

5. WIND MONITORING SYSTEM AND STUDY OF WIND POWER

5.1 Study and Survey Conducted

- Site selection for wind monitoring
- Supervise of wind monitoring system installation
- Analysis of collected data
- Wind power development plan
- Pre-F/S on selected 3 projects

5.2 Installation of Wind Monitoring System

List of Monitoring Site

La Paz

1. Achiri
2. General Gonzales
3. Is. Taquiri
4. Charana
5. Santiago de Llallagua

Oruro

1. Caripe
2. Chachacomani
3. Comjo / Coipasa
4. Sevaruyo
5. Salinas de Garci Mendosa

Anemometer and Wind Vane



Tower Installation



Wiring Work



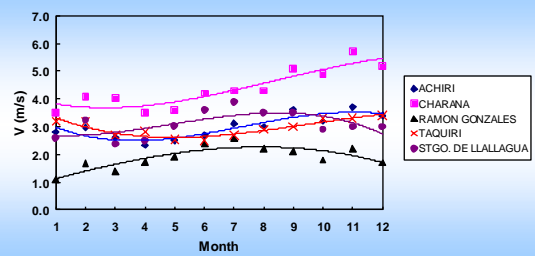
Data Logger Set-up



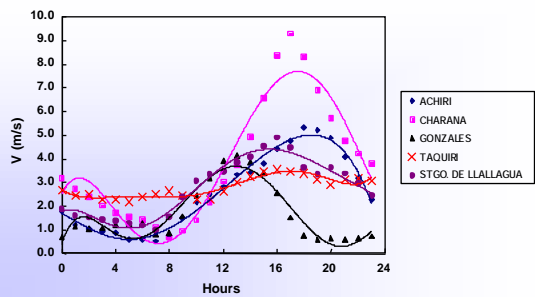
5.3 Monitoring and Data Collection

1) Collected data and Analysis

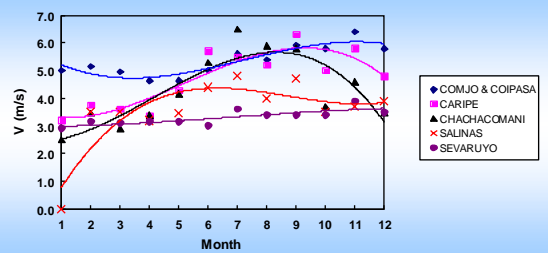
Monthly Wind Speed (La Paz)



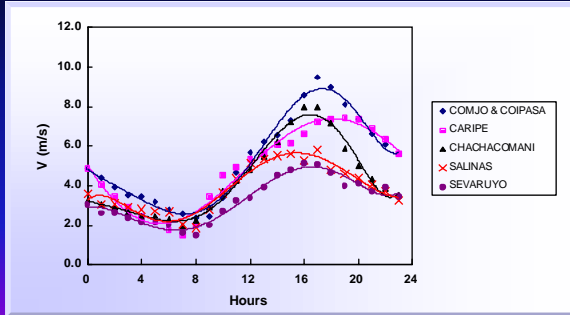
Diurnal Wind Speed (La Paz)



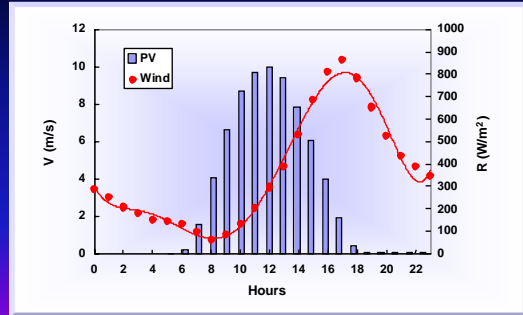
Monthly Wind Speed (Oruro)



Diurnal Wind Speed (Oruro)



Diurnal Wind Speed vs. Solar Radiation at Charana



2) Wind Power Potential



5.4 Selection of Candidate Sites for Pre-feasibility Study

Selection Criteria

- Wind Power Potential
- Population of Canton
- Priority Development Sites of Prefectures

Selected Pre-F/S Sites

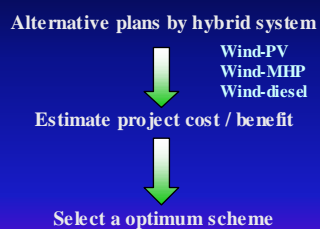
La Paz	Charana
Oruro	Chachacomani Caripe

5.5 Process of Pre-Feasibility Study and Result

1) Work Flow of Pre-Feasibility Study



2) Optimization Study

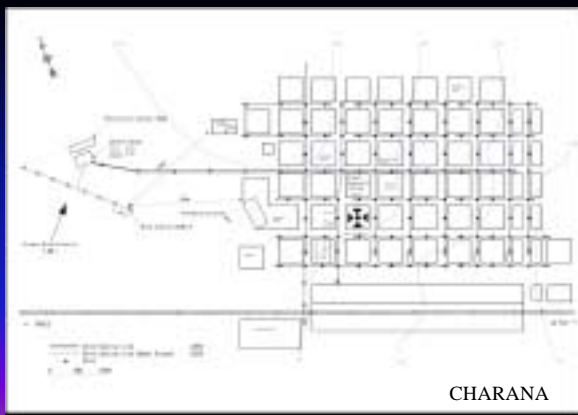
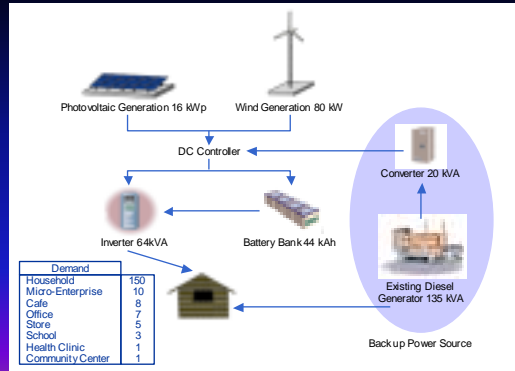


3) Formulated Schemes

Specification of Generation System

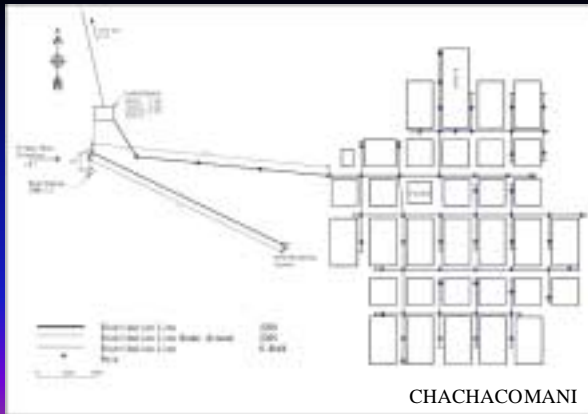
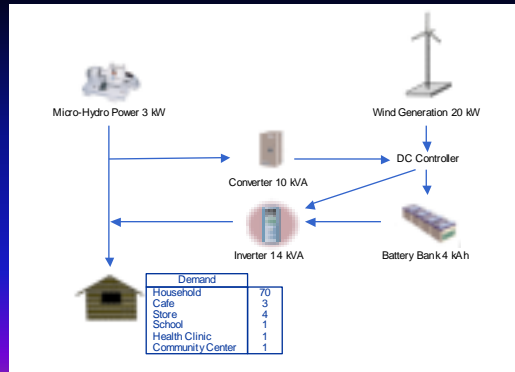
		Charana	Caripe	Chachacomani
Wind Turbine	(kw)	80	10	20
PV	(kWp)	16	4	-
MHP	(kW)	-	-	3
Inverter	(kVA)	64	8	14
Converter	(kVA)	20	-	10
Battery	(kAh)	44	8	4

Charana



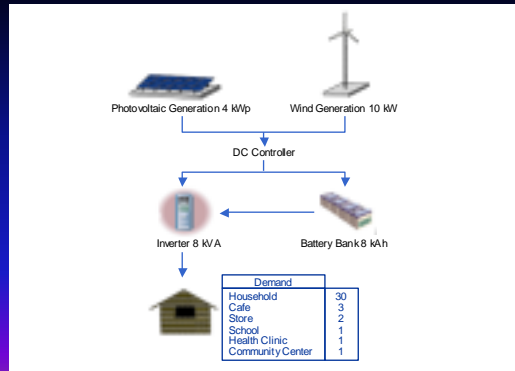
CHARANA

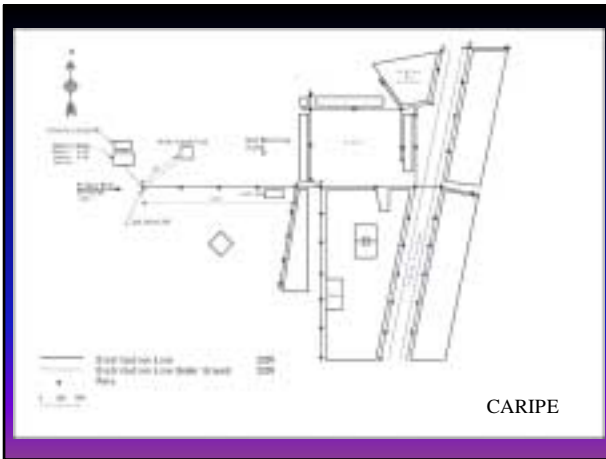
Chachacomani



CHACHACOMANI

Caripe





4) Results of Evaluation

Project Cost Estimation

(Unit: US dollar)

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

EIRR and Financial Evaluation of Pre-F/S Wind Development Projects

EIRR

	Charana	Caripe	Chachacomani
	-2.9%	-1.8%	-3.1%

Minimum Power Tariff to Cover O&M Cost

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

6. Rural Electrification Plan by Renewable Energy

6.1 Target Renewable Energy & Planning Methodology

1) Target Renewable Energy

Micro-hydro Power (MHP)
Wind Power
Photo-voltaic (PV)

2) Cost Comparison

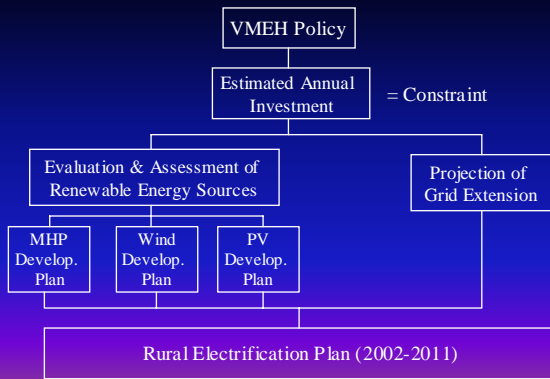
Installed Capacity and Annual Electricity Generation/Consumption

	Grid Extension	PV	MHP	Wind	Diesel
Installed Capacity	-	55W x 100HH	20kW	20kW (15kW Wind/ 5kW PV)	20kW
Annual Electricity Generation/Consumption (kWh/Y)	58,400	70kWh/Y x 100HH	55,480	51,120	52,560

Energy Cost by Energy Source (US\$/kWh)

	Grid		PV	MHP	Wind	Diesel
	Small	Large				
Economic Cost	0.29	0.31	1.60	0.31	0.47	0.40
Financial Cost	0.32	0.35	1.90	0.36	0.56	0.47

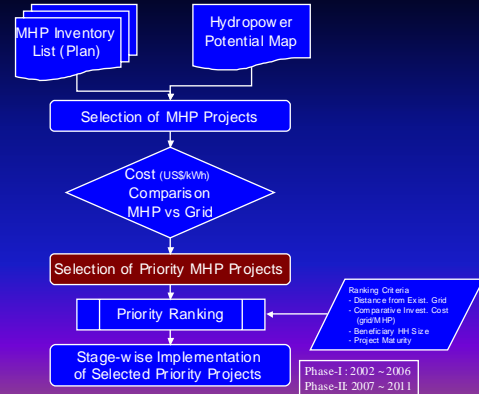
3) Methodology of Rural Electrification Plan

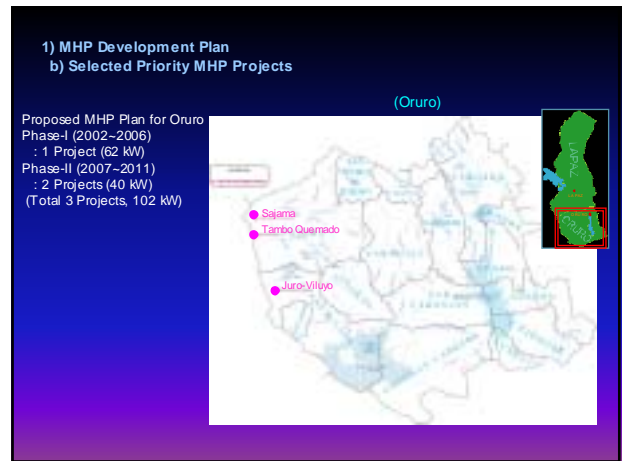
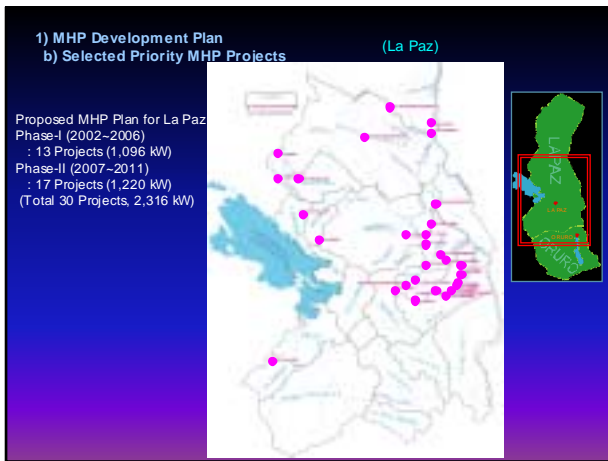


6.2 Rural Electrification Plan

(1) MHP Development Plan

1) MHP Development Plan a) Development Plan Formulation





1) MHP Development Plan
b) Selected Priority MHP Projects

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

Phase	Year	Beneficiary Household (HH)	Installed Capacity (kW)	Investment Cost (MHP) (US\$)
Phase - I	2002 - 2006	45	62	240,000
Phase - II	2007 - 2011	140	40	128,000
TOTAL	(2002 - 2011)	185	102	368,000

(2) Wind Power Development Plan

- ### Selection Criteria
- Located in high wind potential area
 - Population over one hundred
 - No existing electrification plan
 - Estimated project cost is lower than that of grid extension

Site Selection for Wind Development Project

La Paz				
Cantons in high wind potential area	Population	Population for Project	Existing grid or the plan	Result
1. Okzuro	339	suitable	no	selected
2. Chirocala	254	suitable	no	selected
3. E. Abarca	116	suitable	no	selected
4. Greal. Perez	159	suitable	no	selected
5. Ladislao Cabrera	237	suitable	no	selected
6. Rio Blanco	267	suitable	no	selected
7. Cat Acora	278	suitable	no	selected
8. Parumani Grande	124	suitable	no	selected
9. Pajo Pachiri	221	suitable	no	selected
10. Charana	1,016	suitable	no	selected
11. Caracollo	61	not suitable	no	not selected
12. Thola Collo	87	not suitable	no	not selected

Oruro				
Cantons in high wind potential area	Population	Population for Project	Existing grid or the plan	Result
1. Sajama	449	suitable	existing	not selected
2. Lagunas	235	suitable	no	selected
3. Copasa	685	suitable	no	selected
4. Carangas	152	suitable	existing	not selected
5. Caripe	208	suitable	no	selected
6. Chachacomani	476	suitable	no	selected
7. Villa Rosario	96	not suitable	no	not selected

Wind Power Development Projects

La Paz

Cantons	Capacity of System (kW)	Objective HHs	Distance from nearest grid (km)	Economic Cost (US\$)	Financial Cost (US\$)	Selected Plan
Okoruro	36	48	100	259,386	305,293	Wind/PV
Charana	96	150	80	699,136	817,798	Wind/PV
Chinocabi	26	42	96	203,648	240,882	Wind/PV
E Aborca	22	32	60	154,893	182,051	Wind/PV
Gréal Perez	22	28	44	153,805	180,746	Wind/PV
Ladislao Cabrera	22	32	74	154,893	182,051	Wind/PV
Rio Blanco	24	34	94	177,639	209,219	Wind/PV
Catacora	56	72	46	375,214	440,494	Wind/PV
Parumant Grande	36	46	50	258,298	304,031	Wind/PV
Pogo Pajchiri	46	52	46	312,948	367,181	Wind/MPVH

Oruro

Cantons	Capacity of System (kW)	Objective HHs	Distance from nearest grid (km)	Economic Cost (US\$)	Financial Cost (US\$)	Selected Plan
Caripe	23	30	64	125,382	147,296	Wind/PV
Lagunas	521	60	88	282,132	332,462	Wind/PV
Cosapa	0	140	72	445,512	525,313	Wind/PV
Chachacomani	0	70	100	271,738	294,674	Wind/MPVH

MAP



MAP



Priority of Project Implementation

- Distance from the grid
- Size of households
- Investment cost per household
- Preparedness of the project

Allocated Scores for Priority Selection

Distance			Score
A	80 km and over		1
B	60 km and over, less than 80 km		2
C	Less than 80 km		3
Size of Objective Households			Score
A	80 and over		1
B	40 and over, less than 80 km		2
C	Less than 40		3
Investment Cost (US\$/HHs)			Score
A	Less than 5,000		1
B	5,000 and over, less than 6,000		2
C	6,000 and over		3
Project Preparation (Wind Data, F/S)			Score
A	F/S report is existing		1
B	Limited data available		2
C	No F/S report		3

Wind Power Development Plan (Phase 1: 2002 to 2006)

	Cantons	Objective HHs	Capacity (kW)	Investment Cost (US\$)
La Paz	Okoruro	48	36	251,624
	Charana	150	96	678,437
	Chinocabi	44	26	198,042
	Rio Blanco	36	24	172,464
Oruro	Caripe	30	14	122,364
	Copasa	146	60	432,575
	Chachacomani	70	23	267,426
Total		524	279	2,122,931

Wind Power Development Plan (Phase 2: 2007 to 2011)

	Cantons	Objective HHs (A)	Capacity (kW)	Investment Cost (US\$)
La Paz	Eabaroa	32	22	150,150
	Greal Perez	30	22	149,062
	Ladislao Cabrera	34	22	150,150
	Catacora	74	56	363,140
	Pairumani Grande	46	36	250,536
Oruro	Pojo Pajchiri	60	46	303,030
	Lagunas	62	38	273,938
Total		338	242	1,640,006

3) PV System Development Plan

Identification of Candidate Sites

- Evaluation of the PV potential
- PV followed
 - Grid Extension
 - Micro-Hydro,
 - Wind Power

Criteria for Selection

- Outside the Plan of Grid Extension
- Low Population Density
- Basic Human Needs

Possible Sites for PV in La Paz



Possible Sites for PV in Oruro



PV Implementation Plan

(Unit: PV system)

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

(4) Grid Extension Plan

Grid Line Extension Plan for 2002-2006
Projected based on the grid line of 2001

Grid Line Extension Plan for 2007-2011
Projected by prioritizing the non-electrified cantons by the criteria

- Criteria
 - Population density
 - Distance from the existing grid line
 - Basic Needs

Grid Line Extension Plan (2011)
The cantons with the priority A and B

La Paz



Oruro



(5) Overall Projection of Rural Electrification

5) Overall Projection of Rural Electrification

Number of New Beneficiaries

La Paz

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

Oruro

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

Projected Rural Electrification Rate

La Paz

	2000	2002	2006	2011
Total No. of Rural Households	233,202	232,629	231,879	231,669
Existing No. of HHs with Electricity	51,906	70,674	81,436	97,916
New Beneficiaries HHs with Electricity	4,323	2,724	2,969	3,771
Decrease in No. of Electrified HHs by Diesel	-190	-145	-85	-43
Total No. of Rural HHs with Electricity	59,039	73,252	84,321	101,643
Rural Electrification Rate (%)	25.3%	31.5%	36.4%	43.9%

Oruro

	2000	2002	2006	2011
Total No. of Rural Household	62,566	61,981	60,846	59,474
Existing No. of HHs with Electricity	7,908	10,268	16,955	27,303
New Beneficiaries HHs with Electricity	1,093	1,739	1,810	2,445
Decrease in No. of Electrified HHs by Diesel	-44	-31	-20	-10
Total No. of Rural HHs with Electricity	8,887	11,973	18,746	29,739
Rural Electrification Rate (%)	14.2%	19.3%	30.8%	50.0%

Total Beneficiaries and Breakdown by Energy Source

La Paz

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

Oruro

		2000	2002	2006	2011
PV	Total	1,352	2,355	3,981	8,621
	Share	15.2%	19.7%	21.3%	29.0%
Micro-hydro	Total	365	365	410	530
	Share	4.1%	3.0%	2.2%	1.8%
Wind	Total	0	0	246	388
	Share	0.0%	0.0%	1.3%	1.0%
Total Renewable Energy	Total	1,717	2,720	4,640	9,479
	Share	19.3%	22.7%	24.8%	31.9%
Grid Extension	Total	6,860	9,016	13,968	20,189
	Share	77.2%	75.3%	74.5%	67.9%
Diesel	Total	310	237	138	71
	Share	3.5%	2.0%	0.7%	0.2%
Total	Total	8,887	11,973	18,746	29,739
	Share	100%	100%	100%	100%

(6) Environmental Impact

6) Environmental Impact

Emission of Carbon Dioxide (ton)
 = Calorie Necessary for Electricity Generation (2,646 kcal/kWh x Electricity Generated x 1/10⁹) x Common Energy Unit Conversion Factor (4.1868TJ/Tcal) x Carbon Emission Factor (17.2tC/TJ) x Fraction of Carbon Oxide (0.995) x 44/12

Estimate of Reduction Amount of CO₂ (ton)

La Paz

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

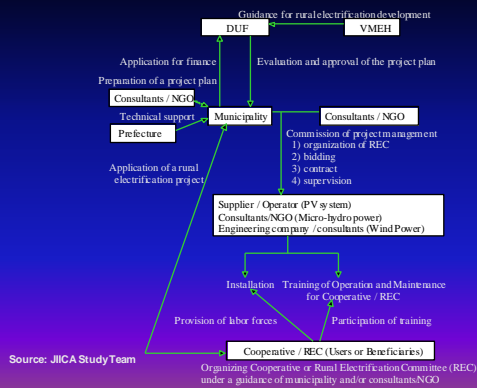
Oruro

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

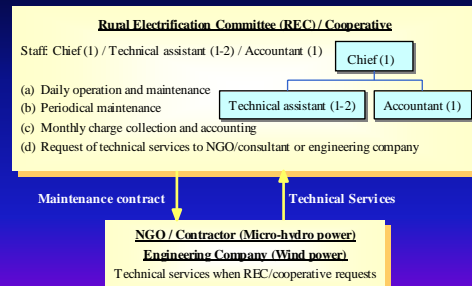
7. Institutional and Financial Plan

7.1 Implementing Structure

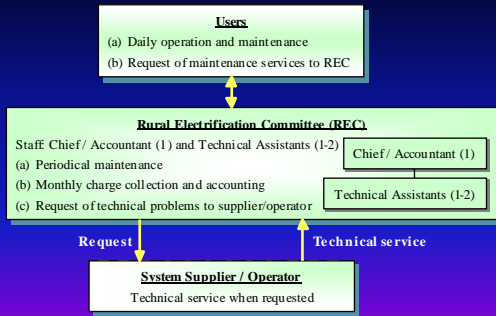
Proposed Implementing Structure



Proposed Operation and Maintenance System for MHP and Wind Power Project



Proposed Operation and Maintenance System for PV System Project



7.2 Fund Arrangement Plan

1) Required Fund (Phase I)

(US\$1,000)

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

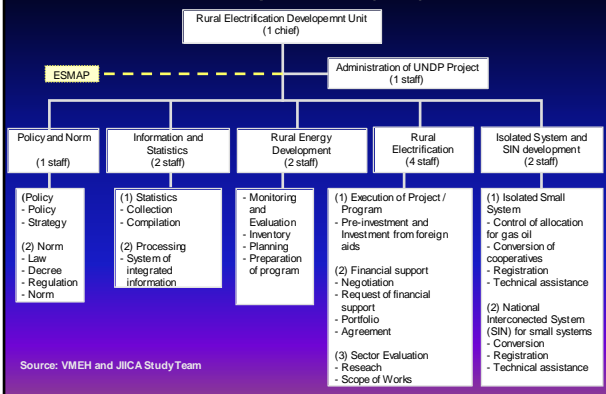
2) Possible Source of Fund (Phase I)

- External Source
US\$3.2 million (overseas agencies)
US\$ 4.3 million (IBRD)
= US\$7.5 million
- Internal Source
US\$ 7.4 million

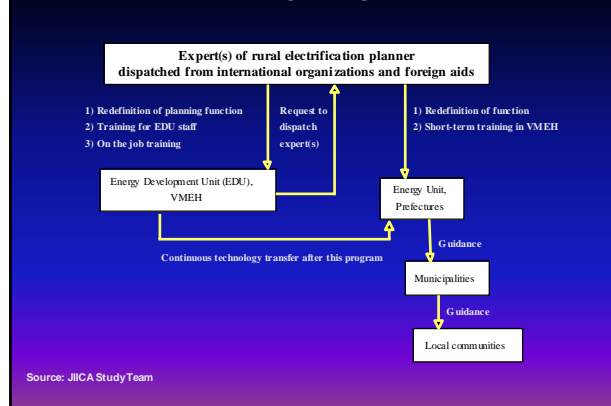
7.3 Institutional Support

- Planning Capacity Improvement
- Improved Coordination
- Research and Training

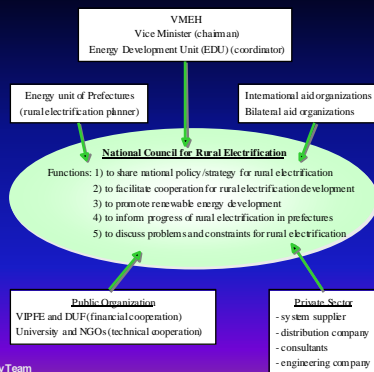
Proposed Re-Organization of Electrification Development Unit (EDU)



Flow Chart of Strengthening of the EDU Staff

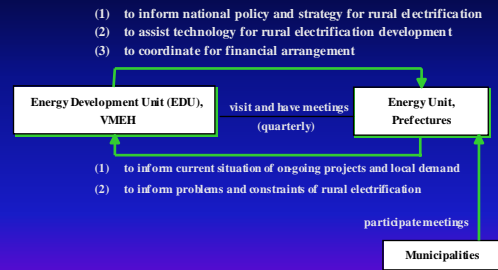


Proposed National Council for Rural Electrification



Source: JICA Study Team

Proposed Regular Meeting with Local Government by VMEH Staff



Source: JICA Study Team

Establishing Research and Training Center for Renewable Energy Development

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

8. Recommendation

Recommendation on Technical Matters

- PV System
 1. to follow up O&M of PV systems installed as a pilot project in La Paz and Oruro by VMEH and La Paz / Oruro prefectures
- Micro-hydro Power
 1. to carry out continuous measurement of water level and discharge for the priority project sites by La Paz / Oruro prefectures

Recommendation on Technical Matters

- Wind Power
 1. to continue the monitoring and wind data collection by La Paz / Oruro prefectures
 2. to assist the private sector for the technology development and promotion of wind power by VMEH

Recommendation on Institutional Strengthening

1. Function of EDU of the VMEH
2. Coordination between the VMEH and prefectures / municipalities
3. Research and training function
4. Financial supporting function of the VMEH
5. Coordination between DUF and municipalities and continuous support for municipality under PRSP

Japan International Cooperation Agency
Vice Ministry of Energy and Hydrocarbons, BOLIVIA

- Third Seminar -

La Paz, September 3, 2001

The Study
On
Rural Electrification Implementation Plan
By Renewable Energy
In
The Republic Of BOLIVIA