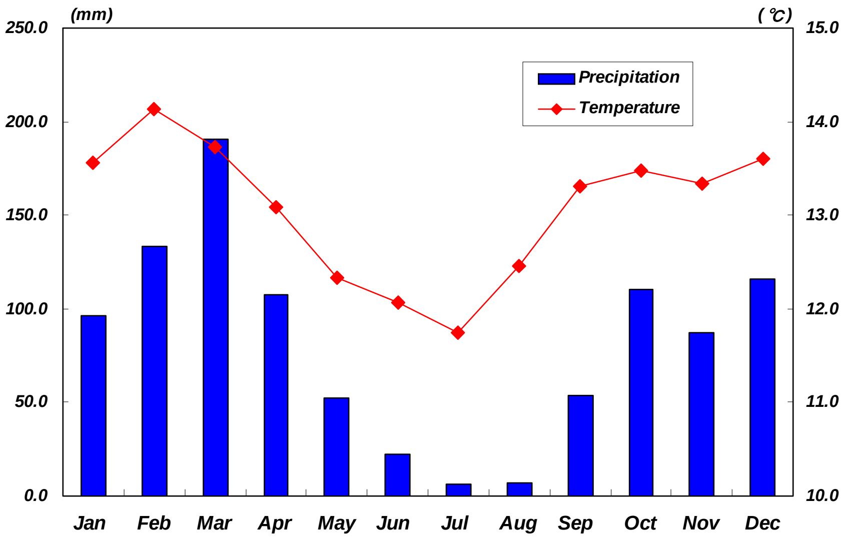


Fig. III-3.5.1-3 Monthly Average Precipitations and Temperature (Encañada)

Table III-3.5.1-9 Monthly Average Precipitations and Temperature (Encañada)

Precipitation Data of Yerba Buena (Encanada) **Unit: mm**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1998	102.1	196.0	223.3	181.7	71.5	6.2	0.5	8.4	36.3	132.7	40.4	86.6
1999	115.3	293.8	108.7	99.7	102.8	62.9	11.0	9.3	132.8	30.3	125.3	143.4
2000	46.9	155.9	184.7	106.7	89.7	18.2	0.9	20.0	88.1	4.7	50.4	117.4
2001	238.0	72.4	203.8	105.1	60.7	0.5	2.7	0.8	30.9	129.3	101.8	86.4
2002	42.9	89.4	241.1	117.7	12.6	14.1	4.4	1.1	28.8	159.2	S/D	S/D
2003	33.1	80.6	145.5	93.0	37.8	38.3	0.0	9.9	41.9	93.8	124.4	85.0
2004	95.4	72.5	54.6	91.1	39.8	5.8	21.7	0.5	44.2	173.2	108.5	171.2
2005	119.6	107.1	260.8	51.2	42.0	12.4	1.2	7.0	13.4	205.5	38.2	145.4
2006	74.6	134.7	292.1	124.5	14.8	41.8	11.4	4.9	65.4	61.2	106.9	91.7
Average	**96.4**	**133.6**	**190.5**	**107.9**	**52.4**	**22.2**	**6.0**	**6.9**	**53.5**	**110.0**	**87.0**	**115.9**

Temperature Data of Yerba Buena (Encanada) **Unit: ℃**

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2003	20.3	20.1	18.8	18.8	18.8	19.0	19.4	20.0	20.6	20.1	19.7	18.6
	9.2	8.5	8.1	7.7	6.6	5.2	4.0	5.0	6.1	7.2	7.8	8.2
2004	19.9	18.6	19.3	19.0	19.4	18.4	18.0	19.0	19.7	19.4	19.0	18.7
	5.6	8.7	8.4	6.7	5.5	4.8	5.6	5.2	6.1	8.0	8.2	8.6
2005	19.1	19.5	18.0	19.0	19.5	19.7	20.1	20.0	20.2	18.6	20.2	18.6
	7.4	9.8	9.6	8.0	4.6	4.8	3.3	5.0	7.3	7.9	5.2	7.8
2006	19.3	18.3	18.1	18.8	19.6	18.7	19.0	19.3	20.0	19.9	19.1	19.4
	7.8	9.6	9.6	6.7	4.8	6.0	4.6	6.3	6.4	6.8	7.4	9.0
Average	**13.6**	**14.1**	**13.7**	**13.1**	**12.3**	**12.1**	**11.8**	**12.5**	**13.3**	**13.5**	**13.3**	**13.6**

*Upper stand: Maximum temperature in each year

*Lower stand: Minimum temperature in each year

The estimation method uses a way of river discharge estimation from hydrological balance in this study. The relation between the precipitation, runoff (direct runoff and base runoff) and evapotranspiration of the river basin at the site can be expressed as shown below from the aspect of the annual hydrological balance.

$$P = R + Et = Rd + Rb + Et$$

Where,

- P : Annual precipitation (mm)
- R : Annual runoff (mm)
- Rd : Annual direct runoff (mm)
- Rb : Annual base runoff (mm)
- Et : Annual evapotranspiration (mm)

Runoff (R) is obtained from the recorded precipitation (P) and estimated evapotranspiration (Et) and estimated evapotranspiration is obtained from the precipitation and evapotranspiration which is estimated by using an equation. Fig. III-3.5.1-4 is a graphic depiction of relation among precipitation (P), potential evapotranspiration (Etp) and estimated evapotranspiration (Et).

The pattern diagram of the annual runoff is shown in Fig. III-3.5.1-5. Runoff consists of the base runoff mainly supplied from ground water with limited seasonal fluctuation and direct runoff resulting from precipitation. The ratio of the ground water (base runoff) to the annual gross runoff is shown in Table III-3.5.1-10. The ratio of South America region is set Rg = Rb, Rg/R = 0.36 from Table III-3.5.1-10. In addition, the potential evapotranspiration is estimated by using Blaney-Criddle equation below.

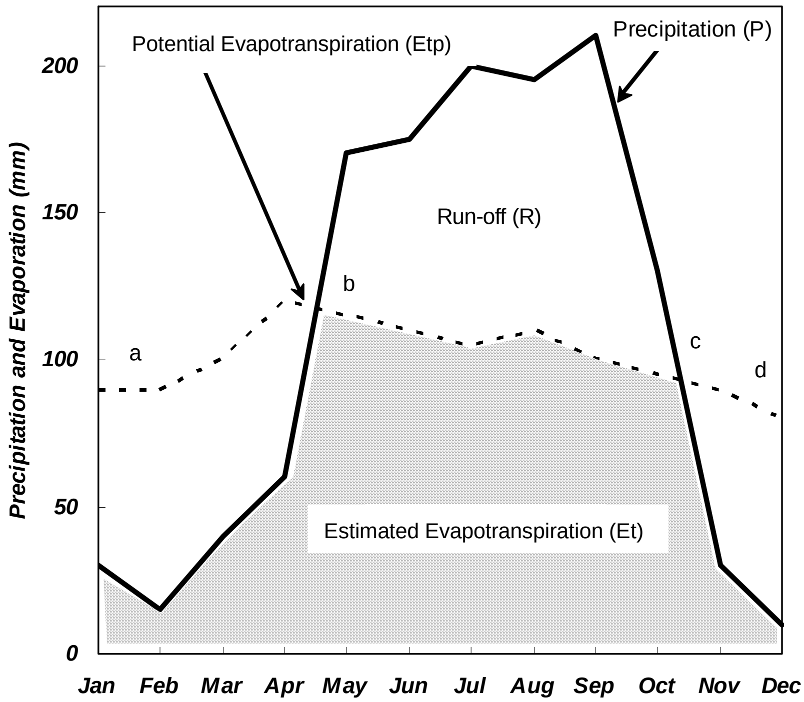


Fig. III-3.5.1-4 Pattern Diagram of Precipitation and Evapotranspiration

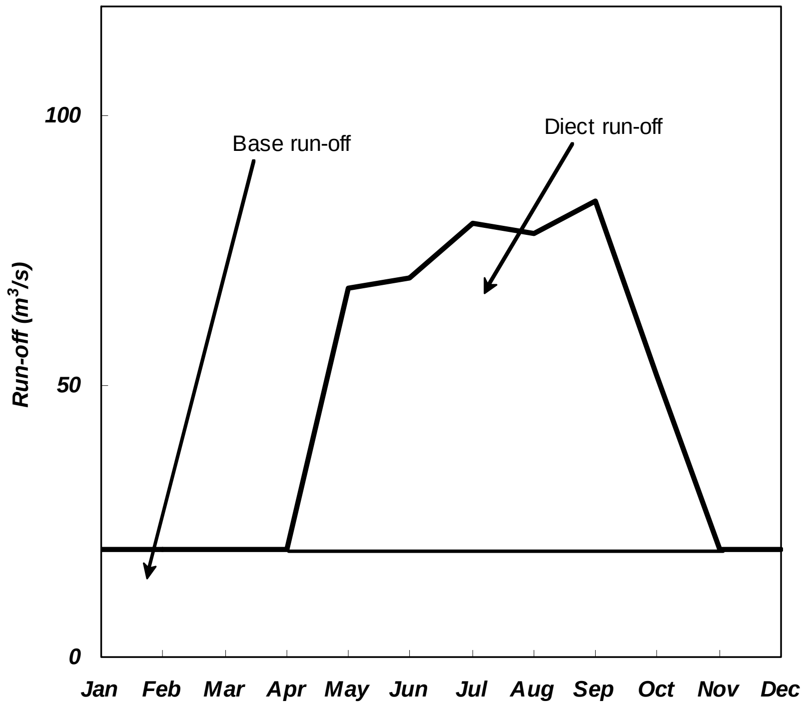


Fig. III-3.5.1-5 Pattern Diagram of Runoff

Table III-3.5.1-10 Hydrological Balance in Each Area

Region		Asia	Africa	North America	**South America**	Europe	Australia	Japan
Precipitation	(P)	726	686	670	**1,648**	734	736	1,788
Run-off	(R)	293	139	287	**583**	319	226	1,197
Direct run-off	(Rd)	217	91	203	**373**	210	172	-
Underground water	(Rg)	76	48	84	**210**	109	54	-
Evaporation	(Et)	433	547	383	**1,065**	415	510	597
Rg/R		26	35	32	**36**	34	24	-

Blaney-Criddle

$$u = K \cdot P \cdot \frac{(45.7t + 813)}{100}$$

Where,

u : Evapotranspiration by month (Consumptive use of water by month) (mm)

K : Coefficient of monthly consumption by vegetation
(*K*=0.3 (usually *K*=0.6) due to few vegetation at this site)

P : Monthly percent of daytime hours of the year (%) (refer to Table III-3.5.1-11)

t : Monthly average temperature (°C)

The result of discharge estimation at this site is shown in Table III-3.5.1-12 and Table III-3.5.1-13 based on the above.

Table III-3.5.1-11 Monthly Percent of Daytime Hours of the Year (Southern Hemisphere)

Month / South Latitude (dgree)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0	8.50	7.67	8.49	8.22	8.49	8.22	8.50	8.49	8.21	8.49	8.22	8.50
2	8.55	7.71	8.49	8.19	8.44	8.17	8.43	8.44	8.20	8.52	8.27	8.55
4	8.64	7.76	8.50	8.17	8.39	8.08	8.20	8.41	8.19	8.56	8.33	8.65
6	8.71	7.81	8.50	8.12	8.30	8.00	8.19	8.37	8.18	8.59	8.38	8.74
8	8.79	7.84	8.51	8.11	8.24	7.91	8.13	8.12	8.18	8.62	8.47	8.84
10	8.85	7.86	8.52	8.09	8.18	7.84	8.11	8.28	8.18	8.65	8.52	8.90
12	8.91	7.91	8.53	8.06	8.15	7.79	8.08	8.23	8.17	8.67	8.58	8.95
14	8.97	7.97	8.54	8.03	8.07	7.70	7.08	8.19	8.16	8.69	8.65	9.01
16	9.09	8.02	8.56	7.98	7.96	7.57	7.94	8.14	8.14	8.78	8.72	9.17
18	9.18	8.06	8.57	7.93	7.89	7.50	7.88	8.10	8.14	8.80	8.80	9.24
20	9.25	8.09	8.58	7.92	7.83	7.41	7.73	8.05	8.13	8.83	8.85	9.32
22	9.36	8.12	8.58	7.89	7.74	7.30	7.76	8.00	8.13	8.86	8.90	9.38
24	9.44	8.17	8.59	7.87	7.65	7.24	7.68	7.95	8.12	8.89	8.96	9.47
26	9.52	8.28	8.60	7.81	7.56	7.07	7.49	7.90	8.11	8.94	9.10	9.61
28	9.61	8.31	8.61	7.79	7.49	6.99	7.40	7.85	8.10	8.97	9.19	9.74
30	9.69	8.33	8.63	7.75	7.43	6.94	7.30	7.80	8.09	9.00	9.24	9.80
32	9.76	8.36	8.64	7.70	7.34	6.85	7.20	7.73	8.08	9.04	9.31	9.87
34	9.88	8.41	8.65	7.68	7.25	6.73	7.10	7.69	8.06	9.07	9.38	9.99
36	10.06	8.53	8.67	7.61	7.16	6.59	6.99	7.59	8.06	9.15	9.51	10.21
38	10.14	8.61	8.68	7.59	7.07	6.46	6.87	7.51	8.05	9.19	9.60	10.34
40	10.24	8.65	8.70	7.54	6.96	6.33	6.73	7.46	8.04	9.23	9.69	10.42
42	10.39	8.72	8.71	7.49	6.85	6.20	6.60	7.39	8.01	9.27	9.79	10.57
44	10.52	8.81	8.72	7.44	6.73	6.04	6.45	7.30	8.00	9.34	9.91	10.72
46	10.68	8.88	8.73	7.39	6.61	5.87	6.30	7.21	7.98	9.41	10.03	10.90
48	10.85	8.98	8.76	7.32	6.45	5.69	6.13	7.12	7.96	9.47	10.17	11.09
50	11.03	9.06	8.77	7.25	6.31	5.48	5.98	7.03	7.95	9.53	10.32	11.30

Table III-3.5.1-12 Results of Estimated Potential Evapotranspiration

Month	(1)*1 Temparature °C	(2)*2 P (%)	(3) BlaneyCriddle (mm)	(4) Precipitation (mm)	(5)*3 Actual evaporation (mm)
Jan	13.6	8.75	37.61	96.4	37.6
Feb	14.1	7.83	34.25	133.6	34.2
Mar	13.7	8.51	36.75	190.5	36.7
Apr	13.1	8.12	34.35	107.9	34.4
May	12.3	8.27	34.16	52.4	34.2
Jun	12.1	7.96	32.56	22.2	22.2
Jul	11.8	8.16	33.05	6.0	6.0
Aug	12.5	8.25	34.20	6.9	6.9
Sep	13.3	8.18	34.88	53.5	34.9
Oct	13.5	8.61	36.89	110.0	36.9
Nov	13.3	8.43	35.95	87.0	36.0
Dec	13.6	8.79	37.84	115.9	37.8

*1 Average value
*2 The monthly rate regarding time of possible exposure to sunlight for the year
*3 Minimum value between (3) and (4)

Table III-3.5.1-13 Results of Estimated Discharge

Month	(6) Run-off (mm) (4)-(5)	(7) Direct run-off (mm) (6)×0.75	(8) Base run-off (mm) A_1	(9) Monthly run-off (mm) (7)+(8)	(10) Avg. monthly run-off (m^3/s) A_2
Jan	58.8	44.1	19.1	63.2	0.543
Feb	99.4	74.5	17.2	91.8	0.872
Mar	153.8	115.3	19.1	134.4	1.154
Apr	73.5	55.1	18.5	73.6	0.653
May	18.3	13.7	19.1	32.8	***0.282***
Jun	0.0	0.0	18.5	18.5	***0.164***
Jul	0.0	0.0	19.1	19.1	***0.164***
Aug	0.0	0.0	19.1	19.1	***0.164***
Sep	18.7	14.0	18.5	32.5	***0.288***
Oct	73.1	54.8	19.1	73.9	0.635
Nov	51.0	38.3	18.5	56.8	0.504
Dec	78.0	58.5	19.1	77.6	0.667

(10) Monthly average run-off is calculated based on the equation below.

$$A_2 = \frac{(9)}{1{,}000} \times CA \times 10^6 \times \frac{1}{86{,}400 \times n}$$

Where,

A_2 : Average runoff of the site in each month (m^3/s)

CA : Catchment area (km^2) = 23.0 km^2

n : Number of days in the month (day)

The result of site survey corresponded approximately to the monthly average discharge from May to September that is equivalent to dry season, 0.212 m^3/s from the result of Table III-3.5.1-13. Consequently, each estimated discharge from the site survey as shown in Table III-3.5.1-8 can be guaranteed.

3) Head Loss

Head loss was estimated by each facility as shown in Table III-3.5.1-14. That is to say, friction loss was allocated in proportion as distance of headrace, penstock and tailrace and entrance and exit loss was also allocated settling basin and turbine, etc.

Table III-3.5.1-14 Head Loss Estimation

Facilities	***Loss***
(1) Headrace	1,300m x 1/1,000 = 1.3 m
(2) Intake, Settling Basin, Inlet Loss, Outlet Loss	0.05 m
(3) Penstock	210m x 1/200 = 1.05 m
(4) Tailrace	2m x 1/1,000 = 0.002 m
(5) Others (Inlet of Turbine)	0.6 m
(6) Total Loss	**3.0 m**

4) Plant Discharge

Effective head was decided as shown in Table III-3.5.1-15 from head loss in Table III-3.5.1-14. The altitude of intake and tailrace used the value obtained from the result of the site survey.

Table III-3.5.1-15 Effective Head

(7) Intak water level	E.L 3,530 m
(8) Tailrace water level	E.L 3,430 m
(9)Total Head	(7) - (8) = 100 m
(10) Effective Heaed	(7) - (8) - (6) = **97.0 m**

In addition, necessary plant discharge was decided based on combined efficiency 75%. Its result is shown in Table III-3.5.1-16. The plant discharge is 0.112 m^3/s less than minimum discharge 0.162 m^3/s in dry season; therefore, even if some of total river discharges are used for irrigation and maintenance flow discharge, the plant discharge will be sufficient.

Table III-3.5.1-16 Plant Discharge

Install Capacity (P)	80 kW
Efficiency of generator and turbine (η)	75 %
Necessary discharge (Q)	$Q = P/ 9.8 \times H \times \eta$ = **0.112 m^3/s**

(2) Preliminary Design

The study contents of preliminary design for civil structures are as follows. A schematic image of power station is shown in Photo III-3.5.1-20 and rough design drawings are shown in Fig. III-3.5.1-6 to Fig. III-3.5.1-9.

1) Weir

- The intake site should be selected in consideration of topographic and geological conditions with stable river bed and narrow river width as much as possible. This site could be seen with rock outcrops on the right bank and its river width being narrow compared with the surrounding points (refer to Photo III-3.5.1-15.).
- The height of weir was assumed at 50 cm in order to secure the necessary water depth at the intake.
- The weir will be kept in a submerged condition because the water level in the river is expected to be 1.43 m above the river bed under the design flood condition.

Photo III-3.5.1-15 Intake Site

[Estimated Design Flood] *by Creager Curves*

$$Q_f = q \times A$$

$$q = a \times A^{(A^{\wedge}(-0.05)-1)}$$

Where,

Q_f : Design flood discharge (m^3/s)

q : Specific discharge ($m^3/s/km^2$)

a : Regional coefficient (refer to Table III-3.5.1-17)

A : Catchment area (=23.0 km^2)

Therefore,

$$q = a \times A^{(A^{\wedge}(-0.05)-1)} = 10.79\ m^3/s/km^2$$

$$Q_f = q \times A = \mathbf{248.08\ m^3/s}$$

If the shape of river is assumed as shown below, design flood level at this site will be calculated by Manning's formula as shown below. Maximum flood level from local resident's interview is shown in Photo III-3.5.1-16.

$$V = \frac{1}{n} \times R^{\frac{2}{3}} \times I^{\frac{1}{2}} \qquad ,Q = AV$$

$I = 0.14,\ n = 0.03,\ L\theta = 30°, R\theta = 60°$

$\boldsymbol{h = 1.42\ m}$

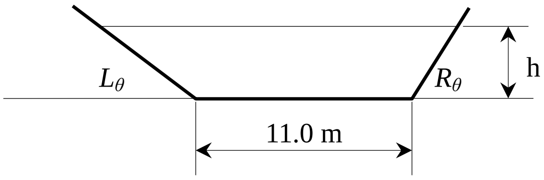


Table III-3.5.1-17 Annual Precipitation and Regional Coefficient

Region	**H**	T	Ka	Ki	S
Region coefficient (a)	**17**	34	48	41	84
Precipitation/year (mm)	**1,080**	1,360	1,710	1,440	2,280

Photo III-3.5.1-16 Maximum Flood Level (Interview survey)

2) Intake

- The intake is installed at adjacent upstream of the weir and also a gate and screen should be installed in order to control the amount of water intake and prevent garbage.
- The intake width should be designed at 1.00 m, so that water velocity at the intake is less than 1.0 m/s.

3) Settling Basin

- Although it is expected that there will be little sedimentation at this site, the settling basin should be installed at the downstream of the intake because of using buried pipe (PVC) at the headrace.
- The length of settling basin should be designed so that average velocity is less than 0.2 m/s and water depth is 1.0 m. As well, the end of the settling basin will be installed sand flushing equipment.

4) Headrace

- The headrace should partially use the existing irrigation channel from a viewpoint of cost saving. As well, a method of buried pipe (PVC) should be selected from a viewpoint of maintenance work saving.
- The length of irrigation channel to be diverted to the headrace was assumed to be 400 m approximately from the result of the simplified location survey.
- The length of headrace is estimated at about 1,300 m.
- A branch valve should be installed at an appropriate point of headrace (PVC pipe) in order to distribute irrigation water to slope area in the river side along the headrace section.

Photo III-3.5.1-17 Existing Irrigation Channel

5) Head Tank

- The head tank is installed at the entrance of penstock.
- The volume of head tank should secure the amount of water that can compensate the plant discharge for 1 minute.
- The inlet valve is installed at the end of penstock without a gate at the inlet of head tank.
- The spillway in the form of overflow is installed at a side of head tank.
- The sand flushing gate is installed in order to remove sand.

6) Penstock

- Steel and PVC pipes are applied for penstock from a viewpoint of cost saving because the head of this site is 100 m approximately.
- The length of penstock will be 210 m (steel: 20 m, PVC: 190 m) and PVC will be installed under the ground.
- Velocity in the penstock should be designed to be less than 3.5 m/s (penstock φ = 30 cm).
- In addition, an air vent is necessary for prevention of negative pressure in PVC pipe in some cases.

Photo III-3.5.1-18 Planned Sites of Head Tank and Penstock from Powerhouse

7) Powerhouse

- The powerhouse should secure a space to take apart and inspect turbine and generator.
- The concrete foundation should be applied to the powerhouse in order to prevent damage from bounding stones, etc. and wooden structure is applied to the upper building of powerhouse.
- In addition, a hoist according to weight of electrical equipment is necessary for its installation and maintenance.

Photo III-3.5.1-19 Planning site of Powerhouse

8) Tailrace and Outlet

- The tailrace is not constructed due to adjacence of the powerhouse and river.
- The layout of outlet should consider the river shape and flow direction.

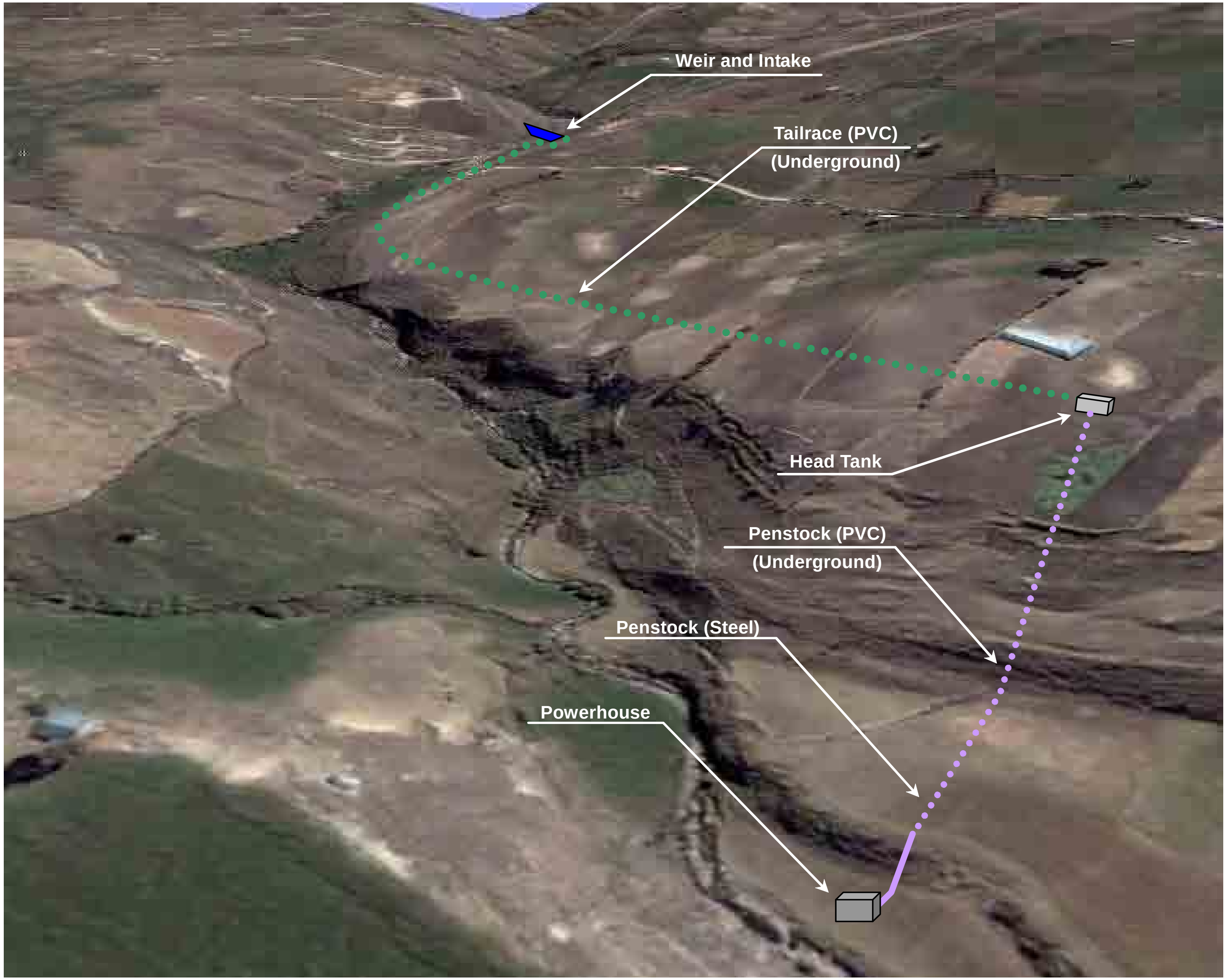


Photo III-3.5.1-20 Schematic Image of Yerba Buena Power Station

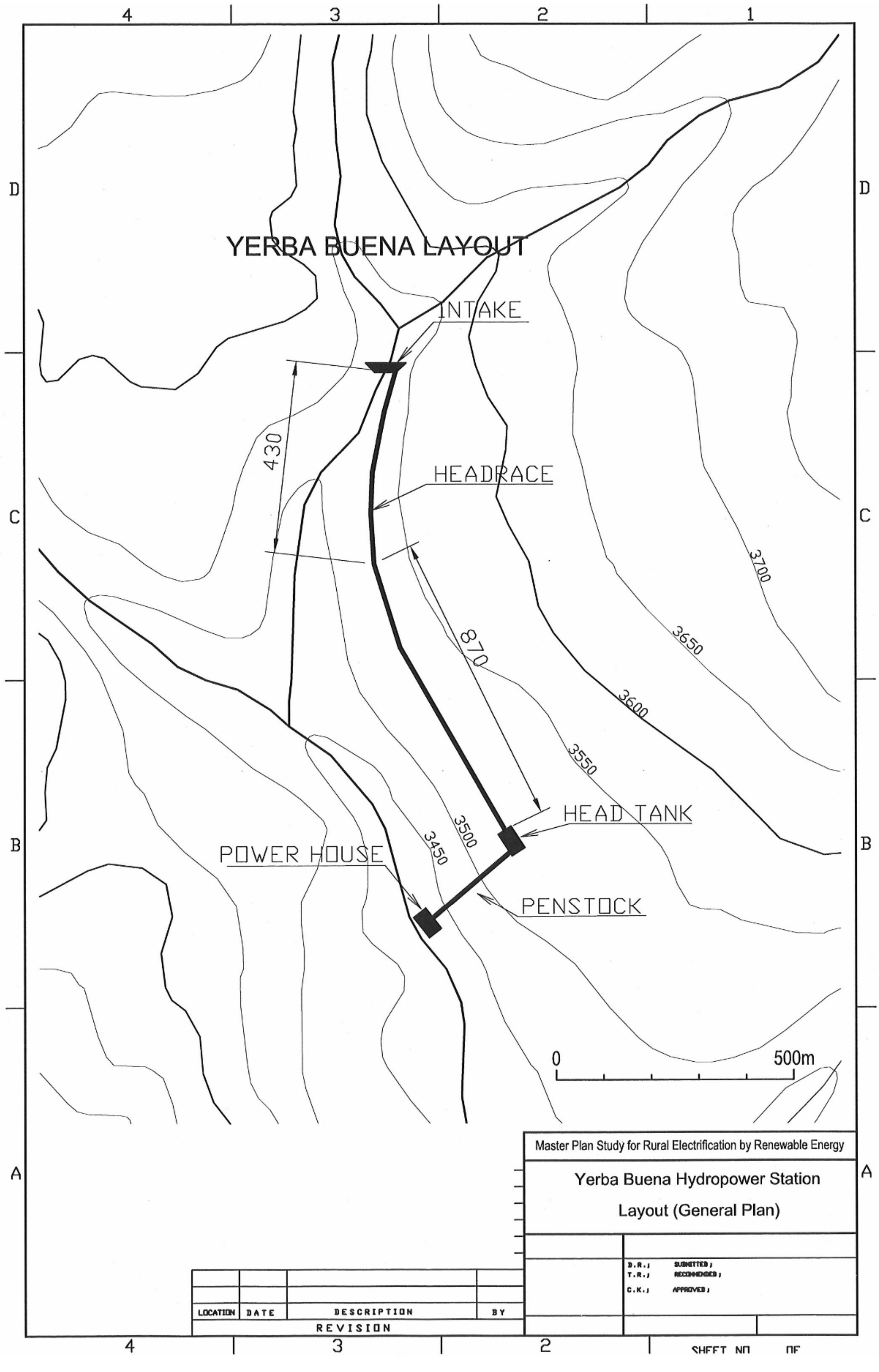


Fig. III-3.5.1-6 Layout of Power Station (Plan)

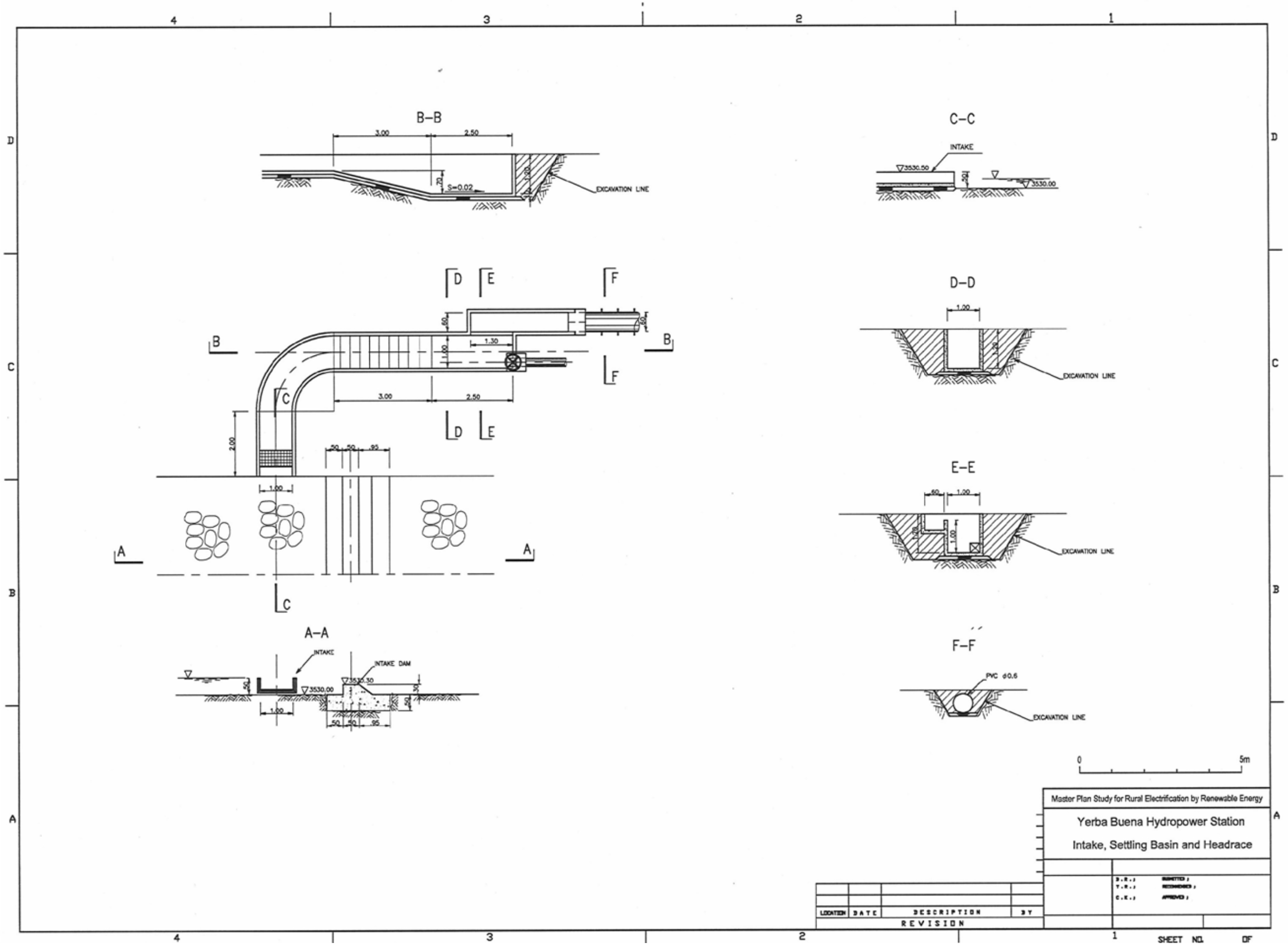


Fig. III-3.5.1-7 Rough Design Drawings of Intake, Settling Basin and Headrace

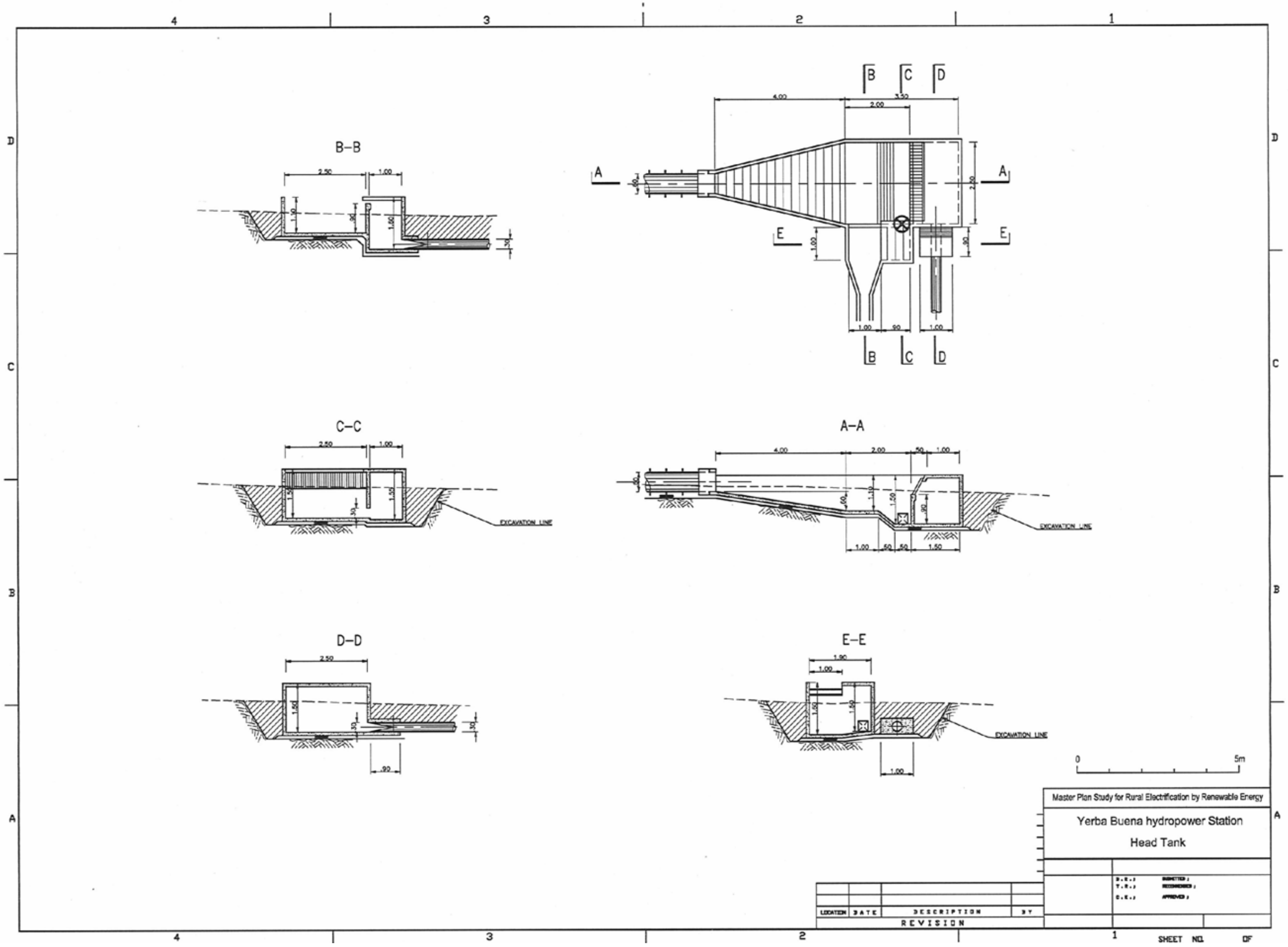


Fig. III-3.5.1-8 Rough Design Drawings of Head Tank

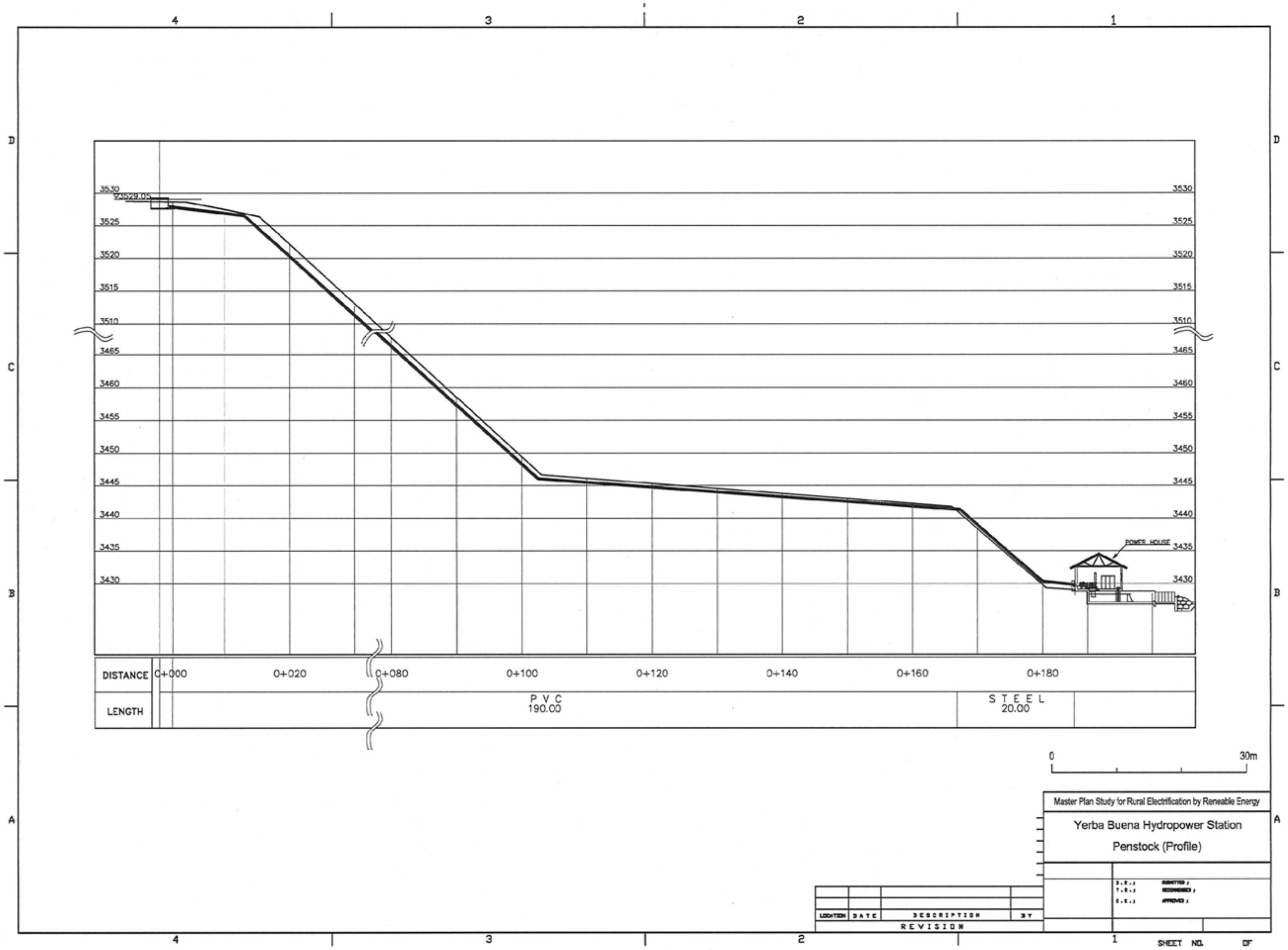


Fig. III-3.5.1-9 Rough Design Drawings of Penstock (Profile)

6. Electrical Design

(1) Choice of Hydro-turbine Type

JICA study team decided the hydro-turbine type, following the chart below and taking the net head and the waterfall volume into consideration.

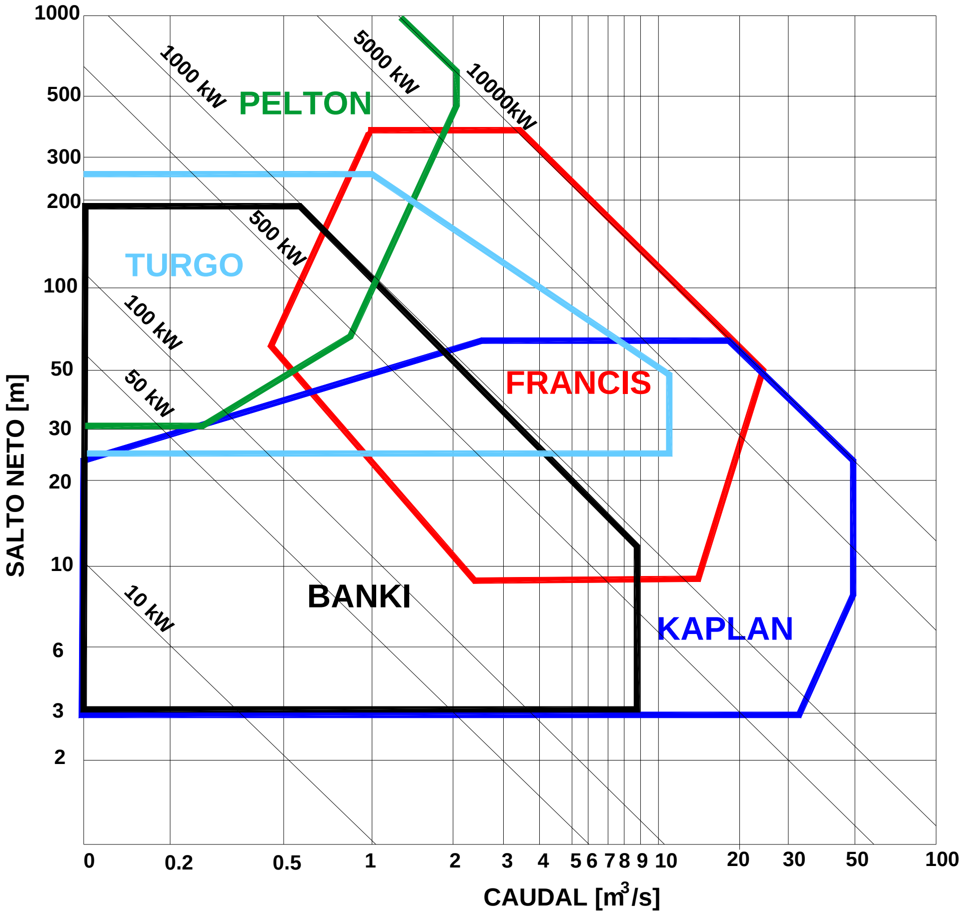


Fig. III-3.5.1-10 Hydro-Turbine Type Selection Chart

<Yerba Buena>

- Judging from the net head of 97.0 (m) and the waterfall volume of 0.112 (m^3/S), BANKI, TURGO, and PELTON are applicable.
- Compared to TURGO and PELTON, BANKI type has a simple structure enough to make operation and maintenance easy, and has high efficiency to waterfall change.
- Therefore, BANKI type is preferable for this location.

(2) Transmission and Distribution

12 villages, or 557 households, are targeted in Yerba Buena.

Table III-3.5.1-18 List of Un-electrified Villages

No	LOCALIDAD	VIVIENDAS
1	YERBA BUENA GRANDE	76
2	YERBA BUENA CHICA (LA TORRE)	102
3	SAN NICOLAS DE CHALLUAGUN	44
4	SAN LUIS	41
5	TOLDOPATA (TOLDO PATA)	70
6	YERBA BUENA ALTA	26
7	CHANCAS	50
8	QUINUA PAMPA	39
9	SANTA ROSA DE YERBA BUENA	19
10	GUAGUAYO	45
11	PORVENIR ENCANADA	50
12	SANTA ROSA DE MILPO	20
13	Electrified	▲25
		557

The distribution map and the total length of the distribution lines are separately shown below.

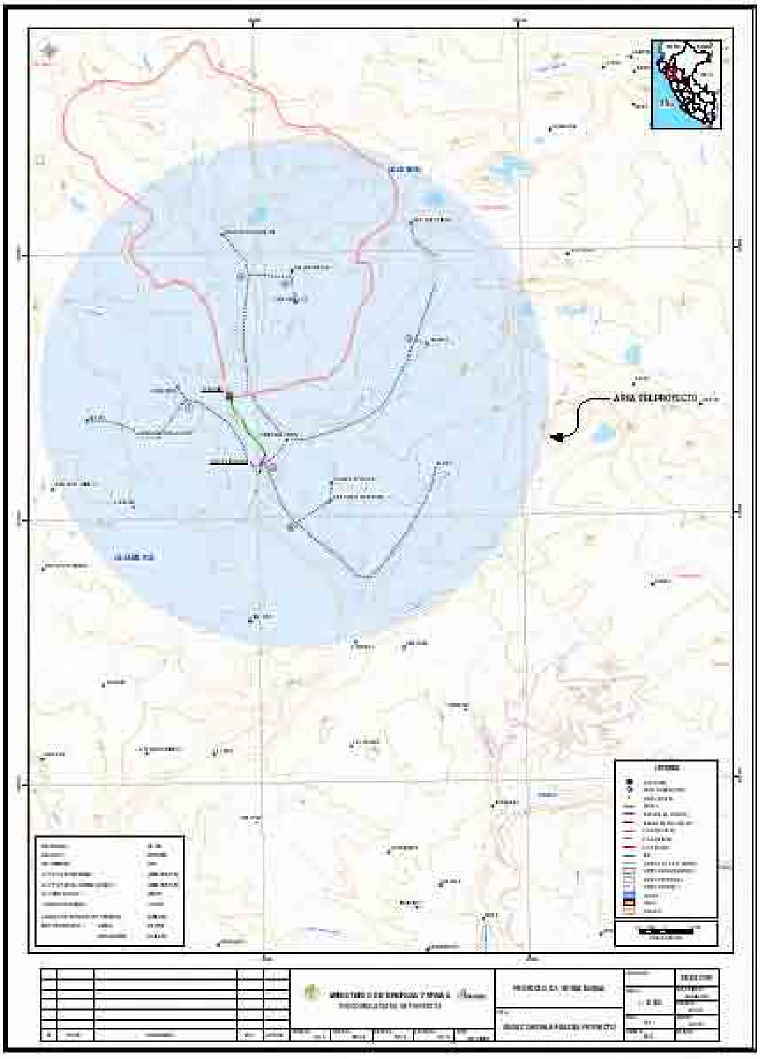


Fig. III-3.5.1-11 Distribution Map of Yerba Buena Grade

Table III-3.5.1-19 Total Length of Distribution Lines

From	To	Length of Primary Lines
CASA DE MAQUINAS	Branch①	1.99
Branch①	QUINUA PAMPA	0.28
Branch①	YERBA BUENA CHICA (LA TORRE)	0.87
YERBA BUENA CHICA (LA TORRE)	SAN LUIS	1.42
	Sub Total	4.56
CASA DE MAQUINAS	Branch②	0.21
Branch②	YERBA BUENA GRANDE	0.63
YERBA BUENA GRANDE	Branch③	3.33
Branch③	GUAGUAYO	0.25
Branch③	SANTA ROSA DE MILPO	2.50
	Sub Total	6.92
YERBA BUENA GRANDE	Branch④	3.39
Branch④	SAN NICOLAS DE CHALLUAGUN	0.91
Branch④	Branch⑤	0.78
Branch⑤	PORVENIR ENCAĐADA	0.12
Branch⑤	YERBA BUENA ALTA	0.50
	Sub Total	5.70
Branch②	Branch⑥	1.27
Branch⑥	SANTA ROSA DE YERBA BUENA	0.77
SANTA ROSA DE YERBA BUENA	TOLDOPATA (TOLDO PATA)	0.30
Branch⑥	CHANCAS	4.23
	Sub Total	6.57
	Total	23.75

III-3.5.2 Cost

1. Hydropower Station

The construction cost of this hydropower station was estimated based on the above study. The estimation method is based on a guide manual (Guide Manual for Development Aid Programs and Study, New Energy foundation 1996) which is generally used in Japan. The detailed contents are shown in Appendix.

Table III-3.5.2-1 Construction Cost for Yerba Buena (in the case of PVC)

I. Summary of Construction Cost for Yerba Buena Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**8,039**	
(1) Access Road	0	
(2) Facilities for Construction Office	3,318	Cost of Civil Works x 0.05
(3) Transportation cost	4,721	Cajamarca to the site, 454ton x $10.4/ton
2. Cost for Environmental Mesures	**663**	Cost of Civil Works x 0.01
3. Civil Works	**66,373**	
(1) Weir	2,798	
(2) Intake	5,384	
(3) Settling Basin	4,448	
(4) Headrace	8,599	
(5) Head Tank	9,850	
(6) Penstock & Spillway Channel	20,674	
(7) Power House	12,407	
(8) Outlet	2,213	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**109,000**	
(1) Gate & Screen	3,560	
(2) Penstock	1,610	
(3) PVC (φ600)	77,571	
(4) PVC (φ315)	8,249	
(5) Others	18,010	
5. Electrical Equipment	**52,800**	
6. Direct Cost	**236,875**	1.+2.+3.+4.+5.
7. Engineering Cost	**23,688**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**23,438**	6. x 0.099
9. IGV	**53,960**	19.00%
10. Total Cost	**337,960**	

In addition, the construction cost is shown in Table III-3.5.2-2 below in the case of open channel (simplified channel) for the headrace. In this case, the construction cost can be reduced 30% approximately compared with PVC for headrace.

Table III-3.5.2-2 Construction Cost for Yerba Buena (in the case of open channel)

I. Summary of Construction Cost for Yerba Buena Power Station

Unit: US$

Work Item	*Construction Cost*	*Remarks*
1. Preliminary Works	**11,931**	
(1) Access Road	0	
(2) Facilities for Construction Office	4,299	Cost of Civil Works x 0.05
(3) Transportation cost	7,632	Cajamarca to the site, 454ton x $10.4/ton
2. Cost for Environmental Mesures	**859**	Cost of Civil Works x 0.01
3. Civil Works	**85,990**	
(1) Weir	2,798	
(2) Intake	5,384	
(3) Settling Basin	4,448	
(4) Headrace	28,216	
(5) Head Tank	9,850	
(6) Penstock & Spillway Channel	20,674	
(7) Power House	12,407	
(8) Outlet	2,213	
(9) Miscellaneous Work	0	
4. Hydraulic Equipment	**16,000**	
(1) Gate & Screen	3,560	
(2) Penstock	1,610	
(3) PVC (φ600)	0	
(4) PVC (φ315)	8,249	
(5) Others	2,581	
5. Electrical Equipment	**52,800**	
6. Direct Cost	**167,580**	1.+2.+3.+4.+5.
7. Engineering Cost	**16,758**	6. x 0.1: Detailed Design and Supervision
8. Contingent Budget	**16,662**	6. x 0.099
9. IGV	**38,190**	19.00%
10. Total Cost	**239,190**	

2. Transmission and Distribution

JICA study team studied the construction cost of the distribution lines of this location, based on its unit price obtained from DPR.

Table III-3.5.2-3 Unit Price of Distribution Line Construction

	Cost
Linea Primaria	5,800 (US$/km)
Redes Primaria	290 (US$/User)
Redes Secundaria	490 (US$/User)

The construction costs are as follows:

Linea Primaria : 5,800 (US$/km) × 23.75 (km) = 137,750 (US$)

Redes Primaria : 290 (US$/User) × 557 (User) = 161,530 (US$)

Redes Secundaria : 490 (US$/User) × 557 (User) = 272,930 (US$)

Then, the total amount of distribution line construction is 572,210 (US$).

III-3.6 Organization of Construction, Operation and Management and Cost

As the capacity is less than 100 kW, the construction will be done by the villagers. Supervised by the experts of university or NGOs, etc, the construction will be done with the initiative of villagers. Through this activity the villagers can also understand the basics of the system. However, if the capacity exceed 500 kW, it will be necessary to have contractors for construction, as the higher the scale, the more difficulty arises.

Operation will be done by selected and trained villagers as a form of micro enterprise. The micro enterprise will be registered legally.

Those who assume the work of the enterprise will be publicly selected from villagers who are willing to undertake the business. As the revenue size of the enterprise is small, the operators of the enterprise will be in principle two: one commercial manager and one technical staff[4].

Before selection, around 10 candidates will be selected from the village who express interests in undertaking the operation and management, and all of them will be trained equally. By doing such, back up staff can be secured and if the final selected members will not continue, the remaining people can substitute.

The training will be held on site in principle. In the case of micro/mini hydropower, it is scheduled to have initial villagers sensitization, two times of civil work, equipment, and distribution line training each, and three times of management training. So both technical and administration training will be

[4] If the service coverage size or revenue is very small, it could be single operator assuming both commercial side and technical side.

held. After starting operation, within 6 months, it is scheduled to have back-stop training for those undertaking the business. In addition, in order to secure sustainability it should have at least three times of monitoring (acompaniamiento) by the trainers after operation.

In order to secure corporate governance, the firm must record accounts with revenues and expenditures. A user organization (junta de usuarios) will be created and the enterprise shall be responsible for periodical reporting of their operation to the user organization. With this, the enterprise will be defined as open enterprise to the users and at the same time, the users will be able to monitor each other, as the enterprise can only be sustained with users' equal participation and assuming responsibility.

The micro enterprise will make a contract with the ownership holder (propietario) in order to undertake the public service. It is a kind of concession contract (sesion en uso). In addition, the enterprise will make contracts with users in order to provide service. By binding contracts, the rights and obligations of enterprise will be secured together with those of users. Users will pay according to the tariff set among them.

The costs needed are shown below. The costs necessary for power generation including spare parts are excluded

Initial investment	:	US$	500
Project assistance and monitoring	:	US$	30,000
Annual operation and management	:	N Soles	1,000

III-3.7 Economic and Social Evaluation

III-3.7.1 Evaluation Method

In this Master Plan study, the analysis method established by SNIP will be applied on the condition that public finance will be used to implement the projects.

In the methodology of SNIP, a financial analysis comparing the costs and benefits using the market price is called economic analysis (Análisis Económico), while an economic analysis comparing them using the economic price is called social analysis (Análisis Social). In order to have consistency with the Peruvian system, the SNIP terms will be used in this report.

The basic flow of the analysis is as follows:

1. Economic Analysis

In Economic Analysis, the expected amount of net benefit will be calculated with the estimates of costs and benefits, using the market price.

- Estimation of costs at market price
- Preparation of a cash flow for capital investment

- Preparation of a cash flow for O&M cost
- Calculation of incremental costs in comparison with "without project"
- Estimation of benefits at market price
- Calculation of incremental benefits in comparison with "without project".
- Calculation of net benefit (Net Present Value)

2. Social Analysis

In Social Analysis, the expected amount of net benefit will be calculated with the estimates of costs and benefits, using the social price which excludes the distorted factors due to economic policy such as taxes and subsidies.

- Estimation of costs at social price
- Preparation of a cash flow for capital investment
- Preparation of a cash flow for O&M cost
- Calculation of incremental costs in comparison with "without project"
- Estimation of benefits at social price
- Calculation of incremental benefits in comparison with "without project"
- Calculation of net benefit (Social Net Present Value)

3. Sensitivity Analysis

Sensitivity analysis tests the impact on the project in the case of varying important input items such as investment amount, electricity tariff, benefit, etc.

III-3.7.2 Assumptions

The following assumptions are used for evaluating the projects:

1. Discount Rate

- Economic analysis 12%
- Social analysis 11%

2. Conversion Factor

Market price is considered to be distorted due to several economic policies such as taxes or tariff duty. In order to obtain real price, i.e. social price, conversion factors are used.

- domestic goods 1.00
- imported goods 0.90
- skilled labors 0.87
- unskilled labors 0.41 (Sierra)
- transportation 1.00
- engineering cost 1.00

- IGV 0.00

3. Service Life

The service life of each facility shall be as follows:

Item	Period (years)
Civil works	40
Electromechanical equipment, transmission lines	20

4. Evaluation Period

The evaluation period for the project shall be 20 years.

5. Alternative Project

Alternative projects to supply electricity to Yerba Buena shall be as follows:

Item	Contents
Alternative 1	Electrification with mini hydropower
Alternative 2	Electrification with extension of grid

III-3.7.3 Project Cost and Benefit of Alternative 1 (Micro Hydropower Project)

1. Construction Cost

The construction cost of the project, using open channel, is estimated as follows:

Table III-3.7.3-1 Initial Investment

(US$)

Item	Amount	Remarks
1. Engineering	16,758	Study and supervision
Environment	859	
2. Construction		
1) Civil Works		
Materials	106,289	Domestic products
Transportation	7,632	Including items 2)
2) Electro mechanical equip.		
Materials	40,128	All imported
Installation	12,672	Skilled labor: 70%
Transportation	0	Estimated in civil works
3) Transmission and distribution lines		
Materials	413,734	
Installation	137,704	Skilled labor: 70%
Transportation	20,772	
4) Contingency	16,656	
IGV	146,916	
Total	**920,120**	

The breakdown of the transmission and distribution lines is as follows:

(US$)

Item	Total	Linea Primaria	Red Primaria	Red Secundaria
Materials	413,734	77,825	120,887	215,023
Installation	137,704	54,134	35,107	48,463
Transportation	20,772	5,791	5,536	9,445

2. O&M Cost

The annual technical operation and maintenance cost is calculated using the following percentage:

Item	Factor (%)	Remarks
Mini hydropower plant	1.5	
Transmission/distribution	2.0-2.5	1st year-20th year

3. Power Demand

As to the power demand, the following values in the Chapter III-3.5.1 was adopted. The number of connections other than household is calculated with the following assumption of the monthly energy volume per user.

	Total Demand (% of household demand)	Monthly kWh/month/user	Connection (1st to 20th year)
Household		15	452~600
Commercial	10	45	15~20
Small industry	10	150	5~8
Public light	5		
Other use	10	75	9~10
Reserve	15		

4. Benefit

(1) Economic Benefit

The economic benefit is electricity sale revenue. In order to avoid excessive estimation, the unit rate is calculated from the electricity tariff (BTB5) dated February 1, 2008, Pliego Cajamarca Rural, by Hidrandina, which serves Cajamarca.

Purpose	Power	Energy	Rate
Domestic	1.30	0.2208	0.126
Commercial	1.33	0.4522	0.074
Industrial	1.33	0.4522	0.189
Other use	1.33	0.4522	0.119
Public lighting		0.3684	0.151

(2) Social Benefit

The social benefit is taken from the date of "Beneficios Económicos de la Electricidad en Areas Rurales del Perú" (NRECA, 1999). 80% of the following values are adopted.

Area	Sierra
Illumination	US$158.40/year × 0.8 = 126.72
Radio & TV set	US$ 60.48/year × 0.8 = 48.38
Others	US$ 0.15109/kWh × 0.8 = 0.12087

III-3.7.4 Alternative 2 (Grid Extension Project)

1. Initial Investment

The breakdown of the cost of transmission and distribution lines required for grid extension is as follows:

Table III-3.7.4-1 Initial Investment

(US$)

Item	Total	Línea Primaria	Red Primaria	Red Secundaria
Materials	430,118	94,209	120,887	215,023
Installation	149,101	65,531	35,107	48,463
Transportation	21,991	7,011	5,536	9,445
IGV	114,230	31,683	30,691	51,857
Total	**715,440**	**198,433**	**192,221**	**324,787**

2. O&M Cost

The technical operation and maintenance cost is calculated using the percentage as follows:

Item	Factor (%)	Remarks
Transmission/distribution	2.0-2.5	1st to 20th year

The unit rate calculated from the electricity tariff parameter for mid voltage (MT-2) dated February 1, 2008, Pliego Cajamarca Rural, by Hidrandina, which serves Cajamarca was used to calculate the cost of electricity purchase.

Weighted Price of Bar Energy at Middle Voltage –February 2008		
Peak Time Power	S/./kW-month	26.63
Peak Time Energy	ctm. S/./kWh	14.13
Off-Peak Time Energy	ctm. S/./kWh	11.80
Weighted Factor		0.283
Weighted Price of Bar Energy equivalent to Middle Voltage	ctm. S/./kWh	**12.46**
	US$	0.043

(Price including IGV: 0.0513)

3. Energy Demand

The same demand volume was used as the Alternative 1.

4. Benefit

The same benefit was used as the Alternative 1.

III-3.7.5 Evaluation

It is found out that the larger benefit is expected with the electrification by the mini-hydropower project than the grid extension. However, both cases have a little lower IRR, as compared to the criteria of 11% established by SNIP.

It does not directly lead to the rejection of the implementing the project at Yerba Buena. It is necessary to decide the most suitable electrification method by re-estimating the social benefit through more detailed social study at the project area in the next stage of the study.

(US$)

	Alternative 1	Alternative 2
NPV (IRR)	–918,259 (-22.8%)	–883,348 (n.a.)
SNPV (IRR)	–37,847 (10.2%)	–46,422 (10.0%)

III-3.7.6 Sensitivity Analysis

As to the sensitivity analysis, the following items are tested to see the variation of net present value of the project.

Item	Contents
(1) Investment cost	10% increase, 10% decrease,
(2) Revenue	10% increase, 10% decrease
(3) Social benefit	10% increase, 10% decrease

1. Investment Cost

(US$)

		Alternative 1	
		NPV	SNPV
	10%	–1,021,244	–116,787
Base Case	0%	–918,259	–37,847
	–10%	–815,273	41,093

2. Electricity Sale Revenue

(US$)

		Alternative 1	
		NPV	SNPV
	10%	–906,791	–37,847
Base Case	0%	–815,273	–37,847
	–10%	–929,726	–37,847

3. Social Benefit

(US$)

		Alternative 1	
		NPV	SNPV
	10%	–815,273	37,633
Base Case	0%	–815,273	–37,847
	–10%	–815,273	–113,327

As a result of the sensitivity analysis, it has been revealed that the change in power sale revenue has a greater impact than in investment cost as to the NPV. On the other hand, impact by change in investment cost is greater than that in social benefit. However, SNPV and NPV show negative values in almost all the cases. However, it is not wise to reject the implementation of the project only with this study, but it is important to estimate the construction cost and social benefit based on more accurate study at Yerba Buena in the following stage of the study.

Table III-3.7-1 Incremental Costs to Each Alternative (Private Cost) - Alternative 1

R U B R O	P E R I O D O																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																					
1. Intangibles																					
Engineering cost	16,758																				
Costo de medio ambiente	859																				
IGV [19%]	3,347																				
2. Construccion																					
1) Obras Civiles	135,566																				
- Suministro de Equipos, Materiales, etc.	106,289																				
Origen Nacional	106,289																				
Origen Importado	0																				
- Montaje	0																				
M.O. Calificado	0																				
M.O. No Calificado	0																				
- Transporte	7,632																				
- IGV [19%]	21,645																				
2) Obras Electromecanicas	62,832																				
- Suministro de Equipos, Materiales, etc.	40,128																				
Origen Nacional	0																				
Origen Importado	40,128																				
- Montaje Electromecanico	12,672																				
M.O. Calificado	8,870																				
M.O. No Calificado	3,802																				
- Transporte	0																				
- IGV [19%]	10,032																				
3) Instalacion de Lineas y Redes	680,930																				
- Suministro de Equipos, Materiales, etc.	413,734																				
Origen Nacional	171,683																				
Origen Importado	242,052																				
- Montaje Electromecanico	137,704																				
M.O. Calificado	96,393																				
M.O. No Calificado	41,311																				
- Transporte	20,772																				
- IGV [19%]	108,720																				
4) Imprevistos (con IGV)	19,828																				
5) Subtotal inversion	899,156	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO																					
Central hidroelectrica	0	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386	2,386
Lineas / Redes Distribucion	0	11,444	11,579	11,716	11,855	11,995	12,136	12,280	12,425	12,572	12,720	12,870	13,022	13,176	13,332	13,489	13,649	13,810	13,973	14,138	14,305
Operacion de servicios electricos	500	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
C) TOTAL COSTOS CON PROYECTO	920,620	14,176	14,311	14,448	14,586	14,726	14,868	15,011	15,156	15,303	15,451	15,602	15,754	15,908	16,063	16,221	16,380	16,541	16,704	16,870	17,037
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES	920,620	14,176	14,311	14,448	14,586	14,726	14,868	15,011	15,156	15,303	15,451	15,602	15,754	15,908	16,063	16,221	16,380	16,541	16,704	16,870	17,037

Table III-3.7-2 Incremental Costs to Each Alternative (Social Price) - Alternative 1

R U B R O		P E R I O D O																				
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																						
1. Intangibles																						
Engineering cost	1.00	16,758																				
Costo de medio ambiente	1.00	859																				
IGV [19%]	0.00	0																				
2. Construccion																						
1) Obras Civiles		113,921																				
- Suministro de Equipos, Materiales, etc.		106,289																				
Origen Nacional	1.00	106,289																				
Origen Importado	0.90	0																				
- Montaje Electromecanico		0																				
M.O. Calificado	0.87	0																				
M.O. No Calificado	0.41	0																				
- Transporte	1.00	7,632																				
- IGV [19%]	0.00	0																				
2) Obras Electromecanicas		45,391																				
- Suministro de Equipos, Materiales, etc.		36,115																				
Origen Nacional	1.00	0																				
Origen Importado	0.90	36,115																				
- Montaje Electromecanico		9,276																				
M.O. Calificado	0.87	7,717																				
M.O. No Calificado	0.41	1,559																				
- Transporte	1.00	0																				
- IGV [19%]	0.00	0																				
3) Instalacion de Lineas y Redes		511,100																				
- Suministro de Equipos, Materiales y Servidumbre		389,529																				
Origen Nacional	1.00	171,683																				
Origen Importado	0.90	217,846																				
- Montaje Electromecanico		100,799																				
M.O. Calificado	0.87	83,862																				
M.O. No Calificado	0.41	16,938																				
- Transporte	1.00	20,772																				
- IGV [19%]	0.00	0																				
4) Imprevistos (sin IGV)	1.00	16,662																				
5) Subtotal inversion		687,074																				
B) COSTOS DE OPERACION Y MANTENIMIENTO																						
Cental hidroelectrica		0	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275	2,275
Lineas / Redes Distribucion		0	9,807	9,922	10,040	10,158	10,278	10,400	10,523	10,647	10,773	10,900	11,029	11,159	11,291	11,424	11,559	11,696	11,834	11,974	12,115	12,258
Operacion de servicios electricos	1.00	500	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345	345
C) TOTAL COSTOS CON PROYECTO		687,574	12,427	12,543	12,660	12,778	12,898	13,020	13,143	13,267	13,393	13,520	13,649	13,779	13,911	14,044	14,179	14,316	14,454	14,594	14,735	14,878
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES		687,574	12,427	12,543	12,660	12,778	12,898	13,020	13,143	13,267	13,393	13,520	13,649	13,779	13,911	14,044	14,179	14,316	14,454	14,594	14,735	14,878

Table III-3.7-3 Incremental Costs to Each Alternative (Private Price) - Alternative 2

R U B R O	P E R I O D O																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																					
1. Intangibles																					
Engineering cost (17%)	121,625																				
2. Construccion																					
1) Instalacion de Lineas y Redes	715,440																				
- Suministro de Equipos, Materiales y Servidumbre	430,118																				
Origen Nacional	176,598																				
Origen Importado	253,520																				
- Montaje Electromecanico	149,101																				
M.O. Calificado	104,371																				
M.O. No Calificado	44,730																				
- Transporte	21,991																				
- IGV [19%]	114,230																				
2) Subtotal inversion	715,440	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO																					
Compra de Energia	0	5,619	5,703	5,788	5,875	5,963	6,053	6,144	6,236	6,329	6,424	6,521	6,618	6,718	6,818	6,921	7,025	7,130	7,237	7,345	7,456
Lineas / Redes Distribucion	0	14,309	14,478	14,649	14,822	14,997	15,174	15,353	15,535	15,718	15,904	16,092	16,282	16,474	16,669	16,866	17,065	17,267	17,471	17,677	17,886
C) TOTAL COSTOS CON PROYECT	837,065	19,927	20,181	20,437	20,697	20,960	21,227	21,497	21,771	22,048	22,328	22,613	22,900	23,192	23,487	23,787	24,090	24,397	24,708	25,023	25,342
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTAL	837,065	19,927	20,181	20,437	20,697	20,960	21,227	21,497	21,771	22,048	22,328	22,613	22,900	23,192	23,487	23,787	24,090	24,397	24,708	25,023	25,342

Table III-3.7-4 Incremental Costs to Each Alternative (Social Price) - Alternative 2

R U B R O		P E R I O D O																				
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
A) COSTO DE INVERSION																						
1. Intangibles																						
Engineering cost (17%) sin IGV	1.00	102,206																				
2. Construccion																						
1) Instalacion de Lineas y Redes		561,251																				
- Suministro de Equipos, Materiales y Servidumbre		430,118																				
Origen Nacional	1.00	176,598																				
Origen Importado	0.90	228,168																				
- Montaje Electromecanico		109,142																				
M.O. Calificado	0.87	90,802																				
M.O. No Calificado	0.41	18,339																				
- Transporte	1.00	21,991																				
- IGV [19%]	0.00	0																				
5) Subtotal inversion		561,251	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
B) COSTOS DE OPERACION Y MANTENIMIENTO																						
Compra de Energia (sin IGV)	0.84	0	4,722	4,792	4,864	4,937	5,011	5,086	5,163	5,240	5,319	5,399	5,480	5,562	5,645	5,730	5,816	5,903	5,992	6,081	6,173	6,265
Lineas / Redes Distribucion		0	11,225	11,358	11,492	11,628	11,765	11,904	12,045	12,187	12,331	12,476	12,624	12,773	12,924	13,077	13,231	13,387	13,546	13,706	13,867	14,031
C) TOTAL COSTOS CON PROYECTO		663,457	15,947	16,150	16,356	16,565	16,776	16,990	17,207	17,427	17,650	17,875	18,103	18,335	18,569	18,806	19,047	19,290	19,537	19,787	20,040	20,296
D) COSTOS DE OPERACION Y MANTENIMIENTO SIN PROYECTO		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
E) TOTAL COSTOS INCREMENTALES		663,457	15,947	16,150	16,356	16,565	16,776	16,990	17,207	17,427	17,650	17,875	18,103	18,335	18,569	18,806	19,047	19,290	19,537	19,787	20,040	20,296

Table III-3.7-5 General Analysis of the Demand

a) Variables importantes		Supuesto	Fuentes de Información
Crecimiento anual de la población	:	**1.5%**	Mision
Porcentaje de abonados domésticos	:	**80%**	Inspecciones de campo.
Porcentaje de pérdidas de energía (en BT y MT)	:	**10%**	Osinerg
Factor de carga	:	**25%**	Mision

b) Proyección

	AÑOS																				
UNIDADES	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Número de hogares	557	565	574	582	591	600	609	618	627	637	646	656	666	676	686	696	707	717	728	739	750
Número de conexiones domesticas		452	459	466	473	480	487	495	502	509	517	525	533	541	549	557	565	574	583	591	600
Número de abonados comerciales		15	15	16	16	16	16	16	17	17	17	17	18	18	18	19	19	19	19	20	20
Número de abonados pequeñas industriales		5	5	5	5	5	5	5	5	5	5	5	5	5	5	6	6	6	6	6	6
Número de abonados de otro uso		9	9	9	9	9	9	9	9	9	9	10	10	10	10	10	10	10	10	10	10
Consumo anual por abonado doméstico		180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180	180
Consumo anual por abonados comerciales		18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Consumo anual por ab. pequeñas industrias		18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Consumo anual por ab. alumbrado publico		9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
Consumo anual por otro uso		18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18	18
Consumo anual de abonados domésticos		81,411	82,632	83,872	85,130	86,407	87,703	89,018	90,354	91,709	93,085	94,481	95,898	97,337	98,797	100,279	101,783	103,310	104,859	106,432	108,029
Consumo anual de abonados comerciales		8,141	8,263	8,387	8,513	8,641	8,770	8,902	9,035	9,171	9,308	9,448	9,590	9,734	9,880	10,028	10,178	10,331	10,486	10,643	10,803
Consumo anual de peq. Industrial		8,141	8,263	8,387	8,513	8,641	8,770	8,902	9,035	9,171	9,308	9,448	9,590	9,734	9,880	10,028	10,178	10,331	10,486	10,643	10,803
Consumo anual de alumbrado público		4,071	4,132	4,194	4,256	4,320	4,385	4,451	4,518	4,585	4,654	4,724	4,795	4,867	4,940	5,014	5,089	5,165	5,243	5,322	5,401
Consumo anual de otro uso		8,141	8,263	8,387	8,513	8,641	8,770	8,902	9,035	9,171	9,308	9,448	9,590	9,734	9,880	10,028	10,178	10,331	10,486	10,643	10,803
Consumo total (KWh)		109,905	111,554	113,227	114,925	116,649	118,399	120,175	121,978	123,807	125,664	127,549	129,462	131,404	133,375	135,376	137,407	139,468	141,560	143,683	145,839
Pérdidas de energía (MT y BT)		10,991	11,155	11,323	11,493	11,665	11,840	12,017	12,198	12,381	12,566	12,755	12,946	13,140	13,338	13,538	13,741	13,947	14,156	14,368	14,584
Energía al ingreso del sistema (KWh)		120,896	122,709	124,550	126,418	128,314	130,239	132,192	134,175	136,188	138,231	140,304	142,409	144,545	146,713	148,914	151,147	153,415	155,716	158,052	160,422
Factor de carga		25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%	25%
Potencia al ingreso del sistema (KW)		**55.20**	**56.03**	**56.87**	**57.73**	**58.59**	**59.47**	**60.36**	**61.27**	**62.19**	**63.12**	**64.07**	**65.03**	**66.00**	**66.99**	**68.00**	**69.02**	**70.05**	**71.10**	**72.17**	**73.25**

Table III-3.7-6 Incremental Benefits to Each Alternative (Private Price) - Alternative 1

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto / With Project																					
Venta de energía / Energy Sales																					
- domésticos / domestic		10,271	10,425	10,582	10,741	10,902	11,065	11,231	11,400	11,571	11,744	11,920	12,099	12,281	12,465	12,652	12,842	13,034	13,230	13,428	13,630
- comerciales / commercial		602	611	620	630	639	649	659	668	678	689	699	709	720	731	742	753	764	776	787	799
- pequeno Industrial / samll industry		1,540	1,563	1,587	1,611	1,635	1,659	1,684	1,709	1,735	1,761	1,788	1,814	1,842	1,869	1,897	1,926	1,955	1,984	2,014	2,044
- uso general / general use		966	980	995	1,010	1,025	1,040	1,056	1,072	1,088	1,104	1,121	1,137	1,155	1,172	1,189	1,207	1,225	1,244	1,262	1,281
- alumbrado público / public lighting		615	625	634	643	653	663	673	683	693	704	714	725	736	747	758	769	781	793	804	817
Subtotal ventas de energía / Subtotal enery sales		13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571
2.- Situación sin Proyecto / Without Project																					
Beneficios sin proyecto / Benefit without project		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) / Incremental Benefit																					
Total ventas de energía / Total energy sales		13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571

Variables importantes:	PERIODO																				
(Important variables)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Tarifa de venta de energ¡a / Energy sale tariff																					
- domestico / domestic	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
- comerciales / commercial	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
- industriales y otros / industry and others	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
- otros / others	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
- alumbrado / public lighting	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151
2. Período de depreciación (años) / Depreciation (year)																					
Ob. Civiles / Civil works	**40**																				
Electromecanico / Electromechanical	**20**																				
3. Tasa de impuesto a la renta	**30%**																				
(Income tax rate)																					

Estado de pérdidas y ganancias:	PERIODO																				
Profit and Loss Statement	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Total ventas de energía / Total energy sales		13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571
2. Compra de energía / Energy purchase		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3. Otros costos de OyM / O&M cost		-14,176	-14,311	-14,448	-14,586	-14,726	-14,868	-15,011	-15,156	-15,303	-15,451	-15,602	-15,754	-15,908	-16,063	-16,221	-16,380	-16,541	-16,704	-16,870	-17,037
4. Depreciación Obras civiles / Civil works		-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657	-2,657
Electromecanico / Electromecha.		-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693	-22,693
5. Utilidad antes de impuestos / Profit before tax		-25,531	-25,456	-25,380	-25,302	-25,223	-25,141	-25,059	-24,974	-24,888	-24,800	-24,710	-24,619	-24,525	-24,430	-24,333	-24,233	-24,132	-24,029	-23,924	-23,816
6. Impuesto a la renta (solamente cuando hay incremento de utilidades) Income tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table III-3.7-7 Incremental Benefit to Each Alternative (Private Price) - Alternative 2

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto / With Project																					
Venta de energía																					
- domésticos / domestic		10,271	10,425	10,582	10,741	10,902	11,065	11,231	11,400	11,571	11,744	11,920	12,099	12,281	12,465	12,652	12,842	13,034	13,230	13,428	13,630
- comerciales / commercial		602	611	620	630	639	649	659	668	678	689	699	709	720	731	742	753	764	776	787	799
- pequena Industrial / small industrial		1,540	1,563	1,587	1,611	1,635	1,659	1,684	1,709	1,735	1,761	1,788	1,814	1,842	1,869	1,897	1,926	1,955	1,984	2,014	2,044
- uso general / general use		966	980	995	1,010	1,025	1,040	1,056	1,072	1,088	1,104	1,121	1,137	1,155	1,172	1,189	1,207	1,225	1,244	1,262	1,281
- alumbrado público / public lighting		615	625	634	643	653	663	673	683	693	704	714	725	736	747	758	769	781	793	804	817
Subtotal		13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571
2.- Situación sin Proyecto																					
Beneficios sin proyecto / Benefit without project		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) / Incremental Benefit																					
Total ventas de energía (Total energy sales)		13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571

Variables importantes:	PERIODO																				
(Important variables)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Tarifa de venta de energ¡a / Energy sale tariff																					
- domestico / domestic	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126	0.126
- comerciales / commercial	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074	0.074
- industriales y otros / industry and others	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189	0.189
- otros / others	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119	0.119
- alumbrado / public lighting	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151	0.151
2. Período de depreciación (años) (Depreciation period – years)	**20**																				
3. Tasa de impuesto a la renta (income tax rate)	**30%**																				

Estado de pérdidas y ganancias:	PERIODO																				
(Profit and Loss Statement)	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1. Total ventas de energía / Total energy sales	0	13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571
2. Compra de energía Energy purchase	0	-5,619	-5,703	-5,788	-5,875	-5,963	-6,053	-6,144	-6,236	-6,329	-6,424	-6,521	-6,618	-6,718	-6,818	-6,921	-7,025	-7,130	-7,237	-7,345	-7,456
3. Otros costos de OyM / O&M cost	0	-14,309	-14,478	-14,649	-14,822	-14,997	-15,174	-15,353	-15,535	-15,718	-15,904	-16,092	-16,282	-16,474	-16,669	-16,866	-17,065	-17,267	-17,471	-17,677	-17,886
4. Depreciación / Depreciation	0	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506	-21,506
5. Utilidad antes de impuestos / profit before tax	0	-27,438	-27,482	-27,525	-27,569	-27,613	-27,656	-27,700	-27,744	-27,788	-27,833	-27,877	-27,921	-27,965	-28,010	-28,054	-28,099	-28,143	-28,188	-28,232	-28,277
6. Impuesto a la renta (solamente cuando hay incremento de utilidades) Income tax		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Table III-3.7-8 Incremental Benefit to Each Alternative (Social Price) - Alternative 1 and 2

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Situación con Proyecto (With Project)																					
Beneficio económico iluminación (Economic benefit of illumination)		60,988	61,848	62,847	63,733	64,632	65,544	66,471	67,537	68,491	69,460	70,570	71,694	72,707	73,735	75,031	76,090	77,165	78,256	79,490	80,614
Voluntad de pago por radio y televisión (Willingness to pay for radio and television)		23,286	23,615	23,996	24,334	24,678	25,026	25,380	25,787	26,151	26,521	26,945	27,374	27,761	28,153	28,648	29,053	29,463	29,880	30,351	30,780
Voluntad de pago por refrigeración (Willingness to pay for refrigeration)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Beneficio económico otros usos (Economic benefit of other uses)		1,968	1,998	2,028	2,058	2,089	2,120	2,152	2,184	2,217	2,250	2,284	2,318	2,353	2,388	2,424	2,461	2,497	2,535	2,573	2,612
Sub total beneficios económicos (Subtotal economic benefit)		86,243	87,460	88,871	90,125	91,398	92,691	94,002	95,509	96,860	98,231	99,798	101,386	102,821	104,276	106,104	107,603	109,126	110,671	112,414	114,005
2.- Situación sin Proyecto (Without Project)																					
Beneficio económico sin proyecto (Economic benefit w ithout project)		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3.- Beneficios Incrementales (1) - (2) Incremental Benefit																					
Beneficios económicos incrementales (Incremental economic benefit)		86,243	87,460	88,871	90,125	91,398	92,691	94,002	95,509	96,860	98,231	99,798	101,386	102,821	104,276	106,104	107,603	109,126	110,671	112,414	114,005

Table III-3.7-9 Actual Value of Benefits to Each Alternative (Private Price)

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Beneficios Incrementales - Privados / Incremental Benefit - Private																					
ALTERNATIVA 1	0	13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571
ALTERNATIVA 2	0	13,995	14,205	14,418	14,634	14,854	15,077	15,303	15,532	15,765	16,002	16,242	16,485	16,733	16,984	17,238	17,497	17,759	18,026	18,296	18,571
2.- Costos Incrementales - Privados / Incremental cost - Private																					
ALTERNATIVA 1	920,620	14,176	14,311	14,448	14,586	14,726	14,868	15,011	15,156	15,303	15,451	15,602	15,754	15,908	16,063	16,221	16,380	16,541	16,704	16,870	17,037
ALTERNATIVA 2	837,065	19,927	20,181	20,437	20,697	20,960	21,227	21,497	21,771	22,048	22,328	22,613	22,900	23,192	23,487	23,787	24,090	24,397	24,708	25,023	25,342
3.- Beneficios Netos Totales - Privados / Total net benefit -Private																					
ALTERNATIVA 1	-920,620	-181	-106	-30	48	128	209	292	376	462	550	640	732	825	920	1,018	1,117	1,218	1,321	1,427	1,534
ALTERNATIVA 2	-837,065	-5,932	-5,976	-6,019	-6,063	-6,107	-6,150	-6,194	-6,238	-6,282	-6,327	-6,371	-6,415	-6,459	-6,504	-6,548	-6,593	-6,637	-6,682	-6,726	-6,771

	NPV	IRR
ALTERNATIVAS	**VAN (12%)**	**TIR**
ALTERNATIVA 1	-918,259	-22.8%
ALTERNATIVA 2	-883,348	#DIV/0!

Table III-3.7-10 Actual Value of Benefits to Each Alternative (Social Price)

	PERIODO / PERIOD																				
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1.- Beneficios Incrementales (Incremental Benefit)																					
ALTERNATIVA 1	0	86,243	87,460	88,871	90,125	91,398	92,691	94,002	95,509	96,860	98,231	99,798	101,386	102,821	104,276	106,104	107,603	109,126	110,671	112,414	114,005
ALTERNATIVA 2	0	86,243	87,460	88,871	90,125	91,398	92,691	94,002	95,509	96,860	98,231	99,798	101,386	102,821	104,276	106,104	107,603	109,126	110,671	112,414	114,005
2.- Costos Incrementales (Incremental Cost)																					
ALTERNATIVA 1	687,574	12,427	12,543	12,660	12,778	12,898	13,020	13,143	13,267	13,393	13,520	13,649	13,779	13,911	14,044	14,179	14,316	14,454	14,594	14,735	14,878
ALTERNATIVA 2	663,457	15,947	16,150	16,356	16,565	16,776	16,990	17,207	17,427	17,650	17,875	18,103	18,335	18,569	18,806	19,047	19,290	19,537	19,787	20,040	20,296
3.- Beneficios Netos Totales (Net total benefit)																					
ALTERNATIVA 1	-687,574	73,816	74,918	76,211	77,347	78,500	79,671	80,859	82,242	83,467	84,711	86,150	87,607	88,910	90,232	91,925	93,288	94,672	96,077	97,678	99,127
ALTERNATIVA 2	-663,457	70,296	71,310	72,515	73,561	74,622	75,700	76,795	78,082	79,210	80,356	81,695	83,052	84,252	85,470	87,057	88,313	89,589	90,884	92,374	93,709

	NPV	IRR
ALTERNATIVAS	**VAN (11%)**	**TIR**
ALTERNATIVA 1 (CH)	-37,847	10.2%
ALTERNATIVA 2 (PSE)	-46,442	10.0%

III-3.8 Electricity Tariff Setting and Fund Mechanism

1. Electricity Tariff Setting

There are two types of electricity tariff system: one is the metered rate system; the other is the flat-rate system. In the former case, the following actions are made: installation of electricity meter, periodical meter inspection, submission of electricity bill according to the energy consumption. For these activities, a person in charge of inspection and tariff calculation is required. Thus, it would be a time-consuming and less-effective job especially in a low population area. On the other hand, the flat-rate system does not involve such fiddly procedure, and an electricity bill with a constant price will be issued to the consumers. This would save much cost in paperwork.

Item	Advantage	Disadvantage
Metered rate system	Fair in cost sharing	Fiddly for meter inspection
Flat-rate system	No need for meter inspection	Unfair to the small consumer

In this project, it is expected to establish a local micro-enterprise, which will be the service provider of electricity, as a part of bottom up approach. Therefore, it can be considered that a pursuit of business efficiency would contribute equally to all the consumers concerned. From this viewpoint, the flat-rate system is adopted in this study.

<Items for Examination and Conditions>

In order to examine the level of electricity tariff, the following items will be referred. Basically, the tariff should cover the operation and maintenance cost form a viewpoint of sustainability. It also should be set at an affordable level to the most of the local people. In the case that the tariff rate thus calculated is expensive in comparison with the level of current tariff rate level, the application of a certain subsidiary system should be considered.

(1) O&M cost
(2) Current level of electricity tariff
(3) Willingness to pay
(4) Connection rate

Each item is examined as follows:

(1) O&M Cost

As with the past examples in rural electrification projects in Peru, it is expected that the initial investment cost will be completely subsidized. Therefore, a calculation will be made to figure out a tariff rate to cover the operation and maintenance cost required for project operation. Operation and Maintenance cost will consist of the following: (1) O&M cost for power plant, (2) O&M cost for transmission/distribution lines, and (3) operation cost of the micro-enterprise for electricity service

Item	Amount/month (US$)	Remarks
(1) O&M cost of power plant	199	1.5% of investment cost
(2) O&M cost of T/D lines	953	2.0% of investment cost
(3) Operation of micro-enterprise	29	S/.1,000 / year
Total	**1,181**	

(2) Current Level of Electricity Tariff

The unit rate calculated from the electricity tariff (BTB5) dated February 1, 2008, Pliego Cajamarca Rural, by Hidrandina, which serves Cajamarca, is adopted.

With the estimated monthly consumption at Yerba Buena being 15 kWh/month (for a household), a monthly rate is calculated as follows:

Fixed charge : 1.30 Soles

Energy charge : 6.624 Soles = 0.4416 × 15 kWh

Total : 7.924 Soles (with IGV19%: 9.43 Soles)
(With FOSE, S/.4.61 and S/.5.49 respectively)

(3) Willingness to Pay

A willingness to pay mentioned here refers to the value of the current energy expenditure, obtained by an inquiry conducted for local people as a part of social study. It is not the value obtained as "willingness to pay" in the inquiries.

Table III-3.8-1 Willingness to Pay: Yerba Buena

(Nuevos Soles)

Max	56.0
Min	3.25
Average	21.3
Median	15.0

(4) Connection Rate

This project contemplates to serve 80% of the households in the target area. Therefore, it is desirable to set a tariff also affordable to more than 80% of the households. In order to achieve this level, it would require introduction of a certain system of subsidiary.

<Result of Examination>

A tentative calculation of average electricity tariff required to recover the cost for electricity service, with a condition that the micro-enterprise does not earn any profit.

As a result, the level of electricity tariff was calculated as follows:

No subsidy to initial investment	26.47 Soles
100% subsidy to initial investment	6.47 Soles

A tariff to cover the operation and maintenance cost for this project is calculated as 6.47 Soles/month. If the difference with the current electricity tariff in the neighboring area should be compensated, the amount would be some 2 Soles.

Under the condition that the initial investment is totally subsidized, the subsidy level to recover the O&M cost was calculated for the following cases:

1) Median value : 15.00 Soles
2) 80% of the willingness to pay : 10.00 Soles
3) Grid tariff (with FOSE) : 5.49 Soles

(unit: Nuevos Soles)

Unit rate/month	Subsidy amount	Annual amount	Remarks
10.00	0.00	0	80% coverage
6.47	0.00	0	Base amount
5.49	0.98	5,316	0.98 ×452 HH × 12

2. Fund Procurement

(1) Construction Cost

The initial investment cost required for the project shall be procured from the SPERAR Fund, as well as the fund of the local government (e.g. CANON).

(2) Training Cost

The cost required for providing training for project management shall be procured form the SPERAR fund.

(3) Operation and Maintenance Cost

The operation and maintenance cost shall basically be borne by the consumer as an electricity tariff. The operation cost of a micro-enterprise to be established by local people shall also be covered with this fund.

(4) Subsidy

Subsidy is indispensable in order to secure stably a certain level of revenue. At least, it is desirable to set the electricity tariff at a similar level with the neighboring area electrified with a grid. For this purpose, it is important for a micro-enterprise to register as an electricity serving company in MEM, and apply to OSINERGMIN for a provision of cross subsidy based on FOSE.

III-3.9 Social and Environmental Consideration

The following table shows the result of evaluation and measures to the environmental factors that are supposed to give impact on natural and social environment in Yerba Buena.

Table III-3.9-1 Result of Environmental Survey and Measures

Items	Rat-ing	Result of the survey	Measures
Land use and utilization of local resources	C	The land designed for facilities relating to power generation is partly used as irrigation canal or grazing. Construction scale is very small but project implementation possibly causes inconvenience of inhabitant's use.	It is necessary at the study at feasibility level that the implementer explains the draft project design to the inhabitants and confirms the right of land ownership and use right. If inhabitants have these rights, implementer must build consensus among stakeholders.
Misdistribution of benefit and damage Local conflicts of interest Local conflict of interest	C	People with lower income in the community will not be able to use the electrical service after the electrical system is introduced. It is anticipated that misdistribution of benefit will be occur among inhabitants.	The master plan proposes that MEM/DPR should establish the financial supporting system in order that the poor people can use electricity.
Gender	D	At the starting of the electrification by micro hydropower that women will be impossible to participate in the management organization. It is anticipated that electrification fixes the inequity between both genders relating to social development.	The master plan proposes that the implementer should recommend and support inhabitants that women become the candidate of the management organization.

Items	Rat-ing	Result of the survey	Measures
Water usage	C	As the water to be used for power generation is actually used for irrigation, it is anticipated that the quantity of irrigation water possibly decreases after starting generation. The water to be used for power generation is designed to return to the river within Yerba Buena. Thus, the project will not give impact on the communities located in the lower reaches.	- The project design is made within the limit that will not give impact on the quantity of irrigation water based on the result of the simplified measurement for river discharge carried out at the study of pre feasibility level. However, water discharge varies year by year. Thus, it is advisable that the implementer collects hydrological data of different years and analyses them more minutely. - Implementer must apply to the Ministry of Agriculture for the water rights.
Water pollution	D	Materials like concrete used for construction of hydropower plants contain chemical ingredients. If they are disposed in the river water, it may cause water pollution.	The implementer makes a construction plan that minimizes water pollution. At construction stage, the implementer should be obliged to supervise contractor's engineering work from environmental point of view.
Solid wastes	D	As there is no legal framework for control, it is anticipated that water pollution and dust pollution might occur during the construction.	Though the scale of construction is small, implementer must supervise construction contractor properly. And, as the need arises, MEM/DPR is recommended to give administrative directives to violators.
Noise and vibration	D	At construction and operation stages of mini/micro hydropower plants, it is anticipated that noise and vibration occur.	The capacity of power generation at Yerba Buena is the micro level of 80 kW and it is not anticipated the remarkable noise and vibration will occur. However, as the construction site is not far from the residential area, implementer should inform the construction schedule to the neighbouring people beforehand.
Topography and geological features	D	Construction of facilities for power generation (weir, intake, headrace 1.3 km, penstock 210 m, power house etc.) will change the topography along the river.	Implementer should supervise the construction design and construction work properly for avoiding erosion and other damages.

Note: Evaluation classification
A: Serious impact is expected.
B: Impact is expected to a certain extent.
C: Not strong impact is expected but impact sometimes occurs.
D: Low level impact may happen. More minute investigation and evaluation are required at the FS.
Source: JICA study team, 2008