Chapter 7 Examination on Renewable Energy Utilization

7.1 Preparation of Wind Power Potential Map all over the Country

Nationwide wind power potential map of El Salvador will be prepared to identify the potential area in this study. Wind potential map indicates distribution of wind potential over large regions at certain height above ground level. The potential is simulated based on GIS data and global meteorological model. Data is corrected by surface wind data which being monitored in the assessment areas. Accordance with the following scope of works, selected organization will produce the nationwide wind potential map of El Salvador.

7.1.1 Specifications of Wind Power Potential Map

The study team of Japan International Cooperation Agency (JICA) is executing "The Project for Master Plan for the Development of Renewable Energy in the Republic of El Salvador". The nationwide wind potential map will be prepared in the study. This specification shall be applied to the procurement of the wind potential map in El Salvador. The main use of the map is to identify wind potential area in the country. In the study, following scope of works is prepared for the tender.

7.1.1.1 Scope of Work

A. Output materials

The materials for wind power potential map shall be prepared in the following format.

Output:

Nationwide Wind Potential Map of El Salvador

Data Set, Handbook

Format:

DVD (wind potential map (ArcGIS ver.9.3 (.gdb file), pdf), data set, instruction): 10 copies

Printed Map (A1: 594 mm x 841 mm, color, 1:400,000):

15 copies (5 for each height)

Language: Spanish (Map, Instruction)

B. Contents of the materials

Wind Potential Map:	El Salvador (nationwide)
Resolution:	500 meters mesh
Height:	30 m, 50 m and 80 m above ground level
Classification of Wind Potential:	
	7 classes (Wind potentials are separated by colors) 0~200, 200~300, 300~400, 400~500, 500~600, 600~800, >800
Data Set:	Selected Wind Potential Site (12 sites) Wind speed (m/s) /Wind density (W/m^2) Wind Direction (wind rose 16 direction) Weibull parameter (k, c)
Instruction:	Process of wind map preparation Instruction for use of contents in DVD

C. Input Data

Global Meteorological Model	(by contractor in Japan)
Analysis Software	(by contractor in Japan)
Surface Data	(by the JICA Study Team)
GIS Data	(by the JICA Study Team)
	After the simulation, GIS data shall be removed or disposed by the responsibility of contractor.

7.1.1.2 Appointed date of delivery

A. Instruction (Spanish)

The Constructor has to submit the draft of the instruction to JICA study team on 31st December 2011.

B. Other products

The contractor has to complete the works and submit all of products by 16th January 2012 to JICA study team. JICA study team has to check the contents promptly, after receiving the products.

7.1.1.3 Schedule

Work schedule of preparation of the wind potential map is shown in the table below.

Table 7.1.1 Schedule of Works

Item	2011 October	November	December	2012 January
1. Tender and Contract Negotiation.	■			
2.Schedule Planning, Preparation		■		
3.Review of Data, Pre-processing		■		
4.Simulation of Wind Potential		■	■	
5.Confirmation, Statistical work			■	
6.Mapping, Data processing			■	■
7. Confirmation of Accuracy				■
8.Instruction Manual			■	
Comment from counterpart organization in El Salvador				3 ←→ 15
Output				
Wind Potential Map				△
Instruction Manual			Draft △	Final △

(Source: JICA Study Team)

7.1.2 Preparation of Wind Power Potential Map

7.1.2.1 Procedure

The wind potential map and the data set were prepared in the following procedures.

a. As a result of analysis on the meteorological data and influence such as the El Nino phenomenon, meteorological data in 2008 was chosen as suitable annual data for calculation.

b. Meteorological data by the global model, topography data and land-use data were collected and arranged in an available form. Those data are necessary for following calculation.

c. Annual wind characteristics (500 m mesh) of target year (2008) were calculated by a numerical value simulation model.

d. Based on a calculation result, the statistics conversion from wind speed level to wind power energy, and annual average wind speed, accumulated value and relative frequency of wind speed was carried out.

e. Annual average wind power potential map (30 m, 50 m and 80 m above ground level) were prepared.

f. Based on the wind potential maps, considering with natural and social condition area, high potential area (10 sites) were selected. In the selected sites, various data were maintained as a wind characteristics database and recorded in DVD with a designated format.

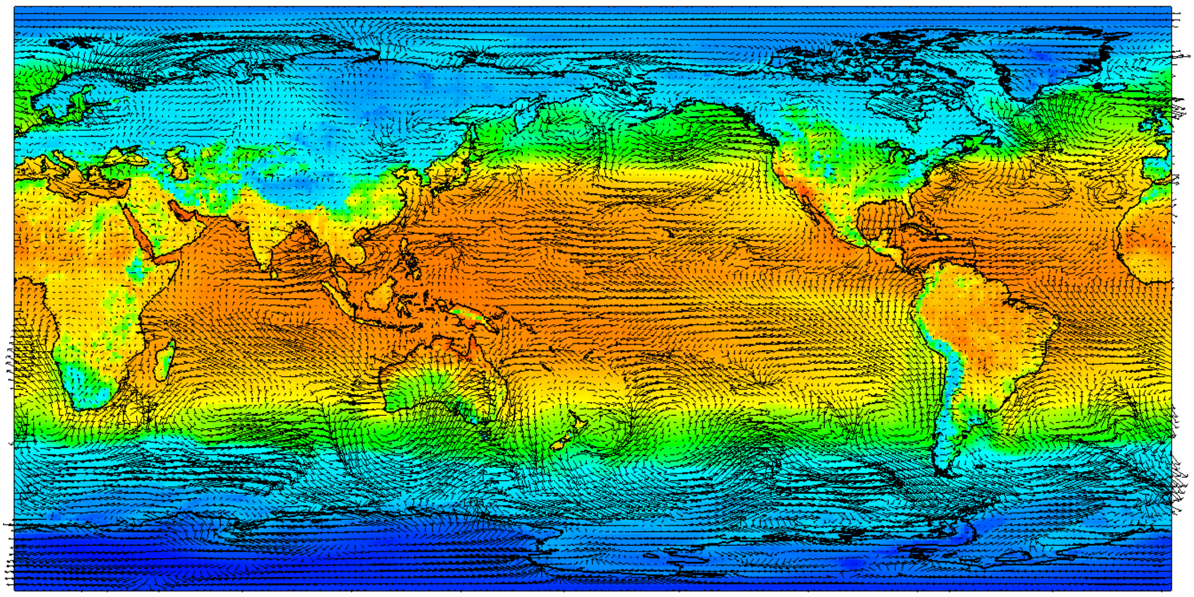
g. The handbook for the wind map was made. In addition to preparation and operation procedures, analysis results are explained.

7.1.2.2 Weather Simulation Model for Evaluation of Wind Potential

A. Weather Research and Forecasting Model (WRF Model)

On the basis of WRF Model, annual wind power potential was simulated in this study. WRF model was developed under the cooperative work between U.S. Centers for Environmental Prediction (NECP) and American Center for Atmospheric Research (NCAR). The model is used all over the world as regional weather model. One-year weather simulation of 2008 which is targeted year for the simulation was carried out using this model. The situation of the wind of 8,784 hours in a year was calculated in 5km mesh every day for every one hour.

Global Final Analysis (FNL), objective analysis data of NECP, was used for the simulation of initial value and boundary value for weather simulation by WRF. FNL is re-analyzed global weather data by NCEP. NFL includes value of distributed meteorological data in three-dimension which are calculated based on monitored meteorological data such as ground surface data and upper air observation, and satellite data. The following figure shows sample of FNL data on wind and temperature distribution. Data of terrain and land-use are included in WRF Model which prepared by United States Geological Survey (USGS).

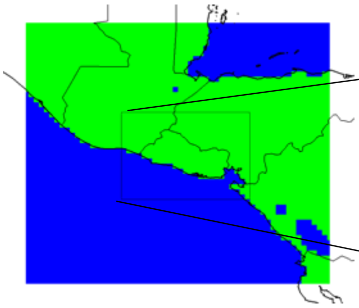
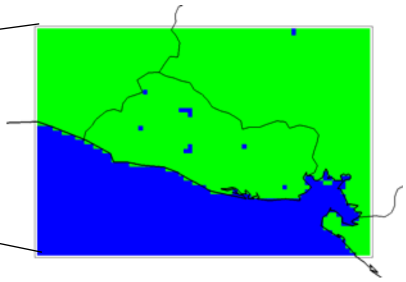


(Source: Japan Weather Association)

Figure 7.1.1 Sample of FNL Data (Wind and Temperature)

Monitoring period for the simulation is one year, from January to December 2008. The calculation area is categorized into 2 areas. In the wide area (area 1), it was calculated each 15 km horizontal mesh. In the neighboring area of El Salvador (area 2) , it was calculated each 5 km horizontal mesh.

Table 7.1.2 Area for calculation（WRF Model）

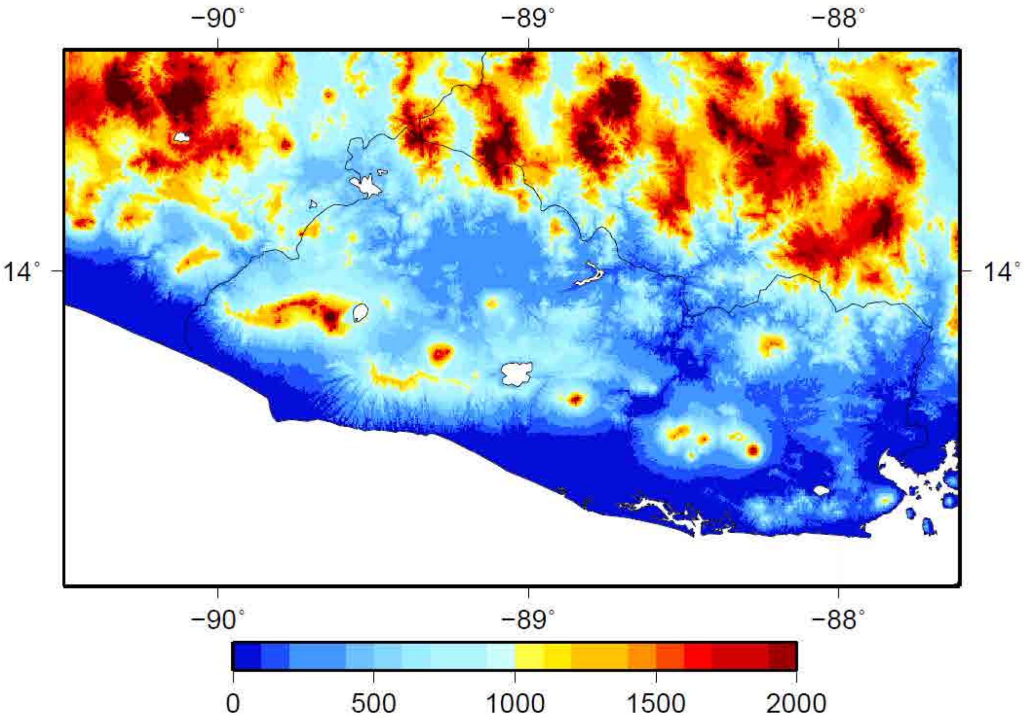
	Area1	Area2
Horizontal Mesh	15 km	5 km
No. of Mesh	60×52	75×51
Calculation Area		

(Source: Japan Weather Association)

B. MASCON Model

On the basis of the results of calculation on wind speed in each 5 km horizontal mesh by WRF Model, wind potential data which cover nationwide of the country area by 500 m horizontal mesh is calculated. MASCON model is a model to correct wind velocity to satisfy law of conservation of mass using topography data (an altitude level). This calculation can examine detailed topography effect by relatively little time. And, initial value to input into the calculation was prepared based on the result of WRF by interpolating weight points of the distance. DEM of resolution approximately 500 m which prepared by digital data of SRTM was used for the topography altitude level.

Table 7.1.3 Calculation Area (MASCON MODEL)

	MASCON MODEL Calculation Area
Horizontal Mesh	Around 500 m
No. of Horizontal Mesh	625×367
No. of Vertical Mesh	15 (layer)
End points of the area	Longitude: West:90.497685, East:87.608796 Latitude: North:14.696759, South:13.002315
Calculation Area and altitude	

(Source: Japan Weather Association)

7.1.2.3 Wind Power Potential Map

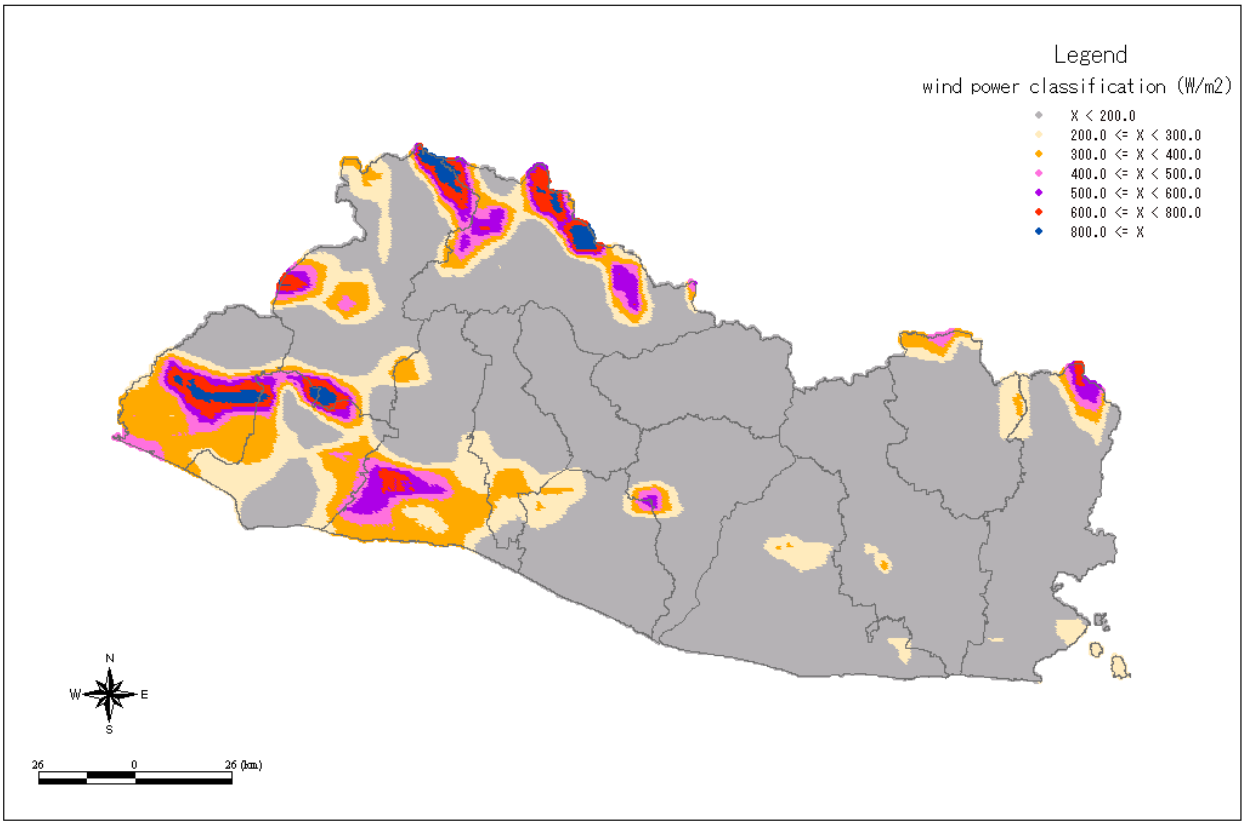
The height of wind potential maps which prepared in the studies are 30 m, 50 m and 80 m above ground level. According to NREL, the area where wind power energy density becomes over 320 (W/m^2) at 30 meters above ground level, and over 400 (W/m^2) at 50 m above ground level is suitable for wind power development. The table below shows an evaluation standard of the wind power energy density and wind speed.

Table 7.1.4 Standard definitions of wind power class

Class	Resource potential	Wind speed (m/s) (30 m height)	Wind power density (W/m^2) (30 m height)	Wind speed (m/s) (50 m height)	Wind Power density (W/m^2) (50 m height)
1	Poor	0.0 - 5.1	0 - 1 60	0 – 5.6	0 – 200
2	Marginal	5.1 – 5.9	1 60 – 240	5.6 – 6.4	200 – 300
3	Considerable	5.9 – 6.5	240 – 320	6.4 – 7.0	300 – 400
4	Good	6.5 – 7.0	320 – 400	7.0 - 7.5	400 – 500
5	-	7.0 – 7.4	400 – 480	7.5 – 8.0	500 – 600
6	-	7.4 – 8.2	480 – 640	8.0 – 8.8	600 – 800
7	-	8.2 – 11.0	640 – 1,600	8.8 – 11.9	800 – 2,000

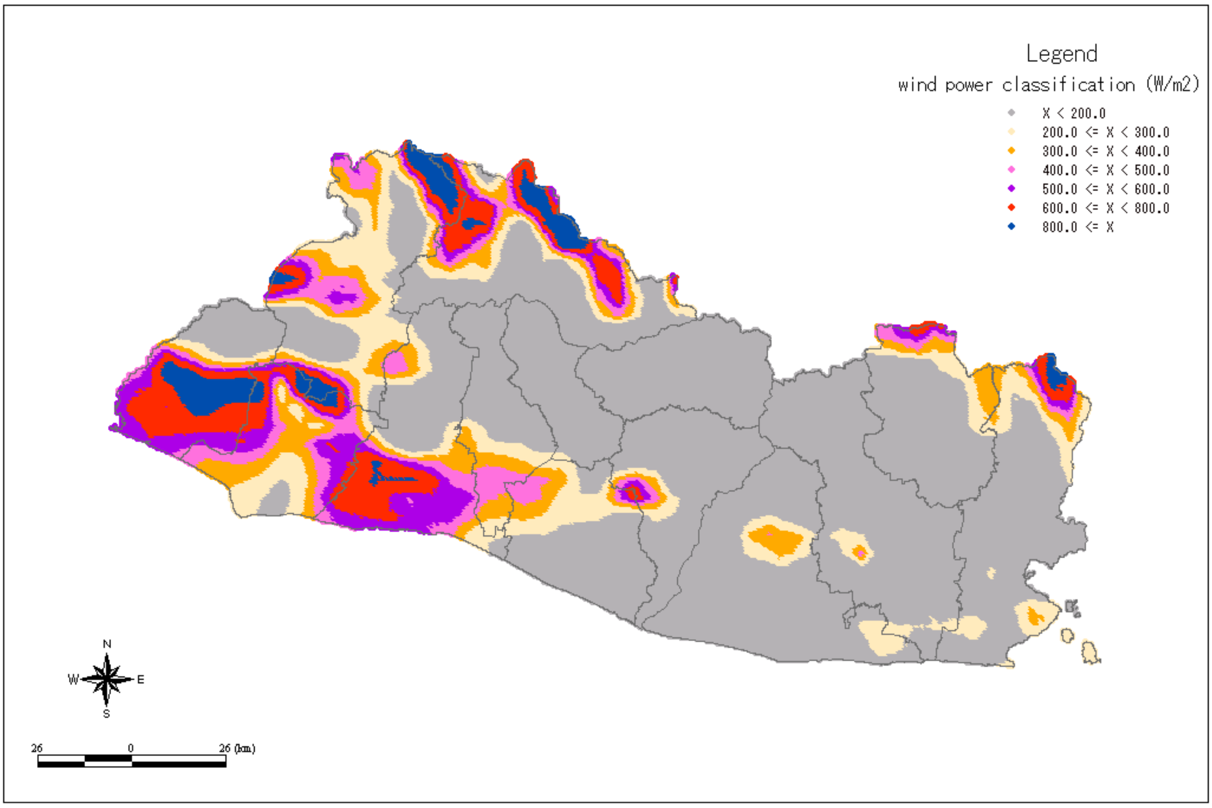
(Source: NREL)

Nationwide wind potential maps of El Salvador are as shown below.



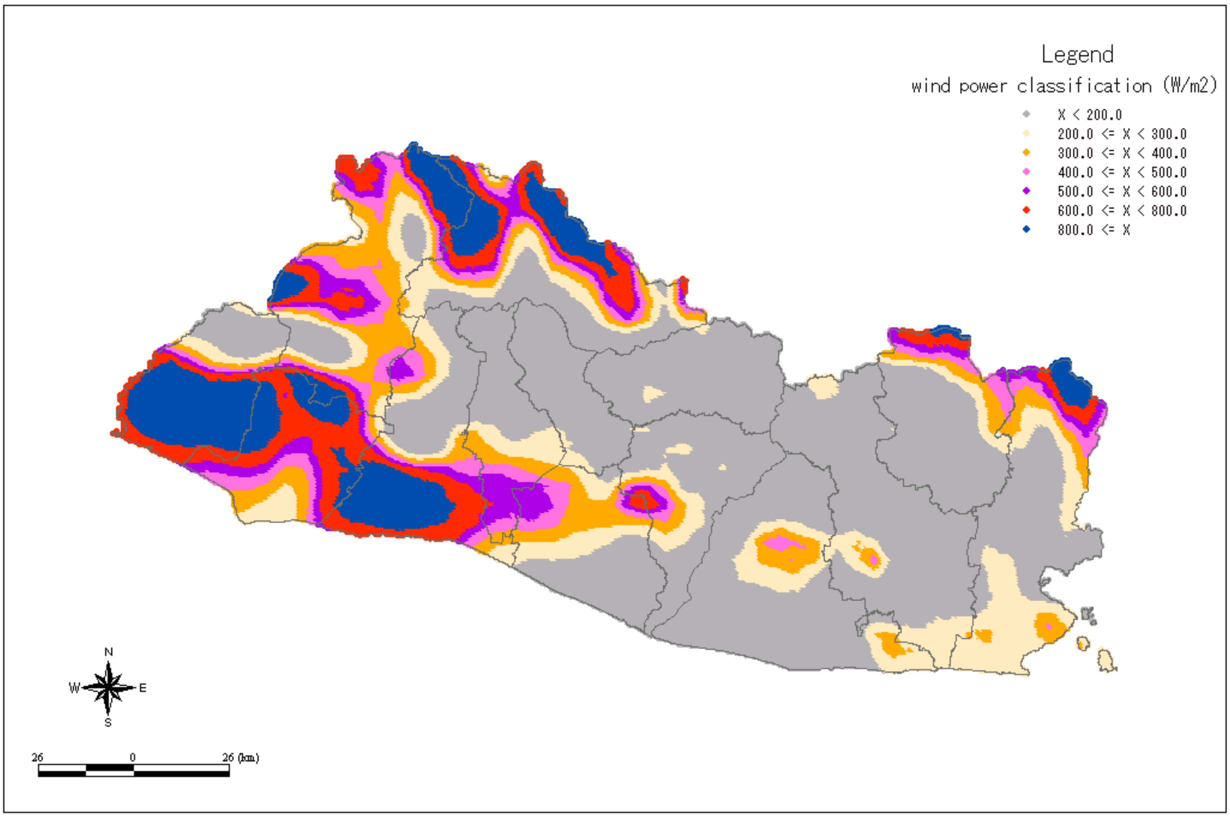
(Source: Japan Weather Association)

Figure 7.1.2 Wind Potential Map of El Salvador (30m above ground level)



(Source: Japan Weather Association)

Figure 7.1.3 Wind Potential Map of El Salvador (50m above ground level)



(Source: Japan Weather Association)

Figure 7.1.4 Wind Potential Map of El Salvador (80m above ground level)

7.1.3 Analysis Results

7.1.3.1 Wind Power Potential

As a result of wind potential analysis in El Salvador, it was recognized that wind potential was large in the following areas.

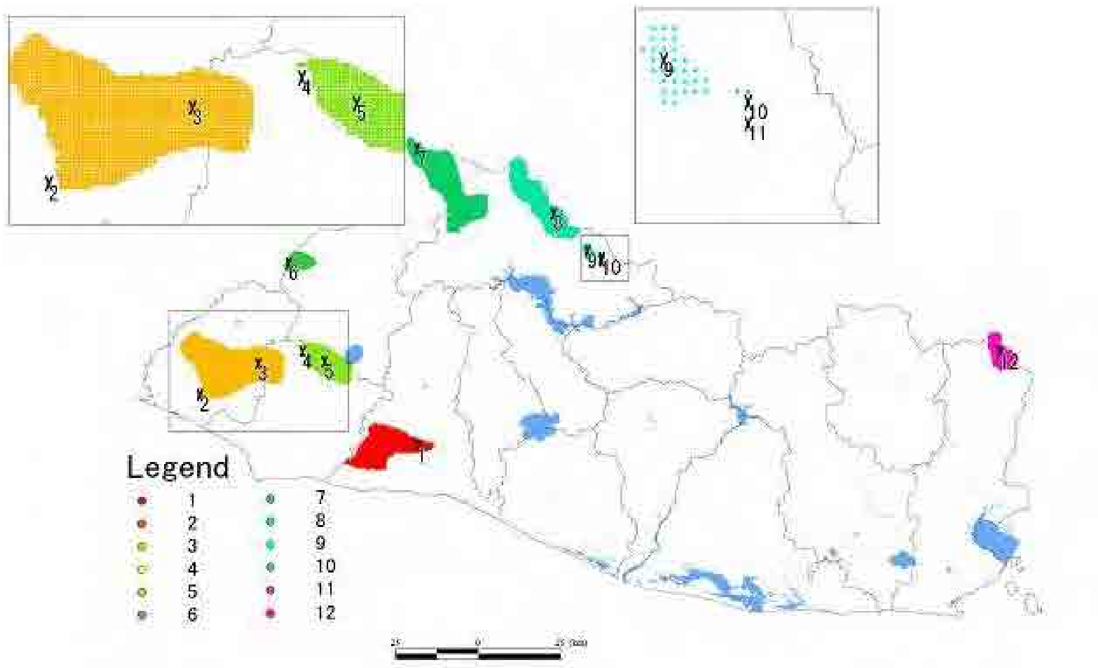
- A southwest mountainous area (area from a ridgeline in the south side)
- A northwest mountainous area (around ridgeline)
- A northeast mountainous area (around ridgeline to border)

In addition, the distribution of wind potential in the site mentioned above is almost similar at each altitude. However, the potential becomes larger with the increase of altitude. The area with over 800 W/m^2 is large at 80 meters above ground level,.

The result of wind potential map at 50 meters above ground level is similar to that of which prepared by SWERA. In this map, wind potential at the south side of southwest mountainous area appears clearly.

7.1.3.2 Wind Power Potential Sites

In the study, suitable sites for wind power development were identified from the wind potential map. On the basis of the map, a database was prepared. For the selection of wind potential area, the area where wind potential greater than 700 W/m^2 at 50 m above ground level are selected. As a result, 12 areas shown in the figure below were selected. Largest potential in the area was selected as a representative data of the area.



(Source: Japan Weather Association)

Figure 7.1.5 Wind Potential Sites

Wind speed and potentials at 30m, 50m and 80m above ground level are shown in Table 7.1.5. Similarly, each Weibull distribution parameter (c,k) is shown in the table 7.1.6.

Table 7.1.5 Data of wind potential sites (wind speed, wind potential)

point(area)	latitude	longitude	altitude	annual mean wind speed(m/s)			annual wind potential(W/m^2)		
	deg	deg	m	30 m	50 m	80 m	30 m	50 m	80 m
1	13.6181	-89.3773	956	6.50	7.32	7.66	574.0	843.8	1010.2
2	13.7569	-89.9653	224	5.15	5.94	6.62	401.6	703.4	1036.7
3	13.8403	-89.8079	1796	8.20	8.52	8.69	1072.2	1231.2	1348.9
4	13.8727	-89.6875	1925	6.61	7.42	7.94	485.1	707.0	899.1
5	13.8449	-89.6273	2096	8.19	8.48	8.55	1100.8	1237.1	1281.8
6	14.1134	-89.7245	1318	8.22	8.87	9.33	806.0	1013.6	1193.8
7	14.4236	-89.3773	2214	8.61	8.95	9.08	1183.2	1363.3	1460.1
8	14.2477	-89.0069	1266	7.26	7.81	7.96	1029.6	1287.6	1402.6
9	14.1458	-88.9144	1447	5.82	6.26	6.44	589.5	749.0	849.5
10	14.1273	-88.8773	1178	5.96	6.30	6.47	591.6	708.8	794.9
11	14.1181	-88.8773	1101	5.94	6.30	6.46	576.9	700.9	782.6
12	13.8727	-87.7986	1001	6.75	7.56	7.98	636.4	911.5	1103.1

(Source: Japan Weather Association)

Table 7.1.6 Data of wind potential sites (Weibull parameter (c, k))

point (area)	Weibull parameter c			Weibull parameter k		
	30 m	50 m	80 m	30 m	50 m	80 m
1	7.05	7.91	8.20	1.33	1.30	1.25
2	5.46	6.13	6.70	1.16	1.07	1.00
3	8.72	9.06	9.26	1.36	1.33	1.29
4	7.12	7.90	8.39	1.49	1.45	1.43
5	8.80	9.02	9.13	1.27	1.29	1.28
6	9.05	9.73	10.22	1.69	1.68	1.66
7	9.03	9.39	9.56	1.37	1.32	1.29
8	7.33	7.90	8.01	1.10	1.07	1.04
9	5.89	6.30	6.45	1.10	1.07	1.04
10	6.20	6.54	6.69	1.15	1.13	1.10
11	6.21	6.60	6.71	1.16	1.14	1.11
12	7.09	7.92	8.33	1.34	1.31	1.26

(Source: Japan Weather Association)

7.1.3.3 Comparison to Monitoring Data

The annual average wind speed is calculated based on wind speed of every hour and day in each mesh area. In addition, annual average wind speed and wind potential are almost corresponding if there are no large differences on the frequency distribution. In addition, in area of existing weather stations, which compared actual value with calculated value is shown below. It is considered that the calculated values are almost corresponding with the actual values of 2008.

Table 7.1.7 Monitored data and calculated data

Code	Weather station	Annual average wind speed (m/s) (2008)	Calculated wind speed (m/s)	
		H = 10 m	H = 10m	H = 30m
4	Ilopango	4.6	3.5	4.6
31	La Union	2.9	3.4	4.5
32	San Miguel	2.0	2.4	2.7

(Source: Japan Weather Association)

7.1.4 Recommendation

In the study, a nationwide wind potential map for El Salvador was prepared. As a result, wind potential area in El Salvador became clear. The followings are recommendations for further actions:

A. The installation of the wind monitoring system:

   It is necessary to install wind monitoring tower to monitor wind characteristics in the wind potential sites.

B. Wind characteristics data analysis:

   It is necessary to analyze the data which monitored, and to select suitable area for introduction of wind generation system.

C. Establishment of observation and analysis system:

   It is necessary to establish a system for installation of monitoring tower, data collection, analysis and evaluation to carry out wind monitoring.

7.2 Preparation of Guidelines for the Promotion of Small Hydropower System

The guidelines for the promotion of small hydropower (SHP) with a capacity of less than 20 MW were prepared through discussion and collaboration between CNE and the JICA Study Team. The guidelines were prepared only in Spanish, separate from the main report. The guidelines include 1) necessary procedures for the development of small hydropower system, 2) plan formulation and evaluation of the project, 3) Operation and Maintenance (O&M), 4) environmental impact monitoring and 5) recommendations and attachments (Format of Concession Procedure of SIGET, MARN)

7.2.1 Outline of the Guidelines to be Prepared

The purposes of the guidelines for the promotion of small hydropower in El Salvador are as follows:

A. To increase installed capacity of renewable energy, especially of small hydropower in the future, and to reduce fossil fuels and CO_2 emissions.

B. To serve as reference for deciding the overall development plan and prioritization of renewable energy in El Salvador by the government.

C. To breach the barrier in the introduction of small hydropower development, various complex procedures will be introduced in an easy manner to facilitate works by developers.

D. To serve as guidance to the developer for processing necessary procedures in obtaining environmental permit from MARN or development permit from SIGET, etc.,.

E. To evaluate the preliminary study of the possibility of the plan for the developers, simplified process of technical, economical, financial and environmental evaluation for the primary stage for small hydropower planning will be introduced.

F. To introduce operation and maintenance methods including a list of necessary spare parts, etc.

The guidelines include the following items:

a. Introduction

b. Necessary Procedure for Development of SHP

c. Plan Formulation & Evaluation of SHP Project

d. O&M of SHP Project

e. Environmental Impact Monitoring

f. Recommendations

g. Attachments (Format of Concession Procedure of SIGET, MARN)

7.2.2 Development Target for Small Hydropower

The government of El Salvador has no official development target for the development of small hydropower systems. According to CNE demand forecast and expansion plan, "Plan Indicativo de la Expansión de la Generación de El Salvador 2012 - 2026" (CNE, 2011), 20 MW is assumed as the development target for the installation of small hydro up to 2026, as shown in Table 7.2.1.

Table 7.2.1 Power Expansion Plans by CNE

Año	Proyecto	Potencia (MW)
2011	Expansión Ingenio El Ángel	15
2012	Contrato Xacbal	30
2013	Expansión Ingenio La Cabaña	15
2015	Hidroeléctrica Chaparral Optimización Geotérmica Ahuachapán.	66 5
2016	Expansión hidroeléctrica 5 de Noviembre Geotérmica Berlín, Unidad 6 Ciclo Combinado Gas Natural -a Ciclo combinado Gas Natural –b	80 5 250 107
2017	Central Geotérmica Chinameca Geotérmica Berlín, Unidad 5 Ciclo Combinado Gas Natural – b	47 26 143
2019	Motores de media velocidad, gas natural	100
2020	Motores de media velocidad, gas natural	100
2021	Motores de media velocidad, gas natural	100
2023	Ciclo combinado Gas Natural – c	250
2026	Ciclo combinado Gas Natural – d	250

Año	Proyecto	Potencia (MW)
2011	Expansión Ingenio El Ángel	15
2012	Contrato Xacbal	30
2013	Expansión Ingenio La Cabaña	15
2015	Hidroeléctrica Chaparral Optimización Geotérmica Ahuachapán. Fotovoltaico - a	66 5 5
2016	Expansión hidroeléctrica 5 de Noviembre Geotérmica Berlín, Unidad 6 Ciclo Combinado Gas Natural -a Ciclo combinado Gas Natural - b Pequeña Central Hidroeléctrica - a	80 5 250 250 10
2017	Central Geotérmica Chinameca Geotérmica Berlín, Unidad 5 Pequeña Central Hidroeléctrica - b Fotovoltaico - b Parque Eólico Térmico Solar Concentrado	47 26 10 3 42 50
2018	Fotovoltaico - c	10
2021	Motores de media velocidad, gas natural	100
2022	Ciclo combinado Gas Natural - c Cimarrón	250 261

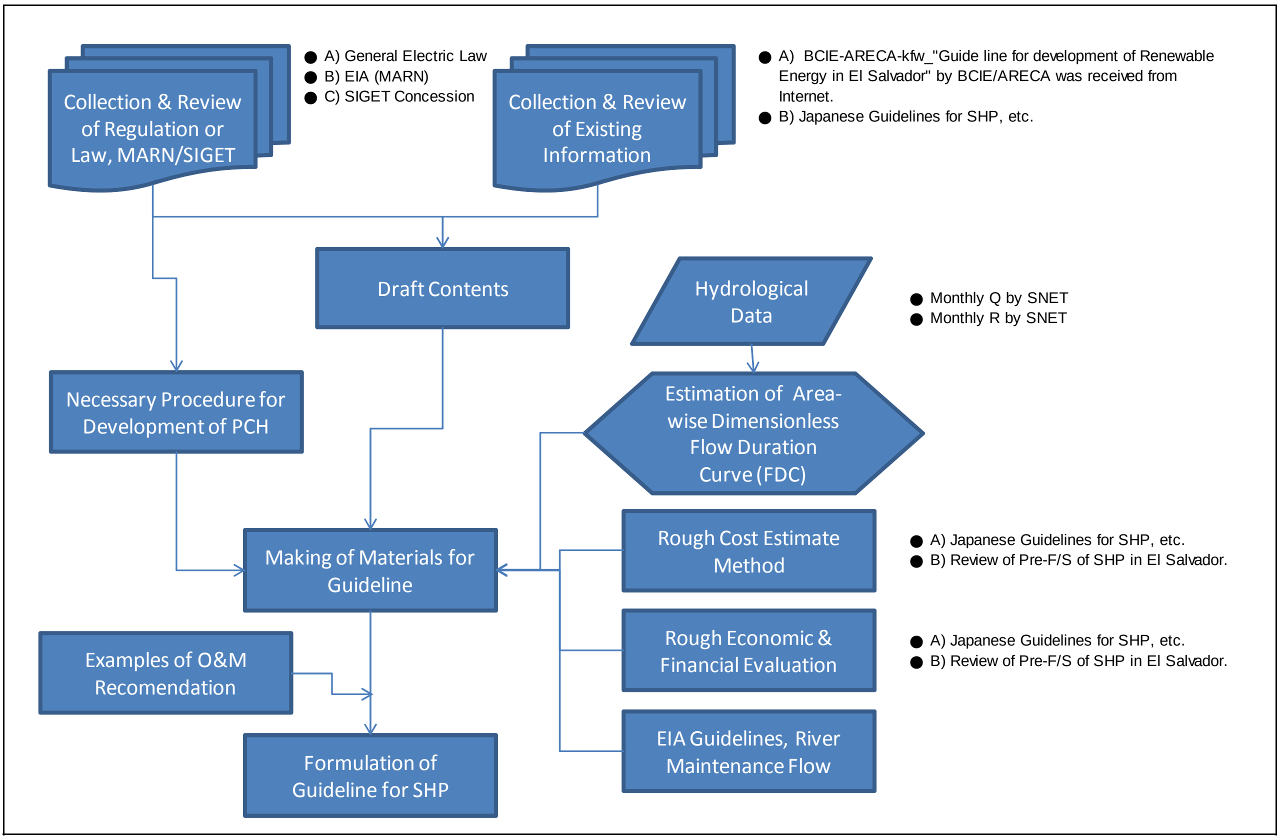
Source: "Plan Indicativo de la Expansión de la Generación de El Salvador 2012 - 2026" , CNE, 2011.

The target for the development of the installed capacity on small hydropower in the guideline is set at 20 MW up to 2027.

7.2.3 Guidelines for the Promotion of Small Hydropower

7.2.3.1 Basic Considerations of Technical Aspects

Basic considerations of technical aspects for the guidelines for the promotion of small hydropower are shown in Figure 7.2.1. To estimate the investment cost of a small hydropower project at an early stage, rough cost estimation method was introduced based on Japanese hydropower guidelines shown in Table 7.2.2. Also, to estimate the design discharge for the small hydropower project at a planned site, Dimensionless Flow Duration Curve (FDC) for each area (Department-wise) using available hydrological data, will be attached in the guideline as shown in Figure 7.2.2 and Table 7.2.3.



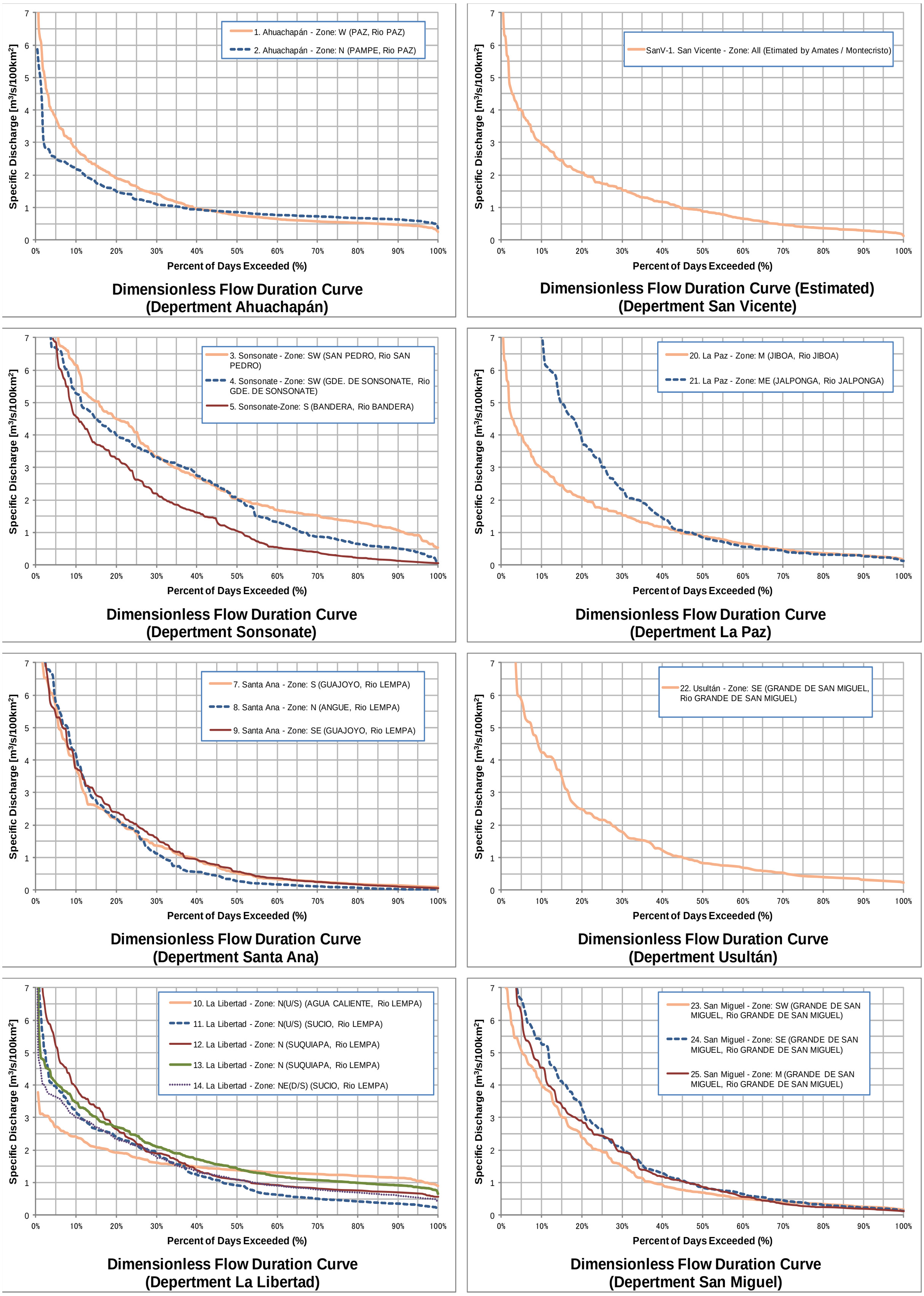
(Source: JICA Study Team)

Figure 7.2.1 Flow of Guideline Formulation and Related Technical Aspects

Table 7.2.2 Rough Formulas for Estimating Construction Cost of SHP

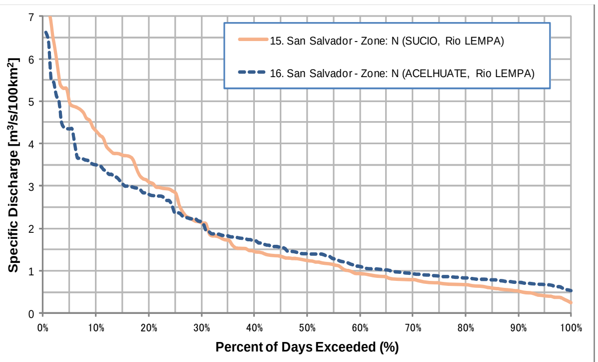
Items	Formula
Power House	Cost [x1000 US$] = 0.084 * (P[kw])$^{\wedge 0.830}$ / 80
Intake Weir	Q_{max} = Q / Plant Factor {(H: Height of Weir [m])^2 * (L:Length of Weir [m])} = Q_{max} * 198 Concrete Volume [m^3] = 11.8 * (H^2 * L)$^{\wedge 0.781}$ Cost [mil.US$] = 0.21 * (Concrete Volume)$^{\wedge 0.866}$ / 80
Intake	[Q < 4.4 m^3/s] Inner Diameter [m] = 1.8 m [Q >= 4.4 m^3/s] Inner Diameter [m] = 1.036 * Q$^{\wedge 0.375}$ Cost [x1000 US$] = 19.7 * (Inner Diameter * Q)$^{\wedge 0.506}$ / 80
Settling Basin	Cost [x1000 US$] = 18.2 * Q$^{\wedge 0.830}$ /80
Open Canal	√(Width * Height) = 1.09 * Q$^{\wedge 0.379}$ Unit Cost [x1000 US$/m] = 122 * (√(Width * Height))$^{\wedge 1.19}$ / 80
Penstock Pipe	Inner Diameter [m] = 0.888 * Q$^{\wedge 0.370}$ Unit Cost [x1000 US$/m] = 357 * (Inner Diameter)$^{\wedge 1.14}$ /80
Outlet Chanel	Cost [mil.US$] = 9.54 * { (Radius of Chanel) * Q }$^{\wedge 0.432}$ / 80 ※Radius of Outlet Chanel is decided by Penstock Pipe
Mechanical Works	Cost [mil.US$] = 0.0595 * { Q * $H_e$$^{\wedge 2/3}$ * (number of turbine)$^{\wedge 1/2}$ }$^{\wedge 1.49}$ /80
Electrical Facilities	Cost [mil.US$] = 12.8 * (P[kW] / √$H_e$)$^{\wedge 0.648}$ / 80

(Source: New Energy Foundation (NEF), Japan, "Medium and Small Hydroelectric Guidebook")

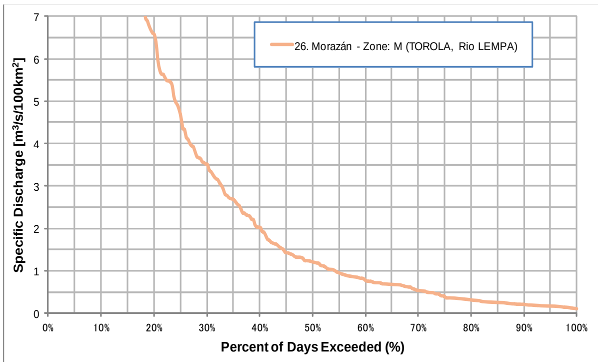


(Source: SNET (Prepared by JICA Study Team))

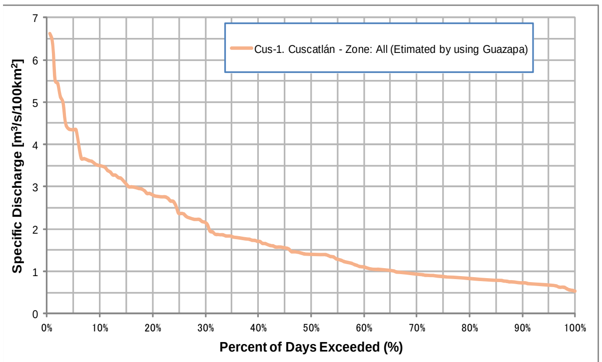
Figure 7.2.2 Dimensionless FDC by Department (1/2)



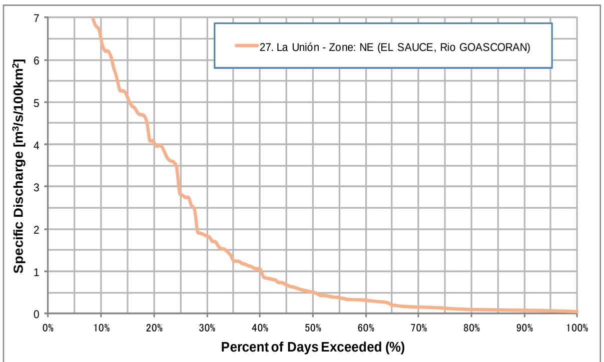
Dimensionless Flow Duration Curve
(Depertment San Salvador)



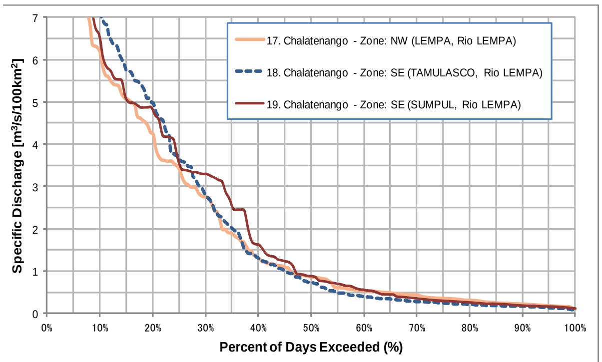
Dimensionless Flow Duration Curve
(Depertment Morazán)



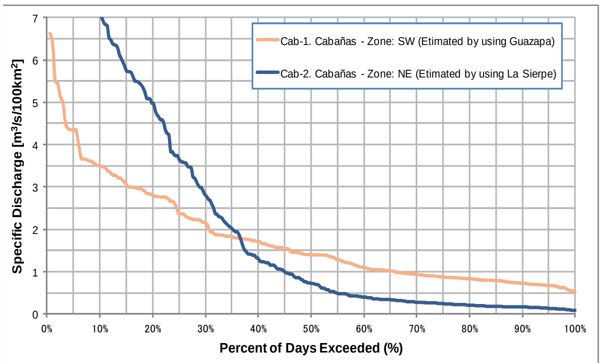
Dimensionless Flow Duration Curve (Estimated)
(Depertment Cuscatlán)



Dimensionless Flow Duration Curve
(Depertment La Unión)



Dimensionless Flow Duration Curve
(Depertment Chalatenango)



Dimensionless Flow Duration Curve (Estimated)
(Depertment Cabañas)

(Source: SNET (Prepared by JICA Study Team))

Figure 7.2.2 Dimensionless FDC by Department (2/2)

Table 7.2.3 Specific Flow Duration by Department

Average Specific Discharge [$m^3/s/100km^2$] by Duration of Percent of Days Exceeded by Each Department

No.	No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Department	Departmento	Ahuachapán	Ahuachapán	Sonsonate	Sonsonate	Sonsonate	Sonsonate	Santa Ana	Santa Ana	Santa Ana	La Libertad	La Libertad	La Libertad	La Libertad	La Libertad	San Salvador	San Salvador
Zone	Zona	W	N	SW	SW	S	M	S	N	SE	N(U/S)	N(U/S)	N	N	NE(D/S)	N	N
Basin	Cuenca	PAZ	PAZ	SAN PEDRO	GDE. DE SONSONAT	BANDERA	BANDERA	LEMPA	LEMPA	LEMPA	LEMPA	LEMPA	LEMPA	LEMPA	LEMPA	LEMPA	LEMPA
River	Río	PAZ	PAMPE	SAN PEDRO	GDE. DE SONSONAT	BANDERA	CENIZA	GUAJOYO	ANGUE	GUAJOYO	AGUA CALIENTE	SUCIO	SUQUIAPA	SUQUIAPA	SUCIO	SUCIO	ACELHUATE
Station	Estacion	LA HACHADURA	SAN LORENZO	LA ATALAYA	SENSUNAPAN	SANTA BEATRIZ	CONACASTE HERRADO	SINGUIL	LOS PUENTES	SAN FRANCISCO	SAN ANDRES / E.N.A.	SAN ANDRES	LAS PAVAS	TACACHICO	EL JOCOTE	DESEMBOCADURA	GUAZAPA
Latitude	Latitud	13º51'34.3"	14º02'	13º37´	13º36´	13º36´	13º40´	14º07´	14º20´	14º02´	13º49´	13º48'	14º02´	13º59´	13º55'	14º02´	13º53´
Longitude	Longitud	90º05'17.1"	89º47'	89º50´	89º50´	89º44´	89º44´	89º36´	89º33´	89º30'	89º24´	89º24'	89º18´	89º20´	89º18'	89º16´	89º12´
El. [m]	Elevacion	30.16	507.53	3.20	1.77	24.03	148.87	615.37	427.21	393.88	445.02	440.85	264.57	288.24	321.70	245.06	320.84
C.A. [km^2]	Area drenaje	1,991.0	351.2	102.2	219.0	422.0	167.7	114.5	587.4	199.7	112.6	379.2	435.0	308.0	724.0	843.0	366.0
Obs.Period		Apr.62-Oct.85, Jun.93-	Feb.60-Feb.85	Sep.68-Jun.88, Feb.90-	Jun.59-Oct.82	Jul.60-Jun.87	Feb.70-Sep.80, Jan.90-Oct.98	Jun.69-Oct.85	May.59-Nov.85	Apr.61-Nov.86	Aug.65-Aug.91, Dec.81-	Apr.59 -	Oct.68-Sep.82, Mar.90-	Nov.60-Jul.87	Feb.67-Abr.87	Apr.60-Aug.74	67-68, 74-84
Duration [%]	Days of Year Dias	Specific.Discharge [$m^3/s/100km^2$]															
5%	18	3.750	2.548	7.221	6.708	6.872	4.609	5.790	6.027	5.533	2.718	3.966	5.402	4.104	3.649	5.302	4.344
10%	37	2.819	2.178	6.155	5.315	4.600	3.667	3.764	4.270	3.766	2.371	3.201	3.979	3.474	3.006	4.377	3.503
15%	55	2.294	1.765	5.039	4.493	3.725	3.381	2.594	2.785	2.954	2.034	2.661	3.333	3.029	2.728	3.760	3.074
20%	73	1.906	1.538	4.511	4.009	3.270	2.856	2.201	2.215	2.399	1.865	2.402	2.651	2.721	2.355	3.149	2.814
25%	91	1.654	1.256	4.090	3.658	2.628	2.600	1.782	1.820	2.033	1.696	2.136	2.237	2.471	2.131	2.881	2.377
30%	110	1.411	1.108	3.346	3.329	2.201	2.338	1.371	1.129	1.612	1.572	1.912	1.887	2.107	1.830	2.159	2.167
35%	128	1.173	1.039	2.994	3.132	1.855	2.212	1.144	0.735	1.172	1.501	1.582	1.699	1.906	1.532	1.732	1.839
40%	146	0.962	0.945	2.691	2.763	1.618	2.010	0.969	0.557	0.936	1.430	1.253	1.372	1.724	1.378	1.476	1.716
45%	164	0.869	0.897	2.427	2.466	1.436	1.860	0.751	0.446	0.771	1.385	1.076	1.184	1.571	1.231	1.357	1.566
50%	183	0.760	0.863	2.035	2.091	1.055	1.550	0.524	0.274	0.561	1.561	0.912	1.078	1.460	1.097	1.251	1.410
55%	201	0.708	0.812	1.888	1.516	0.727	1.389	0.419	0.201	0.421	1.510	0.730	0.959	1.299	0.999	1.157	1.301
60%	219	0.648	0.777	1.693	1.324	0.547	1.091	0.341	0.169	0.366	1.279	0.620	0.917	1.195	0.907	0.940	1.117
65%	237	0.601	0.752	1.614	1.100	0.467	0.877	0.306	0.145	0.290	1.226	0.554	0.851	1.123	0.840	0.870	1.030
70%	256	0.569	0.735	1.536	0.877	0.396	0.674	0.253	0.111	0.245	1.190	0.501	0.814	1.078	0.786	0.794	0.951
75%	274	0.544	0.706	1.409	0.790	0.294	0.501	0.218	0.089	0.200	1.296	0.464	0.768	1.039	0.738	0.719	0.891
80%	292	0.523	0.678	1.321	0.658	0.218	0.441	0.183	0.063	0.165	1.245	0.419	0.749	0.994	0.696	0.673	0.842
85%	310	0.499	0.658	1.204	0.584	0.175	0.376	0.157	0.039	0.130	1.194	0.382	0.713	0.951	0.649	0.600	0.798
90%	329	0.469	0.638	1.076	0.516	0.126	0.328	0.140	0.026	0.105	1.153	0.353	0.694	0.922	0.610	0.530	0.738
95%	347	0.432	0.592	0.920	0.402	0.092	0.286	0.114	0.012	0.075	1.122	0.309	0.655	0.860	0.543	0.414	0.689
100%	365	0.245	0.376	0.538	0.096	0.055	0.149	0.087	0.002	0.050	0.949	0.166	0.554	0.656	0.383	0.249	0.541

Source: JICA Study Team. Prepared by using Mean Monthly Discharge Data at each Hydrological Stations by SNET.

No.	No.	Cus-1	17	18	19	Cab-1	Cab-2	SanV-1	20	21	22	23	24	25	26	27
Department	Departmento	Cuscatlán	Chalatenango	Chalatenango	Chalatenango	Cabañas	Cabañas	San Vicente	La Paz	La Paz	Usultán	San Miguel	San Miguel	San Miguel	Morazán	La Unión
Zone	Zona	All	NW	SE	SE	SW	NE	All	M	ME	SE	SW	SE	M	M	NE
Basin	Cuenca	Etimated	LEMPA	LEMPA	LEMPA	Etimated	Etimated	Etimated	JIBOA	JALPONGA	GRANDE DE SAN MIGUEL	GRANDE DE SAN MIGUEL	GRANDE DE SAN MIGUEL	GRANDE DE SAN MIGUEL	LEMPA	GOASCORAN
River	Río	Etimated	LEMPA	TAMULASCO	SUMPUL	Etimated	Etimated	Etimated	JIBOA	JALPONGA	GRANDE DE SAN MIGUEL	GRANDE DE SAN MIGUEL	GRANDE DE SAN MIGUEL	GRANDE DE SAN MIGUEL	TOROLA	EL SAUCE
Station	Estacion	Etimated by using Guazapa	CITALA	LA SIERPE	LAS FLORES	Etimated by using Guazapa	Etimated by using La Sierpe	Etimated by Amates / Montecristo	AMATES / MONTECRISTO	LA CEIBA	LAS CONCHAS	VADO MARIN	MOSCOSO	VILLERIAS	OSICALA	EL SAUCE
Latitude	Latitud		14º22.1'	14º01.7´	14º02.7'				13º30.5´	13º31´	13º17'	13º18´	13º27.7'	13º31´	13º50'	13º40'
Longitude	Longitud		89º12.9'	88º56.5´	88º48.5'				88º59.5´	88º57´	88º25'	88º17´	88º09.2'	88º11´	88º09'	87º48'
El. [m]	Elevacion		701.63	344.18	174.33				68.21	98.34	7.47	19.78	76.02	87.43	277.40	71.79
C.A. [km^2]	Area drenaje		914.0	74.0	980.5				426.0	58.0	2,238.0	1,900.0	1,074.0	910.0	908.0	319.5
Obs.Period		N.D.	May.72-Oct.82, Jul.90-	May.74-Sep.85, Dec.93-		N.D.	N.D.	N.D.	Jun.59-Mar.77, Sep.77-Aug.86, Jan.93-	Jul.65-Sep.85	Jul.63-Jan.82	May.59-Apr.81, Jun.93-99, Apr. 2006-	May.64-Apr.81	70-79, 95-96, 2002-		
Duration [%]	Days of Year Dias	Specific.Discharge [$m^3/s/100km^2$]														
5%	18	4.344	7.911	9.108	8.129	4.344	9.108	3.993	3.993	9.052	5.943	5.069	6.620	6.407	13.326	9.718
10%	37	3.503	6.277	7.135	6.578	3.503	7.135	3.005	3.005	7.052	4.245	4.026	5.253	4.545	10.570	6.720
15%	55	3.074	5.098	5.743	5.119	3.074	5.743	2.451	2.451	4.966	3.677	3.051	4.113	3.434	8.283	5.205
20%	73	2.814	4.269	4.973	4.875	2.814	4.973	2.073	2.073	4.086	2.493	2.411	3.268	2.911	6.601	4.085
25%	91	2.377	3.488	3.635	3.685	2.377	3.635	1.734	1.734	3.017	2.158	1.975	2.628	2.440	4.792	2.836
30%	110	2.167	2.751	2.811	3.299	2.167	2.811	1.580	1.580	2.328	1.810	1.512	2.058	1.960	3.513	1.828
35%	128	1.839	1.895	2.041	2.707	1.839	2.041	1.310	1.310	1.983	1.538	1.137	1.547	1.396	2.694	1.380
40%	146	1.716	1.327	1.311	1.642	1.716	1.311	1.167	1.167	1.466	1.270	0.944	1.287	1.182	2.026	1.052
45%	164	1.566	1.111	1.014	1.260	1.566	1.014	0.974	0.974	1.069	1.028	0.770	1.039	1.038	1.432	0.701
50%	183	1.410	0.859	0.716	0.886	1.410	0.716	0.878	0.878	0.845	0.835	0.684	0.846	0.864	1.211	0.504
55%	201	1.301	0.602	0.486	0.705	1.301	0.486	0.782	0.782	0.724	0.758	0.593	0.743	0.725	0.954	0.376
60%	219	1.117	0.532	0.392	0.565	1.117	0.392	0.655	0.655	0.569	0.693	0.503	0.638	0.562	0.787	0.310
65%	237	1.030	0.486	0.338	0.452	1.030	0.338	0.566	0.566	0.483	0.603	0.453	0.540	0.443	0.677	0.194
70%	256	0.951	0.430	0.270	0.367	0.951	0.270	0.467	0.467	0.448	0.536	0.395	0.443	0.347	0.533	0.147
75%	274	0.891	0.350	0.243	0.300	0.891	0.243	0.399	0.399	0.362	0.432	0.363	0.372	0.274	0.400	0.122
80%	292	0.842	0.302	0.203	0.267	0.842	0.203	0.354	0.354	0.310	0.405	0.327	0.296	0.242	0.307	0.085
85%	310	0.798	0.247	0.176	0.230	0.798	0.176	0.315	0.315	0.310	0.368	0.297	0.256	0.216	0.249	0.078
90%	329	0.738	0.218	0.162	0.191	0.738	0.162	0.282	0.282	0.259	0.321	0.248	0.219	0.189	0.206	0.069
95%	347	0.689	0.174	0.135	0.168	0.689	0.135	0.245	0.245	0.224	0.285	0.223	0.189	0.157	0.164	0.056
100%	365	0.541	0.101	0.081	0.122	0.541	0.081	0.117	0.117	0.121	0.229	0.160	0.116	0.113	0.100	0.034

Source: JICA Study Team. Prepared by using Mean Monthly Discharge Data at each Hydrological Stations by SNET.

(Source: JICA Study Team. (Mean Monthly Discharge Data by SNET))

For estimation of design flow for the planned small hydropower, it is possible to calculate the discharge [m^3/s] easily if the catchment area [km^2] at the proposed intake site is known. This is done by using the specific flow duration discharge [m^3/s/km^2] at each zone (Department-wise) from Table 7.2.3, and applying the following formula:

$$Q = A * Qsp$$

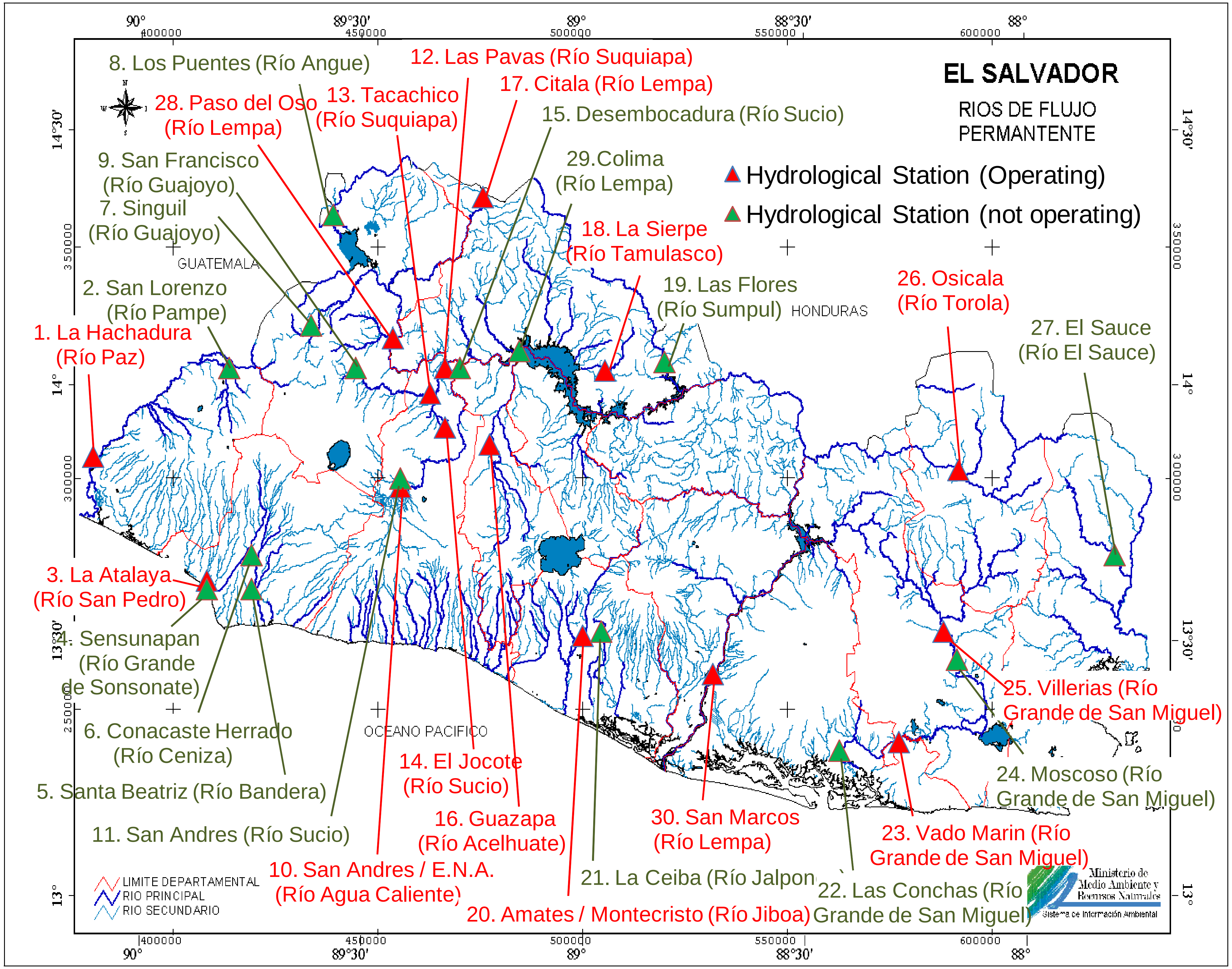
Q : Discharge at Proposed Intake Site [m^3/s]

A : Catchment Area at Proposed Intake Site [km^2]

Qsp : Specific Discharge at Planned Zone (Department) [m^3/s/100km^2]

Location map of hydrological stations by SNET is shown in Figure 7.2.3. The list of hydrological stations and the observed period are shown in Table 7.2.4. As shown in Figure 7.2.3 and Table 7.2.4, works in most stations were interrupted from 1985 to 1992 due to the Civil War. After the Civil War, some stations continued their operations. The locations of hydrological stations are partially distributed. The hydrological stations are insufficient in the eastern part of Ahuachapán Department, southern part of La Libertad Department, southern part of San Salvador Department, north-west part of Chalatenango Department, northern part of San Miguel Department, and all areas of Morazán Department and La Unión Department. Especially, there are no hydrological stations in the Departments of Cuscatlán, Cabañas and San Vicente.

For the planning of small hydropower or water resources projects, long-term discharge observation data at a nearest station is required. Thus, it is required to build the nationwide hydrological and meteorological observation systems as soon as possible.



(Source: Prepared by JICA Study Team based on the mean monthly discharge data of SNET)

Figure 7.2.3 Location Map of Hydrological Stations by SNET

Table 7.2.4 Hydrological Stations and the Observation Period by SNET

No.	Department / Departmento	Basin / Cuenca	River / Río	Station / Estacion	Latitude / Latitud	Longitude / Longitud	El. [m] / Elevacion	C.A. [km^2] / Area drenaje	Obs. Period / Período de Observación
1	Ahuachapán	Paz	Paz	La Hachadura	13º51'34.3"	90º05'17.1"	30.16	1,991.0	Apr.62-Oct.85, Jun.93-
2	Ahuachapán	Paz	Pampe	San Lorenzo	14º02'	89º47'	507.53	351.2	Feb.60-Feb.85
3	Sonsonate	San Pedro	San Pedro	La Atalaya	13º37´	89º50´	3.20	102.2	Sep.68-Jun.88, Feb.90-
4	Sonsonate	Grande de Sonsonate	Grande de Sonsonate	Sensunapan	13º36´	89º50´	1.77	219.0	Jun.59-Oct.82
5	Sonsonate	Bandera	Bandera	Santa Beatriz	13º36´	89º44´	24.03	422.0	Jul.60-Jun.87
6	Sonsonate	Bandera	Ceniza	Conacaste Herrado	13º40´	89º44´	148.87	167.7	Feb.70-Sep.80, Jan.90-Oct.98
7	Santa Ana	Lempa	Guajoyo	Singuil	14º07´	89º36´	615.37	114.5	Jun.69-Oct.85
8	Santa Ana	Lempa	Angue	Los Puentes	14º20´	89º33´	427.21	587.4	May.59-Nov.85
9	Santa Ana	Lempa	Guajoyo	San Francisco	14º02´	89º30'	393.88	199.7	Apr.61-Nov.86
10	La Libertad	Lempa	Agua Caliente	San Andres / E.N.A.	13º49´	89º24´	445.02	112.6	Aug.65-Aug.91, Dec.81-
11	La Libertad	Lempa	Sucio	San Andres	13º48'	89º24'	440.85	379.2	Apr.59 -
12	La Libertad	Lempa	Suquiapa	Las Pavas	14º02´	89º18´	264.57	435.0	Oct.68-Sep.82, Mar.90-
13	La Libertad	Lempa	Suquiapa	Tacachico	13º59´	89º20´	288.24	308.0	Nov.60-Jul.87, Sep.02-
14	La Libertad	Lempa	Sucio	El Jocote	13º55'	89º18'	321.70	724.0	Feb.67-Abr.87, Aug.92-
15	San Salvador	Lempa	Sucio	Desembocadura	14º02´	89º16´	245.06	843.0	Apr.60-Aug.74
16	San Salvador	Lempa	Acelhuate	Guazapa	13º53´	89º12´	320.84	366.0	67-68, 74-84
17	Chalatenango	Lempa	Lempa	Citala	14º22.1'	89º12.9'	701.63	914.0	May.72-Oct.82, Jul.90-
18	Chalatenango	Lempa	Tamulasco	La Sierpe	14º01.7´	88º56.5´	344.18	74.0	May.74-Sep.85, Dec.93-
19	Chalatenango	Lempa	Sumpul	Las Flores	14º02.7'	88º48.5'	174.33	980.5	Sep.72-Apr.79, May.03-Apr.08
20	La Paz	Jiboa	Jiboa	Amates / Montecristo	13º30.5´	88º59.5´	68.21	426.0	Jun.59-Mar.77, Sep.77-Aug.86, Jan.93-
21	La Paz	Jalponga	Jalponga	La Ceiba	13º31´	88º57´	98.34	58.0	Jul.65-Sep.85
22	Usultán	Grande de San Miguel	Grande de San Miguel	Las Conchas	13º17'	88º25'	7.47	2,238.0	Jul.63-Jan.82
23	San Miguel	Grande de San Miguel	Grande de San Miguel	Vado Marin	13º18´	88º17´	19.78	1,900.0	May.59-Apr.81, Jun.93-99, Apr. 2006-
24	San Miguel	Grande de San Miguel	Grande de San Miguel	Moscoso	13º27.7'	88º09.2'	76.02	1,074.0	May.64-Apr.81
25	San Miguel	Grande de San Miguel	Grande de San Miguel	Villerias	13º31´	88º11´	87.43	910.0	70-79, 95-96, 2002-
26	Morazán	Lempa	Torola	Osicala	13º50'	88º09'	277.40	908.0	Jan.62-Apr.80, May.02-
27	La Unión	Goascoran	El Sauce	El Sauce	13º40'	87º48'	71.79	319.5	Nov.70-Feb.82, May.03-Nov.06
28	Santa Ana / Chalatenango	Lempa	Lempa	Paso del Oso	14º05.5´	89º25´	294.60	4,531.4	Feb.71-Oct.83, Mar.90-
29	Cuscatlan	Lempa	Lempa	Colima	14º04´	89º08´	218.58	7,342.9	May.61-Oct.76
30	Usultán / San Vicente	Lempa	Lempa	San Marcos	13º26´	88º42´	4.88	18,176.3	Dec.59-Oct.82

Year / Año ('59–'85)

No.	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77	'78	'79	'80	'81	'82	'83	'84	'85
1				△	●	●	●	●	●	△	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
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3											△	●	●	●	●	●	●	●	●	●	●	●	●	△	△	△	△
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5		△	●	●	●	●	●	●	△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	△	△	△
6												△	●	●	●	●	●	●	●	●	●	△	●	△	●	●	●
7											△	●	●	●	●	●	●	●	●	●	●	●	●	△	△	△	△
8	△	●	●	●	●	●	●	●	●	●	△	△	△	●	●	●	●	●	●	△	△	△	●	△			
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10												△	●	●	●	●	△	△	●	●	●	●	△				
11	△		●	●	●	●	●	●	●	●	△		△	●	●	●	●	●	●	●	●	●	●	△	●	●	△
12												△	●	●	●	●	●	●	△	△	△	△	△	△			
13			●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●
14									△	●	●	●	●	△		△	●	●	●	●	●	△	●	△	△	△	△
15			●	●	●	●	●	●	●	●	●	●	●	●	●	△											
16									△	●	●	●	△			△	●	●	●	△	●	△	△	△	△	△	
17															△	△		△	●	△	●	△	△	△			
18																△	●	●	●	●	●	●	●	●	△	△	△
19														△	●	●	●	●	●	●	△						
20			△	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△	△	△	●	●	●	●	●	●	△
21											△	●	●	●	●	●	●	●	●	●	●	△			△	△	△
22											△	●	●	●	●	●	●	●	●	●	●	●	△				
23	△		●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	●	△				
24						△	●	●	●	●	●	●	●	●	●	●	●	△	●	●	●	●	△				
25												△	●	●	●	●	●	●	●	●	△						
26				●	●	●	△	△	●	△	△	●	●	●	●	●	△	△	△	●	●	△					
27												△	●	●	●	●	●	●	●	●	●	●	△	△			
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30			●	△	●	●	●	△	△	△	△	●	●	●	●	●	△	△	●	●	●	△	△	△			

Year / Año ('86–'11)

No.	'86	'87	'88	'89	'90	'91	'92	'93	'94	'95	'96	'97	'98	'99	'00	'01	'02	'03	'04	'05	'06	'07	'08	'09	'10	'11
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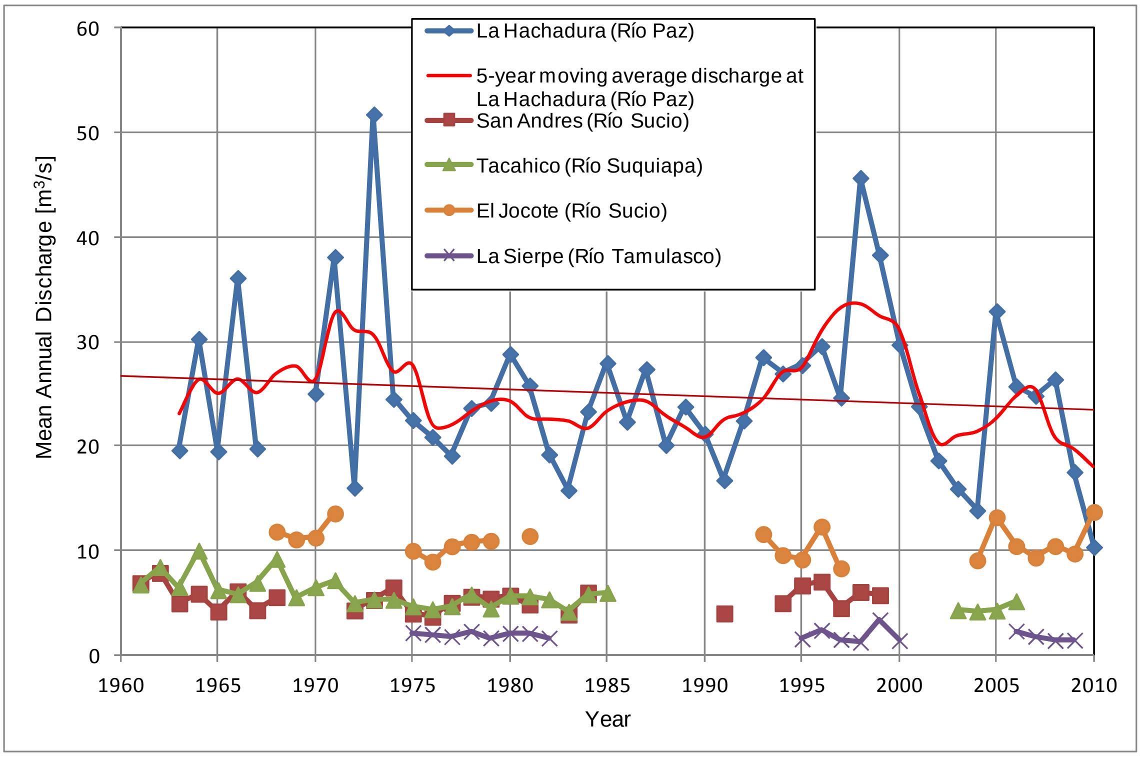
Source: SNET.

Note: ●: Data available completely, △: Data available partially.

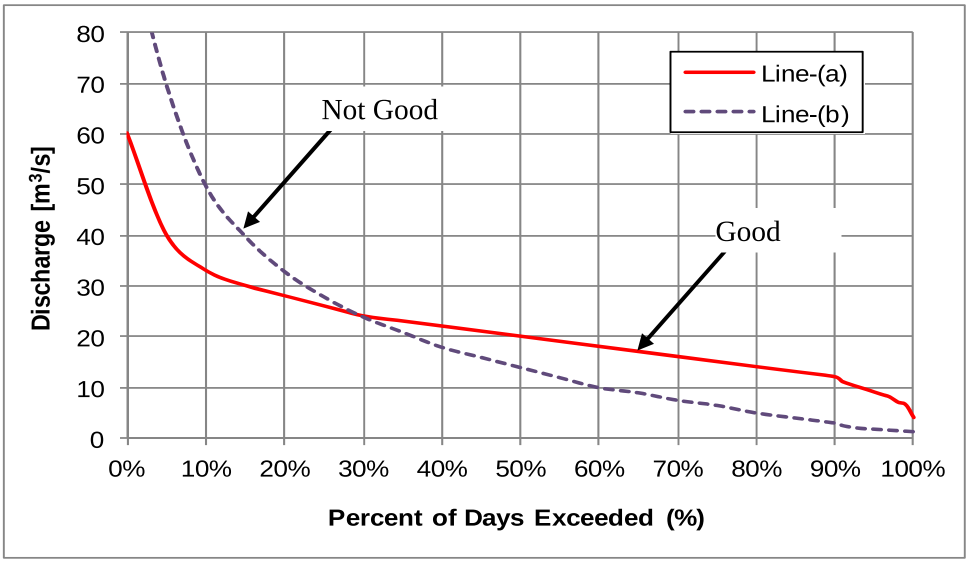
Long-term mean annual discharge at principal hydrological stations is shown in Figure 7.2.4. There is no remarkable trend of fluctuation of long-term mean annual discharge at each station; however, it seems that there is a decrease in trend of the mean annual discharge at La Hachadura station in Río Paz.



(Source: Prepared by JICA Study Team based on the mean monthly discharge data of SNET)

Figure 7.2.4 Long-tern Mean Annual Discharge at Principal Hydrological Stations

In the planning of run-off river-type small hydropower without reservoir, achieving a stable water flow throughout the whole year and rich water flow in the dry season is preferred. Thus, the curve "Line-(a)" in Figure 7.2.5 is suitable for small hydropower.



(Source: JICA Study Team)

Figure 7.2.5 Desirable Type of FDC for Small Hydropower

7.2.3.2 Procedure Related to Regulatory Aspects

To breach the barrier in the introduction of small hydropower development, various complex procedures will be introduced in an easy manner to facilitate related works by the developers. Necessary procedures on regulatory aspects in the guidelines for the promotion of small hydropower are listed below:

A. Summary of General Electricity Law

B. Summary of Environmental Law & Environmental Protected Area / Zone

C. Procedure to MARN / EIA (how to get permit from MARN, description of regulations & flowchart, Water Right)

D. Procedure to SIGET (how to get Permit from SIGET, description of regulations & flowchart)

E. Summary of Law of Renewable Energy Incentives

F. Procedure to get Land Use Permit (for CNR, Municipals, etc.)

G. Procedure to connect Grid Line (SIGET / UT, connection cost, EIA for grid line)

H. Procedure to get CDM Credit

I. Other necessary procedures (if necessary)

7.2.3.3 Contents of Guidelines

Contents of the guidelines were discussed and agreed between CNE and the JICA Study Team during the first field survey period in October 2011. The agreed contents of the guidelines are shown below:

Guidelines for the Development of Small Hydro Power (SHP) in El Salvador

Table of Contents

2.7 Procedure to connect Grid Line

2.8 Procedure to get CDM Credit

3. Key Points of Plan Formulation & Evaluation of SHP Project

3.1 Work Flow of Development of SHP Project

3.2 Pre-Feasibility Study

3.2.1 Topographic Survey

3.2.2 Hydrological Study (Estimation of Discharge by using Dimensionless Specific Flow Duration Curve at nearby hydrological station)

3.2.3 Determination of River Maintenance Flow (Caudal Ecologico)

3.2.4 Determination of Design Discharge and Optimum Install Capacity

3.2.5 Rough Cost Estimation

3.2.6 Estimation of Annual Energy Production

3.2.7 Economic & Financial Analysis (include price of sell energy to market, IRR=TIR, NPV=VAN, B/C, etc.)

3.2.8 Environmental Impact Assessment (EIA)

4. Operation & Maintenance (O&M) of SHP Project

4.1 Operation

4.2 Maintenance

4.3 Environmental Impact Monitoring

5. Recommendations

5.1 Hydrological Observation (items, include Equipments)

5.2 Environmental Monitoring (items, include Equipments)

Attachments

1. Format of Concession Procedure of SIGET

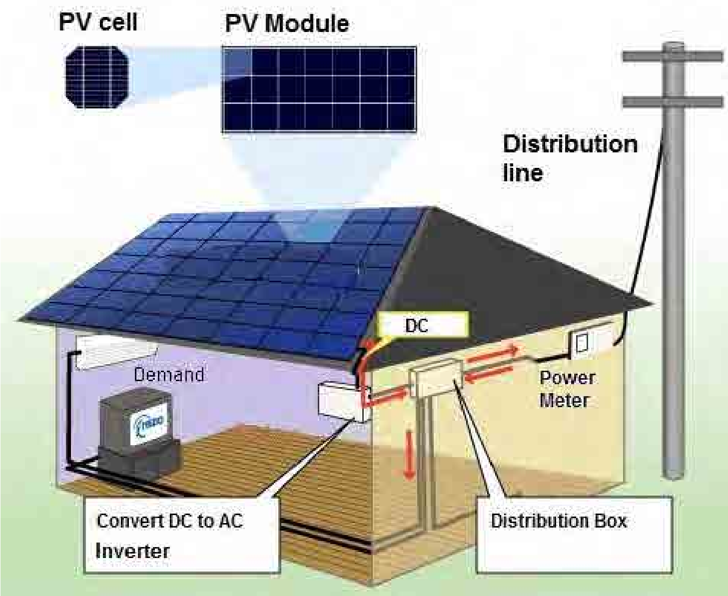
2. Format of Procedure of MARN (EIA)

3. Contact address & telephone of major organization (CNE, MARN, SIGET, MAG, SNET, etc.)

7.3 Examination of Rooftop-Type Solar PV in Urban Areas

Solar PV is expected to be a power source, which steadily supplies electricity to the existing grid, not only for private consumption but also for public use. Therefore, review and examination of technical aspects such as specifications and required infrastructure for connecting solar PV to the grid are conducted. Concept of roadmap for dissemination of rooftop solar PV is subsequently explained.

Figure 7.3.1 shows the concept of a rooftop solar PV system.



(Source: NEDO)

Figure 7.3.1 Concept of Rooftop Solar PV System

7.3.1 Current Status and Future Prospects

7.3.1.1 Potential

Power output from solar PV is calculated by the following expression.

$$Ep = H \times K \times P$$

Ep：Estimated Power Output (kWh/day)

H：Averaged Solar Irradiation (inclined 15 deg.)(kWh/m^2/day)

K： Total System Loss

P：Solar PV System Capacity (kWp)

$$K = k1 \times k2 \times k3 \times k4 \times k5$$

k1: Variation of annual average solar irradiation correction factor: 0.97

k2: Aged deterioration correction factor of PV array: 0.95

k3: Load matching correction factor of PV array: 0.94

k4: Circuit correction factor of PV array: 0.97

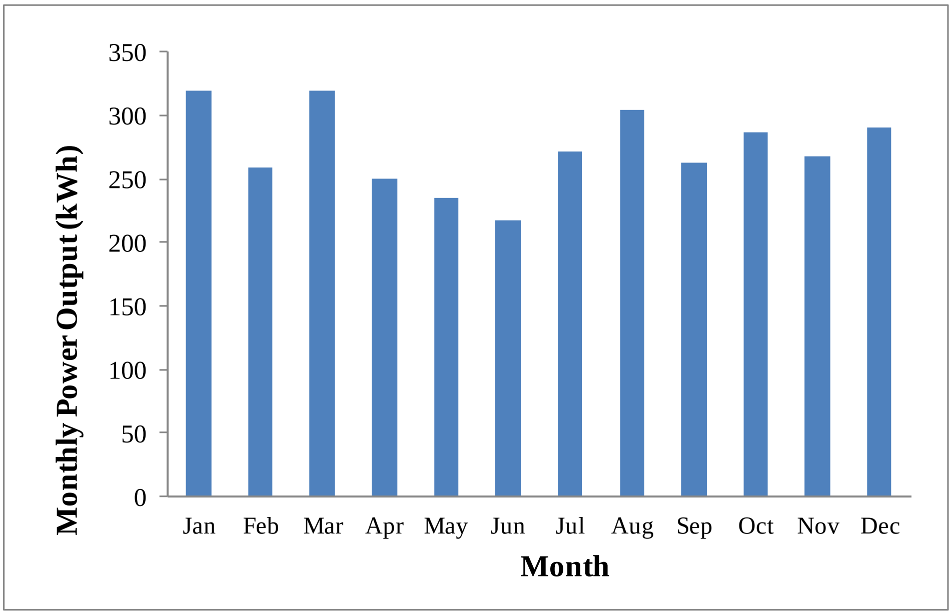
k5: Power conditioner efficiency: 0.90

Solar irradiation is as high as 5.3 kWh/m^2/day in terms of annual horizontal average in El Salvador, especially around San Salvador Metropolitan Area. Therefore, rooftop solar PV can be one of the best options for power supply in this urban area. Table 7.3.1 and Figure 7.3.2 show the monthly solar irradiation, which is monitored at CEL and estimated power output form 2kW rooftop solar PV system.

Table 7.3.1 Estimated Monthly Power Output in San Salvador Metropolitan (2kW)

Month	days	Irradiation angle 15 (kWh/m^2-day)	Ambient Temp. (℃)	2 kWp	
				Power Output (kWh/day)	Monthly Output (kWh/Mo)
Jan	31	6.80	25.4	10.3	319
Feb	28	6.10	26.0	9.2	258
Mar	31	6.80	26.3	10.3	319
Apr	30	5.50	26.8	8.3	250
May	31	5.00	26.1	7.56	234
Jun	30	4.80	25.6	7.3	218
Jul	31	5.80	26.0	8.8	272
Aug	31	6.50	25.9	9.8	305
Sep	30	5.80	25.2	8.8	263
Oct	31	6.10	25.2	9.2	286
Nov	30	5.90	25.5	8.9	268
Dec	31	6.20	25.4	9.4	291
Average	365	5.94	25.8	9.0	273

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 7.3.2 Estimated Monthly Power Output in San Salvador Metropolitan (2 kW)

7.3.1.2 Estimated Price and Installed solar PV system

The potential of solar irradiation is high in El Salvador; however, the initial cost of rooftop solar PV is still expensive for individual users as compared to the current power tariff. The current range of prices for a rooftop solar PV system with 2kW capacity were studied in San Salvador as shown below.

Solar PV system (2kW): US$8,500.00 - US$10,050.00 (plus VAT)

(Source: DelSol Energy and Tecnosolar companies, Feb. 2012. Prices includes 2kW PV modules, 2kW, AC120V, inverter, mounting structure, electrical accessories, labor, etc.)

Table 7.3.2 shows a list of grid-connected PV systems in El Salvador. There are two systems, which are installed at households. Most of them are installed at government buildings and schools or universities. The largest PV system, 91 kW, is installed at the U.S. base camp. In addition to this, there is a 9 kW solar PV also installed in the camp. There are few companies in El Salvador who are engaged in the solar PV business.

Table 7.3.2 Grid-Connected Solar PV system in El Salvador

Application	Location	Capacity (kW)
Recreational House	Lago Coatepeque, Sta Ana	1.63
Germany School	San Salvador	20.00
Santo Domingo Ecological Farm	Sto Tomás, San Salvador	2.48
Administrative Offices, CEL	San Salvador	24.57
Administrative Offices, FUNDE	San Salvador	2.17
Administrative Offices, SEESA	San Salvador	2.17
Private home	Sn José Villanueva, La Libertad	2.02
Universidad Nacional	San Salvador	2.20
Superstore, San Carlos	Sn Rafael Cedros	6.00
Universidad Politécnica	San Salvador	0.70
U.S. base camp	La Paz	91.0 + 9.0

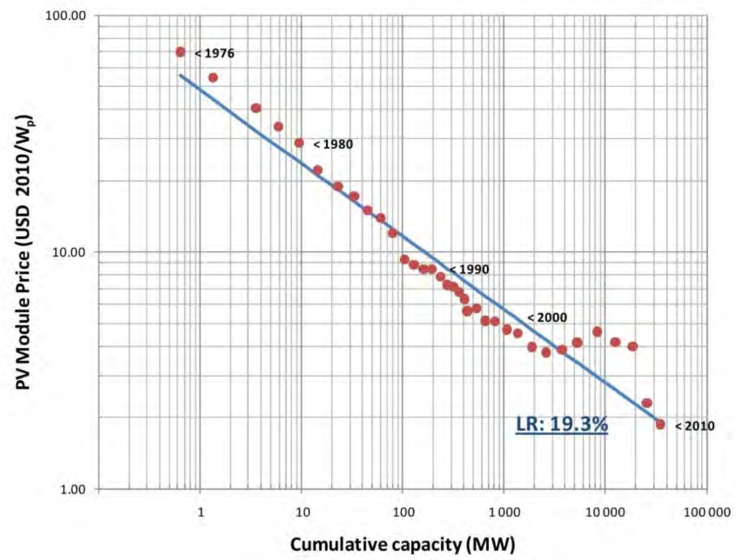
(Source: JICA Study Team)

7.3.2 Cost Trend of Solar PV

Rooftop solar PV will be disseminated through market-driven approach; therefore, its price has to be competitive with the power tariff. Cost trend of solar PV in past and expected future cost trend are given in the following sub-section.

7.3.2.1 Cost Trend in the Past

The costs of PV have been falling consistently over the last three decades, exhibiting a learning rate of 19.3%. Such trends can be expected to continue, given the scope for performance and cost improvements delivered by development efforts, as well as significant benefits from scaling up manufacturing processes. Figure 7.3.3 shows the cost digression of solar PV module.



(Source: Renewable Energy Markets and Prospects By Technology, IEA)

Figure 7.3.3 Cost Digression of Solar PV Modules (1976 - 2010)

In accordance with the IEC report, the current spot market prices for solar modules range between US$1.80/Wp and US$2.27/Wp for crystalline modules, and between US$ 1.37/Wp and US$ 1.65/Wp for thin film modules. It is noted however that prices vary significantly among markets. The total system costs in June 2011 range between US$ 3,300/kWp and US$ 5,800/kWp for rooftop systems. Note that these costs are decreasing quickly and may well be out of date at the time of publication of this report. The resulting generation costs depend on the cost of capital and insulation. Taking the above system costs, levelized costs of electricity will range between US$0.14/kWh and US$0.69/kWh for rooftop systems.

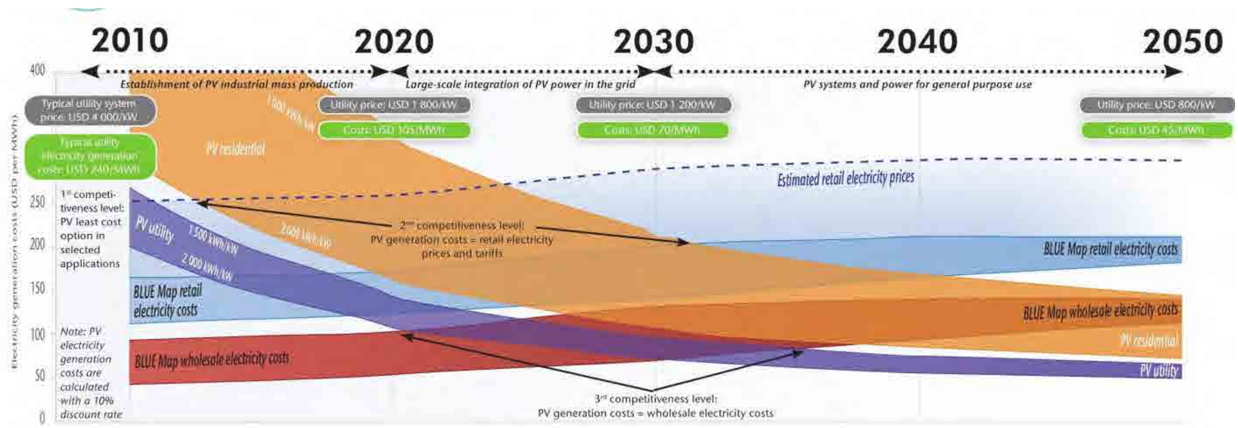
7.3.2.2 Expected Future Cost Trend of Solar PV

Table 7.3.3 shows the roadmap of technology development on solar PV systems, which is prepared by the New Energy and Industrial Technology Development Organization (NEDO), Japan. The target of the roadmap is to decrease the power generation cost by improving the module conversion efficiency and production capability. Meanwhile, Figure 7.3.4 shows the solar PV road map prepared by IEA. Both organizations analyzed the reduction of energy production cost of solar PV system. NEDO assumes the energy production to become US$ 0.18/kWh in 2017 while IEA assumes the cost to be US$ 0.105/kWh in 2020.

Table 7.3.3 Solar PV Technology Roadmap (NEDO)

Target		2010 or later	2017	2025	2050
Power generation cost		Equivalent to household electricity tariff (US$0.29/kWh)	Equivalent to commercial electricity tariff (US$0.18/kWh)	Equivalent to general power source (US$0.09/kWh)	Equivalent to general power source (US$ 0.09/kWh)
Module conversion efficiency (lab. level)		Commercial: 16% (Lab: 20%)	Commercial: 20% (Lab: 25%)	Commercial: 25% (Lab: 30%)	Ultra-high performance: 40% and over
Production (GW/ year)	for Japan	0.5 to 1 GW	2 to 3 GW	6 to 12 GW	25 to 35 GW
	for Overseas	to 1GW	to 3GW	30 to 35 GW	to 300GW
Major applications		Single-family houses, public facilities	Single/multi-family houses, public facilities, offices, etc.	Single/multi-family houses, public facilities, consumer use, charging EV, etc.	Consumer use, industries, transport, agriculture, stand-alone, etc.

(Source: JICA Study Team)



(Source: IEA)

Figure 7.3.4 Solar PV Roadmap (IEA)

Rooftop solar PV will be disseminated through market-driven approach; therefore, its price has to be competitive with the power tariff. The power production cost of a PV system is still higher than that of current power tariff in El Salvador. The availability of the rooftop solar PV system for the general public will increase while the price decreases. Once the price becomes affordable, it will be disseminated widely as in the case for mobile phones. Therefore, it is necessary to prepare human resources in the field of renewable energy.

For solar PV industry, improvement of economic efficiency and reduction of generation cost is the most significant issue in expanding the usage of solar PV system. To address this, it is necessary to develop high-performance and low-cost production technologies for PV modules and system components. Moreover, it is also necessary to simplify installation works and extend the lifetime of solar PV systems. The following table shows the target generation cost of solar PV industry in Japan.

Table 7.3.4 Target Power Generation Cost of Japanese PV Industry

Target Year	2017	2025	2050
Generation Cost (Yen/kWh)	14	7	<7
Generation Cost (US$/kWh)	0.18	0.09	<0.09

(Source: JICA Study Team)

In Japan, around 700,000 rooftop solar PV systems have been installed by the end of 2011, which is the largest number in the world. Most of the rooftop systems, over 90 %, are installed at private households with governmental subsidy and FIT. The number of systems serves around 0.55% of the national population in Japan. In El Salvador, the ratio could be estimated lower value due to lack of governmental subsidy and FIT. Base on the estimated ratio rooftop system and population, 0.005% from year 2012 to 2016, 0.01% from year 2017 to 2021, 0.1% from year 2022 to 2026, plan is prepared as shown the table below:

Table 7.3.5 Master Plan of Solar PV (Rooftop)

	Capacity (MW)	**Power Output (GWh/year)**
2012 to 2016	0.09*1	0.15
2017 to 2021	0.18*2	0.31
2022 to 2026	1.8*3	3.05

*1: 2012 to 2016: 6,200,000 x 15% x 0.005% x 2kW= 93 kW
*2: 2017 to 2021: 6,200,000 x 15% x 0.01% x 2kW= 186 kW
*3: 2022 to 2026: 6,200,000 x 15% x 0.1% x 2kW= 1860 kW
This 15% is the proportion of urban households with electricity in El Salvador
(Source: JICA Study Team)

7.3.3 Issues and Countermeasures on Technical Aspects

The generation electricity from solar PV is not stable and fluctuates depending on the weather condition. Issues and the countermeasures are examined from the viewpoint of electricity quality and installation.

7.3.3.1 Issues and Countermeasures of Electricity Quality

A. Over / Under Voltage

Surplus electricity will flow back to the grid when the power generated by solar PV becomes larger than the consumed energy at the demand side. In this case, electric current flow reverses direction, and the voltage rises as it goes to the end. As PV penetration increases on a grid with a small capacity, the voltage could exceed the upper limit. This issue is called overvoltage. It is possible to control the line voltage to some extent by reducing the sending voltage from the transformer. However, this may cause undervoltage of neighboring lines. Overvoltage and undervoltage could have a negative impact on both the supply-side devices and demand-side equipment.

There are power conditioners for PV systems, which are designed to control voltage rise so as not to exceed the limit. Overvoltage can be completely prevented using this technology. However, a disadvantage is that the PV power output is dumped to control the voltage, leading to lower efficiency of the PV system. Therefore, it is necessary to confirm total capacity of solar PV system which already connected with grid. Accordance with necessity, grid capacity have to be increased as a countermeasures.

B. Harmonics

The inverter converts DC to AC through a semiconductor switching circuit; however, the AC wave obtained from the devices will not be a perfect sinusoidal wave.

The latest inverter models generate little harmonics. The applied scheme is called Pulse Width Modulation (PWM). In PWM, the voltage is controlled by changing the interval and width of the pulse so that the average value of the voltage becomes equal to the desired fundamental waveform.

Therefore, issue on harmonics is a solved in technical aspect, but replace to the latest inverter with PWM is necessary for the solar PV facilities equipped with old-model inverter.

C. Unintended Islanding

Unintended islanding is an electrical phenomenon in which PV systems within a certain network continue to supply power to the load even after the network is disconnected. PV systems are designed to detect the abnormal power quality for immediate disconnection from the network. However, if the power generated from the PV systems and that consumed in the load are identical by chance, the PV systems might not be able to detect the unintended islanding and will continue to supply power.

It is necessary to consider about unintended islanding operation although there is little impact from unintended islanding since the possibility of unintended islanding operation is quite low.

7.3.3.2 Issues and Countermeasures of the Installation

In order to begin planning a grid-connected solar PV system, a site survey is essential. This enables an assessment of the basic conditions for the PV system.

Table 7.3.6 Checklist for Rooftop Solar PV

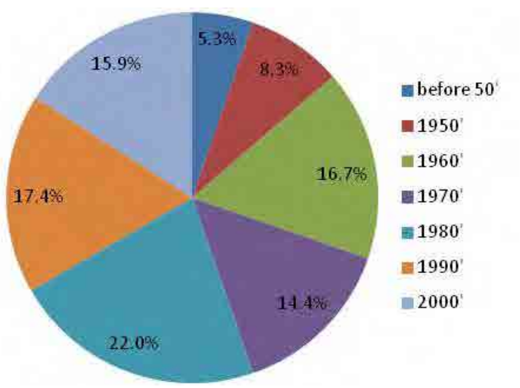
1	Customer's requirements with regard to module type, system concept and method of installation
2	Desired PV power or the desired power output from PV system
3	Usable roof, open space
4	Orientation and angle of inclination
5	Roof shape, roof structure, roof substructure and type of roofing
6	Data on shading
7	Installation sites for PV combiner / junction boxes, isolating facility and inverter
8	Meter cupboard and space for extra meters
9	Cable length, wiring routes and routing method
10	Access, particularly when equipment is required for installing PV array (crane, scaffolding, etc.)

(Source: Planning & Installing Photovoltaic System)

A. Strength Examination of Building Structure

For the installation of rooftop solar PV system, shapes of roofs are not so significant; however direction of its slope, angle and type of household structure are considered as more important. Therefore, it is easier to install a rooftop solar PV system on new buildings being constructed. The total weight of the module and supporting structure of a 2 kW rooftop system is around 220 kg. Installers have to examine the structure prior to installing solar PV on old houses.

Current conditions of buildings have been randomly studied at 132 schools in San Salvador Department. As a result, around 66.7% of school buildings were constructed in the 1980's and the prior years. The following figure shows the percentage distribution of buildings according to their year of construction.



(Source: JICA Study Team)

Figure 7.3.5 Percentage of School Buildings by Year of Construction

As mentioned above, there are a lot of old buildings. About the building targeted for the installation of rooftop solar PV, maintenance of the standard on strength evaluation of building structure, development of organization or persons who carrying out the evaluation are necessary.

B. Shading

Ideally, solar PV should be installed at a location without any shade. However, rooftop grid-connected systems are usually installed even where some shading exists. It is necessary to confirm the situation of shading which described in the table below to avoid the effect of shading.

Table 7.3.7 Classification of Shading

Type of shading	Description
Temporary shading	Typical temporary shading includes factors such as leaves, bird droppings and other type of soiling. A tilt angle of greater than 12^{o} is usually sufficient to achieve self-cleaning of leaves and soils on the array.
Shading resulting from location	Shading from the location covers all shading around the solar PV. Shading of building and trees are included. Growth of trees and vegetation must be taken in account.
Shading resulting from building	Shading resulting from the building involves direct shadows. Attention should be paid to chimney, antennae, lighting conductors, satellite dishes, etc.
Self-shading	Self-shading may be caused by the row of PV modules in front. The space requirement and shading loses can be minimized through optimizing distance between rows or tilt angle.
Direct-shading	Direct shading can cause high losses of energy. The closer the shadow-casting object, the darker the shadow will be since module is hit by core shadow. The core shadow cast by a near object reduces the energy incident to the cells by approximately 60 to 80 %.

(Source: Planning & Installing Photovoltaic System)

C. Confirmation with Customer

It is important to establish whether the building is suitable for installing a solar PV system. A thorough initial investigation avoids planning errors and miscalculations in the related quotation, which will be prepared. The installation work for the PV array, installation site, wiring routes, actual laying of cables and expanding or modifying the meter cupboard can be better estimated and agreed in consultation with the customer. Furthermore, it is important to know the budget of the customer for the installation of solar PV system since it will have an influence in deciding the size of the system.

7.3.4 Predicted Issues for Future Introduction

The installation capacity of solar PV system, stimulated by supportive policies in a relatively small number of countries, has been rapid and accompanied by impressive reductions in prices. Solar PV system is now cost competitive in some isolated systems. If productive capacity of solar PV system continues to grow, it can be expected to become competitive with retail power prices and eventually with wholesale prices in an increasing number of markets, over the next ten to 20 years. This change will open up the possibilities for deploying the technology in a much wider range of countries. Currently, solar PV applications are not cost competitive. If markets are to grow, economic incentives need to be in place. Experience shows that feed-in tariff (FIT) schemes are effective policy tools; however, care should also be taken in the detailed design of the policy so as to avoid runaway markets, when costs reduce more rapidly than policy makers have anticipated.

This potential trend should be seen as a problem stimulated by success, which could be constantly difficult. By taking advantage of the accumulated policy learning, it should be possible to design policies that effectively stimulate capacity and generation in a predictable way while constraining policy costs to an affordable level. Policies need to be able to react rapidly to changing circumstances.

7.3.4.1 Issues and Countermeasures on Institutional Aspects

A. FIT

The concept of FIT is simple. It permits the interconnection of renewable energies with the existing grid and specifies the price paid. Two approaches have emerged for determining the price per kWh. One is bidding or the tendering system, and the second uses a fixed price.

B. Tradable Green Certificates (TGC)

Certificate systems are based on the idea of separating the actual power and its “greenness”. The power is sold on the normal market. In addition, renewable generators can sell a certificate that represents a certain amount of renewable electricity that they generated.

C. Renewable Energy Portfolio Standard (RPS)

An RPS ensures that a minimum amount of renewable energy is included in the portfolio of electricity resources.

D. Loan Softening and Guarantees

Similarly, loan softening programs and loan guarantees, or reassuring of guarantees given by the local governments, can reduce the costs of private lending and thus, improve the project economics.

E. Tendering Schemes

Under a tendering scheme, a regulatory authority announces that it intends to install a certain capacity of a given technology or a suite of technologies. Project developers will then apply to build the project and name their price they are willing to accept for developing the project. Tenders commonly contain specific requirements (e.g. shares of local manufacturing, details of technological specifications, maximum price per unit of energy). The bidder with the lowest offer is selected and can go ahead with the project. Usually, parties sign a long−term contract (power purchasing agreement). Tenders combine two enablers to overcome the economic barriers. They can establish a guaranteed demand, and they ensure, at least in theory, that revenues recover costs for investment.

7.3.4.2 Human Resource Development

Further time is needed to develop human resources before the power production cost of solar PV comes to be able to compete with the cost of existing power generation system. Therefore, in anticipation of price erosion and the dissemination of solar PV system, it is necessary to develop human resources in the field of renewable energy in preliminary stage.

In El Salvador, there are some universities which include renewable technologies in their curriculum. Table 7.3.8 shows the current condition of renewable energy courses in those universities. In El Salvador, human resources on renewable technologies are limited both in lecturers and students.

Table 7.3.8 Current Situation of Universities

No.	University	Number of Students Who Graduated with Degree on Renewable Energies (including Masters Degree)	No. of Lecturers on Renewables		Subjects on Renewable Energies	Studies and Projects in Execution 2011.
			Electrical	Mechanical		
1	Universidad Centro Americana "Josè Simeòn Cañas" (UCA)	20/year	1	2	Renewable Energies	1-Woody biomass as an alternative energy source. 2-Wind monitoring at the campus.
2	Universidad de El Salvador (UES)	3/year	4	-	1-Photovoltaic Systems. 2-Generation Systems. 3-Energy Efficiency.	1-Laboratory of photovoltaic applications. 2-Solar-tracking systems in two axes. 3-Measurement of photovoltaic generation potential of the roofs of the campus. 4-Application to computer centers Island battery inverter and inverter to the grid.
3	Universidad "Don Bosco " (UDB)	11/year	1	1	1-Alternative energy sources. 2-Solar Technologies. 3-Engineering and Environment.	1-Design of an Electronic device for matching and selecting receptor`s surface for solar concentrate collectors. 2-Design and construction of a solar iron mechanism for demo.

(Source: JICA Study Team)

In Universidad de El Salvador, there is a cooperative training program entitled "Masters Degree on Environment and Renewable Energies". The objective of the program is to develop the capacity of lecturers teaching renewable energy in the university. This program is being carried out with the cooperation of "Universidad de Leon Nicaragua" and financed by "Universidad Complutense of Madrid". The program started in April 2011 and continues up to March 2012.

In the program, students are engineers from institutions and companies such as CNE, CEL, LaGeo and

NGOs. Trainers are about 8 teachers with Master from Nicaragua, Spain and the UES. The subjects and schedule of lectures are shown below:

- Subject:

Wind, Solar PV, Solar Thermal, Energy Efficiency, Fuel Cells, Solar Resources, Biomass, Environmental Legislation, Small Hydro, Geothermal, Tidal, Bio-Climatic Architecture, Carbon Credit.

- Schedule:
  Lessons: 5:30 PM to 8:30 PM from Monday to Friday
  Experiments: Saturday, From 8:00 AM to 5:00 PM / Sunday, From 8:00 AM to 2:00PM

Table 7.3.9 shows the current situation of solar PV companies in El Salvador in 2011. The numbers of companies are limited in El Salvador. Moreover, each company has only a few technicians involved in renewable energy technologies.

Table 7.3.9 Current Situation of Private PV Business (November 2011)

No.	Photo Voltaic Company	Established Year	Number of Technicians on Renewables	Installed Capacity Sold (kW)	Represented Manufacturer of PV modules
1	Company A	1992	5	400	KYOCERA, SOLARWORLD, ISOFOTON
2	Company B	1998	6	10,000	KYOCERA, SUNTECH, EVERGREEN, SHARP
3	Company C	1984	5	N/A	KYOCERA, SIEMENS, FOTOWATT, SOLARA, UNISOLAR

(Source: JICA study team)

Capacity building is required as part of technical assistance for both private and public sectors in order to disseminate solar PV system. Any technical support program should attempt at maximizing the involvement of local institutions to foster technology and policy learning. The governments and utilities in El Salvador should be involved to allow them to gain experiences in renewable energy projects and policies.

In addition, structures for local private sectors such as local companies and banks should be established to enable them to gather experience in financing and operation of renewable energy projects.

Technical assistance and capacity building should focus on:

- Development, resource assessment and feasibility studies
- Construction, operation and maintenance
- Grid integration of renewable energy
- Financing and risk mitigation strategies for local financiers
- Policy design for policy makers: e.g. feed−in tariff design

- Price and rate setting
- Policy review and transitional decreasing of financial support over time

Transfer of renewable energy technologies matches the need in El Salvador. In addition, it is required to reduce CO_2 emissions in the country. It is necessary to create sustainable paths for the development of renewable technology. To enable technology transfer on a larger scale, incentives are vital for technology developers to achieve cooperation and share technology.

7.3.4.3 Accumulation of Operative Experiences and Data

For dissemination of solar PV system, it is necessary to accumulate data and experiences on site survey, installation, management, operation and maintenance. Therefore, implementation of pilot project is important. Objectives and expected output from the pilot test are as shown below.

- To accumulate installation experience
- To accumulate O&M experiences
- To demonstrate the benefits of solar PV technology to local people
- To raise awareness on environmental and energy issues

A pilot project related to rooftop solar PV systems with a capacity of 540 kW has been prepared by CEL. That project will be implemented between 2012 and 2016.

7.3.5 Roadmap for Introduction

Current issues and countermeasures on rooftop solar PV can be summarized as shown in below.

- Grid connected solar PV is not disseminated yet although the solar irradiation potential is high in El Salvador. (There are 11 grid connected solar PV system including 2 rooftop system at households)
- Currently, it is difficult to purchase rooftop solar PV for majority in the nation because the initial investment cost of is high.
- In addition, rooftop solar PV will be purchased by individual users, not like other large scale power generation systems. Therefore, if there is no benefit for individual users, it is difficult to disseminate through market driven approach.
- The costs of solar PV have been falling consistently over the last three decades and such trends can be expected to continue. It is estimated the cost becomes lower level as same as current national power tariff by 2020.
- If the cost becomes same level to current power tariff, it is necessary for users to have awareness on environmental and energy issues for the dissemination of solar PV. In addition, economical benefit is necessary for users.

- The issues on grid connect solar PV is solved technically. It does not become the problem if equipped with latest equipments. The problem in the installation varies according to individual cases. It is necessary to have the person who we understand and evaluate the system.

It can be considered preparation stage for the dissemination of rooftop solar PV system in future is by 2020. Therefore, it is necessary to conduct following preparation.

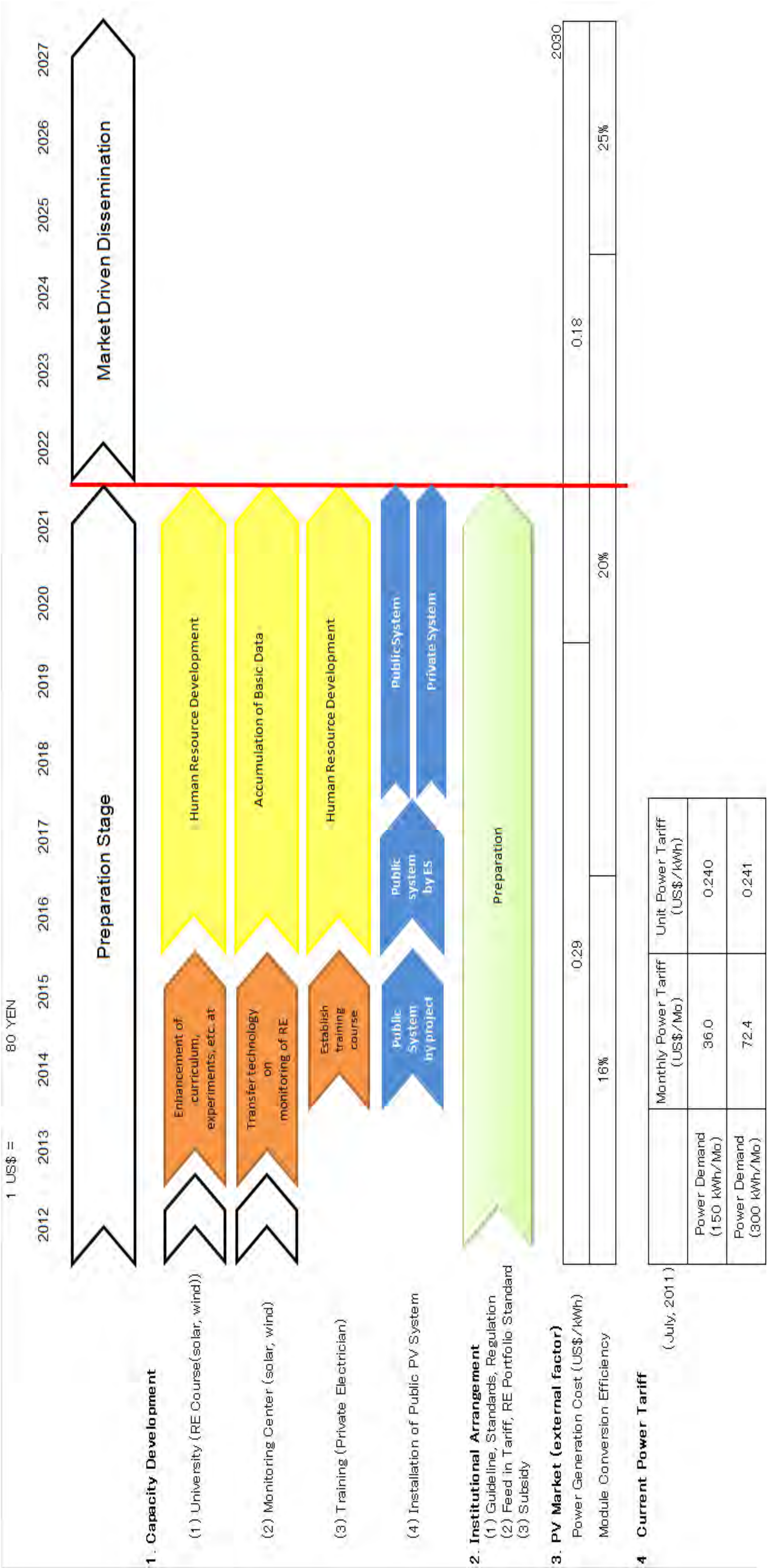
Human resource development

- It is necessary to improve educational opportunities on solar PV engineers in university and so on.
- It is necessary to accumulate solar irradiation data in main cities.
- It is necessary to conduct technical training to empower private sector.
- It is necessary to accumulate experiences and data through implementation of pilot test.

Institutional arrangement

- It is necessary to prepare guideline, standard and regulation for introduction of rooftop solar PV system
- It is necessary to prepare regulation such as FIT and RPS.
- It is necessary to prepare subsidy for introduction of rooftop solar PV.

Figure 7.3.6 shows the road map for introduction of solar PV and other renewable technologies.



(Source: JICA study team)

Figure 7.3.6 Roadmap for Introduction of Solar PV

Chapter 8 Approaches for Examination of the Possibility of Renewable Energy Introduction

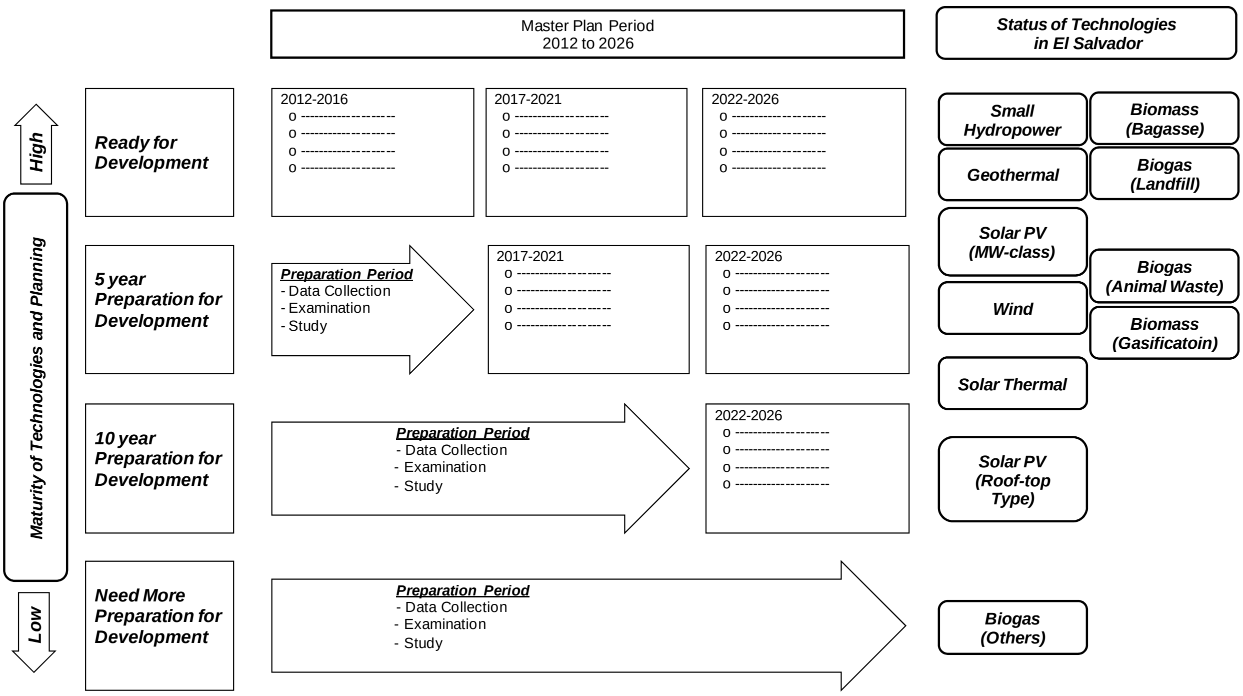
Based on the results of studies and examinations conducted, examinations will be made on the possibility of renewable energy introduction in El Salvador. Such examinations will be made on three aspects namely, “Technical,” “Economic and Financial,” and “Environmental.”

8.1 Technical Aspects

From the result of studies and examination, maturity of technologies and plans for each renewable resource in El Salvador can be categorized as shown in Figure 8.1.1. The figure shows the master plan period of 15 years in the horizontal axis, and the maturity of technologies and planning in the vertical axis. Depending on the maturity of the technologies and planning, four categories were set: (1) ready for development, (2) five-year preparation period required for development, (3) ten-year preparation period required for development, and (4) more preparation period required for development.

Further, based on the review of available information, each technology of renewable energy was positioned in the same chart to show the status of the renewable energy in El Salvador. Small hydropower and geothermal technologies are classified as high maturity while roof-top type solar PV and other biogas are classified as low maturity.

Considering the maturity of technologies as shown in Figure 8.1.1, examinations will be made on the possibilities of introducing renewable energy in El Salvador.



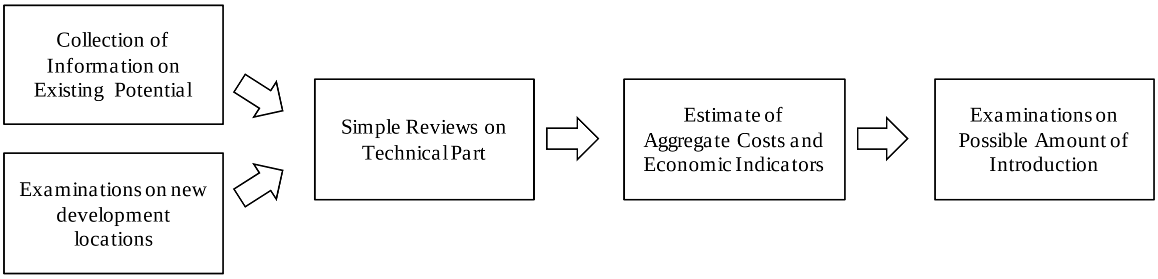
(Source: JICA Study Team)

Figure 8.1.1 Relationships among Maturity on Technologies and Planning, Method of Planning, and Status of Renewable Energy Sources in El Salvador

Methods for examination of each renewable energy source are described hereunder. The results of the examinations are presented in Chapter 10 of this report."

8.1.1 Small Hydropower

There are many studies on small hydropower compared with other energy sources. For small hydropower development, examination on introduced amount will be made after the review of available materials. The steps for the examination on small hydropower development are as illustrated in Figure 8.1.2. Furthermore, aggregate development costs will be developed from the results of review, which will serve as basis for the preparation of schedules for development. The development schedule will be prepared for every five years between 2012 and 2026.



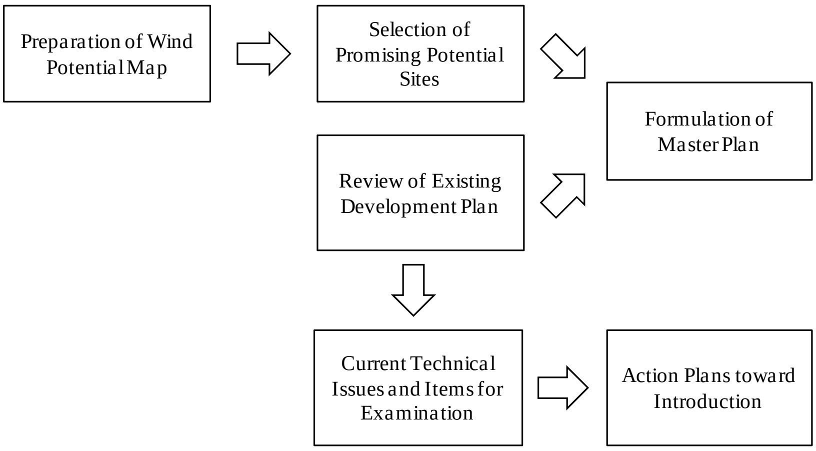
(Source: JICA Study Team)

Figure 8.1.2 Flow of Technical Examination on Small Hydropower Development

8.1.2 Wind Power

High potential areas will be selected using the wind potential maps to be prepared during the course of the study.

In addition, existing plans prepared by power companies will be reviewed to formulate the action plans toward the introduction of wind power. Such action plans and programs include current technical issues and required further studies and examinations. The steps of the technical examination on wind power development are as illustrated in Figure 8.1.3.



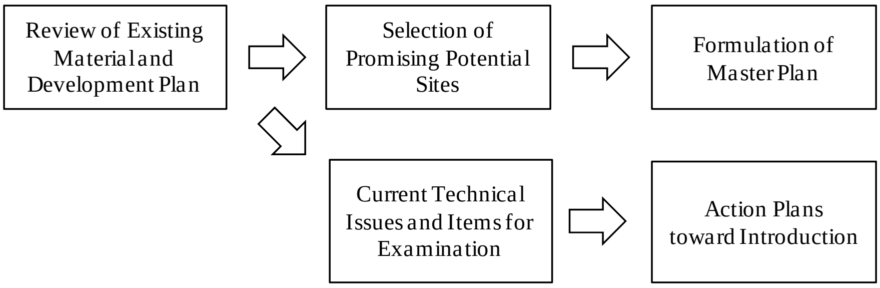
(Source: JICA Study Team)

Figure 8.1.3 Flow of Technical Examination on Wind Power Development

8.1.3 Solar PV

Upon review of available materials and plans prepared by power companies, the most favorable site will be selected.

In addition, action plans will be formulated to describe the current technical issues and the required further studies and examinations, toward the introduction of solar PV, as shown in Figure 8.1.4.

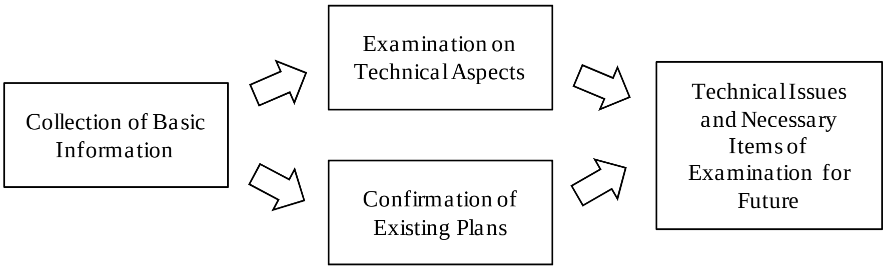


(Source: JICA Study Team)

Figure 8.1.4 Flow of Technical Examination on Solar PV Development

8.1.4 Solar Thermal

Solar thermal still requires high initial investment cost compared with other energy sources and longer preparation period. There is only one plan prepared by a private company related to the development of solar thermal in El Salvador. Examination will be made mainly on the collection of basic information on technical aspects and to acquire the status of the existing plan, as shown in Figure 8.1.5.

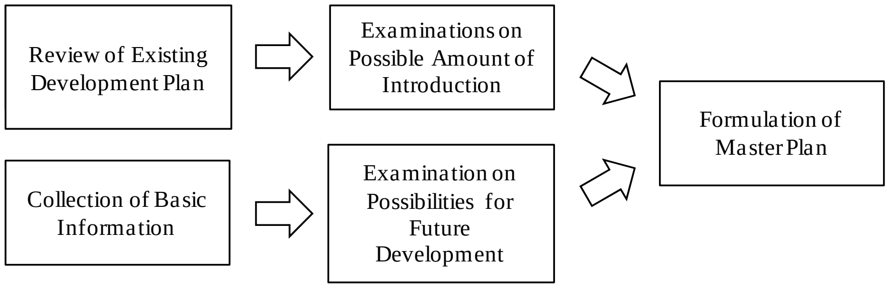


(Source: JICA Study Team)

Figure 8.1.5 Flow of Technical Examination on Solar Thermal Development

8.1.5 Geothermal

Through the review of available materials and interviews with related organizations, a development plan toward 2017 will be formulated. Subsequently, additional studies will be required to identify the introduced potential. Therefore, a plan after 2017 will only indicate the total remaining potential to be developed as guiding figures.



(Source: JICA Study Team)

Figure 8.1.6 Flow of Technical Examination on Geothermal Development

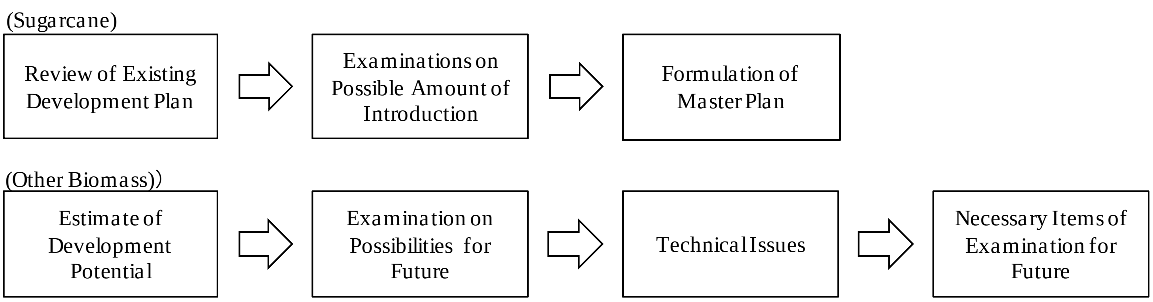
8.1.6 Biomass

Upon review of existing materials, the most favorable biomass resources of bagasse from sugar factories were identified. Coffee and rice husks, which are also possible sources, though not significant, are to be examined for future introduction of biomass.

For power generation using bagasse from sugar factories, examination on introduced amount will be made by reviewing the existing plans.

On the other hand, development potential of coffee and rice husks will be examined by applying the annual production by region using the data from coffee factories and rice mills.

In addition, possibilities of biomass power generation will be examined by indicating the technical issues and required items for further examinations. The steps for this examination are as shown in Figure 8.1.6.

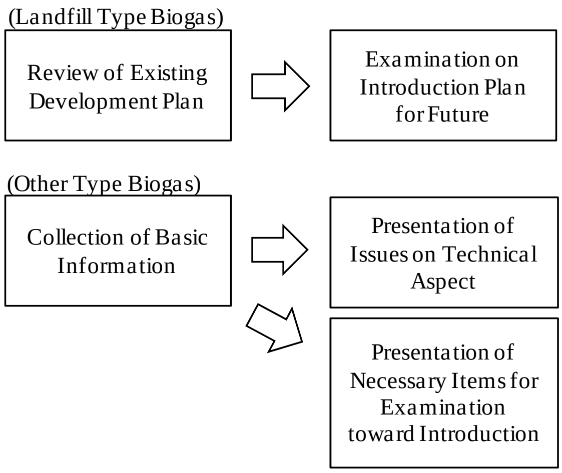


(Source: JICA Study Team)

Figure 8.1.7 Flow of Technical Examination on Biomass Development

8.1.7 Biogas

Upon review of available materials and after conducting site visits to related organizations, it was found that only one location is currently operating biogas power generation through landfill. By reviewing landfill biogas operations, examination will be made on future introduction of biogas. For other biogas options, basic information will be collected as there are no existing power generations using other technologies. In addition, technical issues and further examination required will be arranged toward the introduction of biogas in the future. Actual experiences on introduction in other countries will be indicated, if available.



(Source: JICA Study Team)

Figure 8.1.8 Flow of Technical Examination on Biogas Development

8.2 Economic and Financial Analysis

Economic and financial analysis was proposed in the Inception phase as follows.

- Consideration for factors to increase the cost of the domestic situation in El Salvador,
- Estimate of the introduction cost of renewable energy technologies, and
- Study of optimum energy matrix by using the Economic Model.

JICA Study Team made several discussions with CNE and collected relevant information based on the above considerations. As a result of the consultation with CNE, based on the current and future power supply system of El Salvador, slight modifications of the above scopes were considered and agreed to proceed as follows:

(1) Financial analysis will be made for renewable energy sources which are expected to be introduced, but have fewer examples of introduction. Cash flow analysis for the project will be made for typical development patterns such as type of power source, and development scale;

(2) Based on the analysis, the financial and economic considerations will be clarified for the introduction in their development patterns (policies and institutions) to be required;

(3) In particular, of the target renewable energy sources, three kinds of energy sources, i.e., small hydropower, wind and solar PV will be examined for cash flow analysis with multiple develop patterns;

(4) Other renewable energy sources will not be examined because of the following reasons:

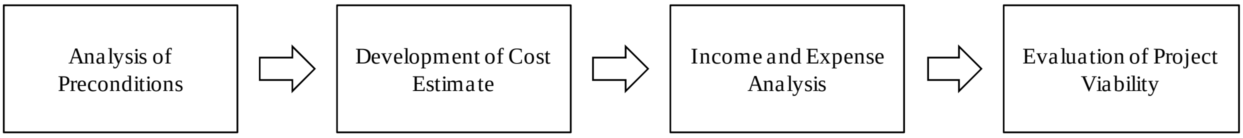
(a) Solar Thermal: It is difficult to introduce Solar Thermal at the moment due to the current technology levels with high initial investment costs. Further reduction of the cost levels are required through innovation.

(b) Geothermal, biomass, biogas: Private companies have their own development and investment plans, and the development sites are limited. Therefore, it seems that the government side does not need to have its own estimate. But it is required to have the information for the elaboration of the indicative plan for Electric Generation Expansion.

The results of the study are described below followed by description of the study flow and conditions for the targets renewable energy sources. Considerations will be made based on the results of the study.

8.2.1 Study Flow

Studies were carried out on three types of energy, i.e., small hydro, wind and solar PV based on the study flow mentioned below.



(Source: JICA Study Team)

Figure 8.2.1 Study Flow of Economic and Financial Analysis

The possibility for the introduction of renewable energy (feasibility) will be examined for each case based on general financial indicators, such as financial internal rate of return (FIRR).

8.2.2 Purpose of Analysis

The plant factors or energy generation efficiencies varies among the different types of renewable energy source. Therefore, examinations will be made for expected typical development patterns (i.e., development scale and plant factor, change of development year in terms of cost reduction by research and development, exclusion of grid connection cost, etc.) to find out the possibility of development of renewable energy sources in the master plan.

8.2.3 Preconditions of Analysis

8.2.3.1 Energy Promotion Policy

For promoting the introduction of renewable energy in Europe and Japan, the introduction policy is in accordance with the RPS, feed-in tariff (FIT), and subsidy provision to developers. However, in El Salvador, renewable energy promotion depends only on the law on tax incentives for electricity generation based on renewable energies that was enacted in December 2007 (Act Order 462). The said law seeks to promote the introduction of renewable energy. The legislation on renewable energy promotion applies an incentive of tax exemption for five to ten years for energy development with capacities of a certain scale (up to 20 MW, refer to 3.4.3 of Chapter 3). Within this legal framework, whether renewable energy is accelerated or not, the commercial viability of the development or commercialization of renewable energy will be identified by analyzing.

8.2.3.2 Preconditions of Analysis

For the examination of wind and solar PV (grid connected), development size is set at 20 MW, the maximum size that can be benefitted from the above mentioned tax incentive. As for small hydropower, in which a few have already been developed, many development potential sites with less than 1MW scale are indicated in Chapter 4. The development potential of small hydropower with capacities from100 kW to 5 MW is to be analyzed for their feasibilities. . There are two electricity markets in El Salvador, namely, wholesale market and retail market. According to the Reglamento de Operacion del Sistema de

Transmision y del Mercad Mayorista Basado en Costos de Production (SIGET, July 2011), generation capacity of more than 5 MW can sell energy to the wholesale market. While, generation capacity of less than 5 MW can sell energy to the retail market. Thus, this analysis is targeted on the retail market in terms of development scale.

Table 8.2.1 Development Scale by Energy

Development Study by Energy	Project Scale
Small hydropower	100 kW – 5 MW
Wind power	20 MW
PV (grid connected)	20 MW

Source: JICA Study Team

8.2.3.3 Profitability Index

Profitability index in development projects is determined by the net present value (NPV), FIRR, and benefit-cost ratio (B/C). The evaluation criteria are mentioned below. These indicators are commonly used in the energy industry and electricity companies in El Salvador.

Table 8.2.2 Profitability Index

Profitability Index	Evaluation Criteria
NPV with 10% discount rate	More than 0
FIRR	More than 12%
B/C	More than 1.5

Source: JICA Study Team

8.2.3.4 Preconditions of Cash Flow for Project Development

Gathering information about conditions in El Salvador and trends in the global development of renewable energy, cash flow for the development project are prepared based on the following preconditions

Table 8.2.3 Precondition for Profitability Estimates

Item	Precondition
1. Construction Period Small Hydropower Wind Energy Solar PV (Grid Connected)	Construction period set up as follows: A small hydropower project takes more than three years, including feasibility study (F/S), etc.. It is assumed that it takes two years for analysis. The IEA report suggested that it takes about two years for a wind energy project. It is expected to take about two years for analysis. The IEA report suggested that it takes one or two years for a solar PV (grid connected) project. It is also expected take about two years for analysis.
2. Loan Conditions (1) Capital Procurement (2) Loan Period (3) Interest Rate	Loan conditions for project development are applied according to the terms of the country. Borrow 70% of the capital cost from the bank. Equal repayment of loan amount within ten years 8% annually
3. Project Evaluation Period and Depreciation	20 years. The evaluation period may be set from 30 to 50 years for small hydropower projects, and up to 20 years for wind and solar energy projects. Depreciation period is 20 years for small hydropower and 15 years for wind and solar PV. Straight line method is adopted respectively
4. Corporate Tax	25% of the annual income before tax deduction
5. Tax Exemption	-Ten years tax exemption for capacity of less than 10 MW -Five years tax exemption for capacity of 10-20 MW.
6. Annual Inflation	It is recognized that electricity prices are expected to rise with the inflation rate due to bidding conditions. Referring to the rate predicted by the IMF and other international organizations, a 4% per annum is applied in this analysis.

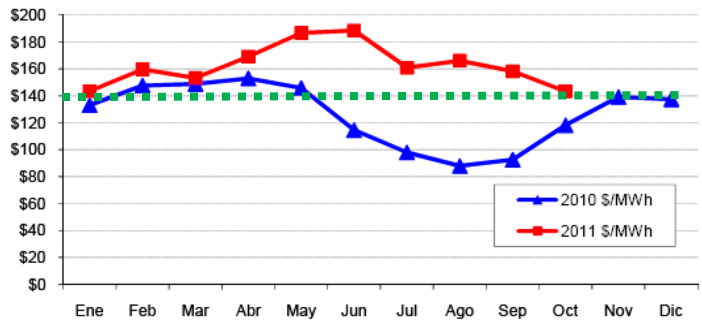
(Source: JICA Study Team)

8.2.3.5 Assumption of the Project Income

The annual project income is to be calculated using the electricity sale unit price (US$/MWh) and the annual energy production revenue.

(1)Unit Price

The electricity sale price was set to US$140/MWh in the first year with reference to current pricing, and the transaction price has been announced by SIGET. It was considered that the sale price has changed significantly from US$87.91/MWh to US$162.90/MWh in 2010, and from US$143.53/MWh to US$186.68/MWh in 2011 (refer to Figure 8.2.2). Therefore, mean value of US$140/MWh is applied.



(Source: September 2011 UT Variation Diagram)

Figure 8.2.2 Price Changes in 2010 and 2011

(2)Annual Energy Generation and Electricity Sales

The annual energy generation is verified depending on the plant factor and energy generation efficiency. Since the annual energy production largely affects the operational income, such can be set based on the plant factor (Base Case), which is set as shown below. Also, several development scenarios in the case study sets the plant factor based on the results of the Base Case, which considers the impact on project profitability.

Table 8.2.4 Plant Factor by Energy

Type of Energy	Operation Factor (Energy Generation Efficiency)
Small Hydro	Plant factor is estimated at about 50% according to the plant factor of a small hydropower project with energy of less than 20 MW, hydroelectric energy generation of 675 GWh and capacity of 158 MW in Chapter 4. On the other hand, some projects have been at about 60% in energy generation according to statistics of SIGET. In the Base Case for this analysis, 50% is applied, while 40% and 60% are applied for other case studies depending on the conditions.
Wind Energy	Plant factor of wind power is basically dependent on wind speed indicators. Therefore economic viability of the project differs largely by the wind speed. The plant factor of the Metapan Project (42 MW) is currently estimated at 34.4%. The plant factor for the Base Case analysis is assumed at 25% by referring to material provided by NEDO.
Solar PV (Grid Connection)	Solar energy generation efficiency is largely affected by photovoltaic systems (grid connected) and natural conditions at the development sites (particularly solar radiation). The average energy generation efficiency is estimated at 12% in Japan. Solar radiation in El Salvador is high at 1.5 to 1.6 times of the average in Tokyo. The energy generation efficiency of 18% is applied for the Base Case.

(Source: JICA Study Team)

8.2.3.6 Development Cost Estimate

(1)Development Costs

The development costs of small hydropower projects consist of the grid transmission and distribution costs in addition to the generation project cost since grid connection costs shall be borne by the generator or developer according to current regulations. Grid connection costs for renewable energy (wind power and grid-connected solar PV) are already included in the development cost. The development costs by type of energy were set, as shown below.

Table 8.2.5 Development Costs by Type of Energy

<table>
<tr><td>Type of Energy</td><td>Development Cost</td></tr>
<tr><td>Small Hydropower</td><td>Although small hydropower potential projects less than 20 MW are listed in Chapter 4, the analysis for small hydropower projects will be made for 5 MW to 100 kW as case study. Development costs including construction costs were set as follows, referring to the development costs estimated in F/S reports on small hydropower projects by CECSA and other companies.
For projects that cannot identify the development site, a small hydropower project cost was considered for the grid connection cost at a distance of about 3 km from the site.
<table>
<tr><td>Installed Capacity</td><td>5 MW ~ 1.0 MW</td><td>1.0 MW ~ 100 kW</td></tr>
<tr><td>Capital Cost (US$000/MW)</td><td>2,500</td><td>3,000</td></tr>
<tr><td>Interconnection Cost (US$000/km)</td><td colspan="2">50</td></tr>
</table></td></tr>
<tr><td>Wind Power</td><td>Referring to the IEA and GWEC reports, the wind power development costs per kW are as shown in the following table. In case there are several different estimates by development scenario in these reports, the mean values (costs) are adopted. Development costs in 2030 are expected to be reduced by approximately 20% or more of the development costs in 2010.
<table>
<tr><td>Year</td><td>2010</td><td>2015</td><td>2020</td><td>2025</td><td>2030</td></tr>
<tr><td>IEA (US$/kW)</td><td>1,725</td><td></td><td>-</td><td></td><td>1,420</td></tr>
<tr><td>GWEC (US$/kW)</td><td>1,890</td><td></td><td>1,730</td><td></td><td>1,590</td></tr>
<tr><td>JICA Study Team (US$/kW)</td><td>1,800</td><td>1,700</td><td>1,600</td><td>1,600</td><td>1,500</td></tr>
</table>
Notes: 1) IEA price at 2008 was applied for 2010
2) IEA: International Energy Agency
3) GWEC: Global Wind Energy Council</td></tr>
<tr><td>Solar PV (Grid Connected)</td><td>Referring to the reports of EPIA and IEA, the cost per kW of PV (grid connected) projects are as shown in the following table. In case there are several different estimates by development scenario in these reports, the mean values (costs) are adopted. Development costs in 2030 are expected to be reduced by approximately one-third of development costs in 2010. Development costs in 2020 are expected to be about less than half of the costs in 2010.
<table>
<tr><td>Year</td><td>2010</td><td>2015</td><td>2020</td><td>2025</td><td>2030</td></tr>
<tr><td>IEA (US$/kW)</td><td>4,060</td><td></td><td>1,830</td><td></td><td>1,220</td></tr>
<tr><td>EPIA (US$/kW)</td><td>3,600</td><td></td><td>1,380</td><td></td><td>1,060</td></tr>
<tr><td>JICA Study Team (US$/kW)</td><td>3,800</td><td>2,700</td><td>1,600</td><td>1,300</td><td>1,100</td></tr>
</table>
Notes: 1) IEA price at 2008 was applied for 2010
2) IEA: International Energy Agency
3) EPIA: European Photovoltaic Industry Association</td></tr>
</table>

(Source: JICA Study Team)

(2)O&M Costs

O&M costs for small hydropower, wind power and solar PV power are shown as follows. The O&M costs will reflect the annual inflation.

Table 8.2.6 O&M Costs

Type of Energy	O&M Costs
Small Hydropower	Annual O&M costs consist of routine cost and special cost for urgent repair. Routine cost is assumed at 5% of the annual energy sales and special cost is assumed at US$0.35/MWh for a small hydropower project. These costs include direct costs such as personnel costs and other expenses related to repair and maintenance of the plants, and indirect costs such as local taxes imposed by the department at the power plant site and surcharges of SIGET, etc.
Wind Power	As shown in the IEA report (IEA Annual Report 2010), the O&M costs of wind power on land are US$12~32/MWh. Mean value of US$22/MWh is adopted in this analysis.
Solar PV (Grid Connected)	As shown in the IEA report (IEA Annual Report 2010), O&M costs of solar PV (grid connected) are US$4/MWh. US$4/MWh is adopted in this analysis.

(Source: JICA Study Team)

8.2.3.7 Preconditions for Typical Development Case

Income and expenditure simulation will be conducted considering the following factors that affect the profitability of the project:

- Project Scale: Project profitability is greatly affected by the scale of the development costs and O&M costs.
- Capacity Factor: Project income will be increased/reduced by operation factor which would be increased/reduced by the ratio set up in the base case.
- Development Year: The development year is to be postponed because development costs will reduce the current cost through research and development, especially in case of wind power and solar PV.
- Site Development Conditions: For the cost of small hydropower development, the development project costs are significantly affected by the access condition to the site and the distance from the potential site to the grid connection point. The cost of grid connection accounts for a large portion of development cost.

Income and expenditure simulation for energy project is conducted based on the conditions shown as follows.

Table 8.2.7 Preconditions for Income and Expenditure Simulation

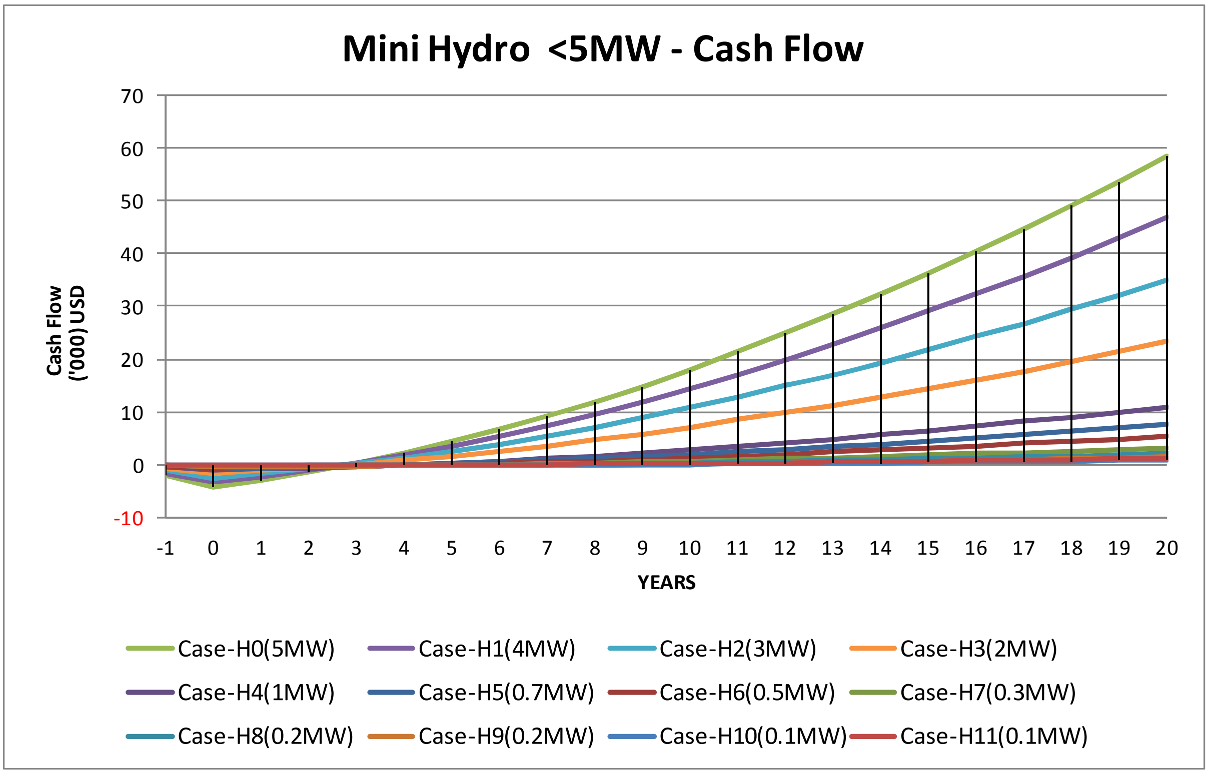
Case Study by Type of Energy	Project Scale	Preconditions for Simulation
Small Hydropower		
Case H0	5 MW	Created a cash flow based on the preconditions mentioned above under the Base Case (H0) simulation.
Case H1	4 MW	Changed development cost due to change of the development scale from Case H0 above.
Case H2	3 MW	Changed development cost due to change of the development scale from Case H0 above.
Case H3	2 MW	Changed development cost due to change of the development scale from Case H0 above.
Case H4	1 MW	Changed development cost due to change of the development scale from Case H0 above.
Case H5	0.7MW	Changed development unit cost due to change of the development scale from the cost of Base Case above.
Case H6	0.5MW	Changed development cost due to change of the development scale from Case H5 above.
Case H7	0.3 MW	Changed development cost due to change of the development scale from Case H5 above.
Case H8	0.2 MW	Changed development cost due to change of the development scale from Case H5 above..
Case H9	0.2 MW	Changed capacity factor with 40% from Case H8 above.
Case H10	0.1 MW	Changed development cost due to change of the development scale from Case H5 above.
Case H11	0.1 MW	Changed capacity factor with 60% from Case H10 above.
Wind Power		
Case W0	20 MW	Created a cash flow based on the preconditions mentioned above under the Base Case (W0) simulation.
Case W1	20 MW	Changed development costs in 2015 prices and the operation factor is 25%.
Case W2	20 MW	Changed the operation factor to 34% similar to the Metapan Project.
Case W3	20 MW	Changed development costs in 2020 prices and the operation factor is 34%.
Solar PV		
Case S0	20 MW	Created a cash flow based on the preconditions mentioned above under the Base Case (S0) simulation.
Case S1	20 MW	Changed development costs in 2015 prices from Base Case above.
Case S2	20 MW	Development costs same as Case S1 in 2015 prices and changed energy generation efficiency (25%) from Base above.
Case S3	20 MW	Changed development cost in 2020 prices and generation efficiency (25%) from Base Case above.

(Source: JICA Study Team)

8.2.4 Evaluation of Project Profitability

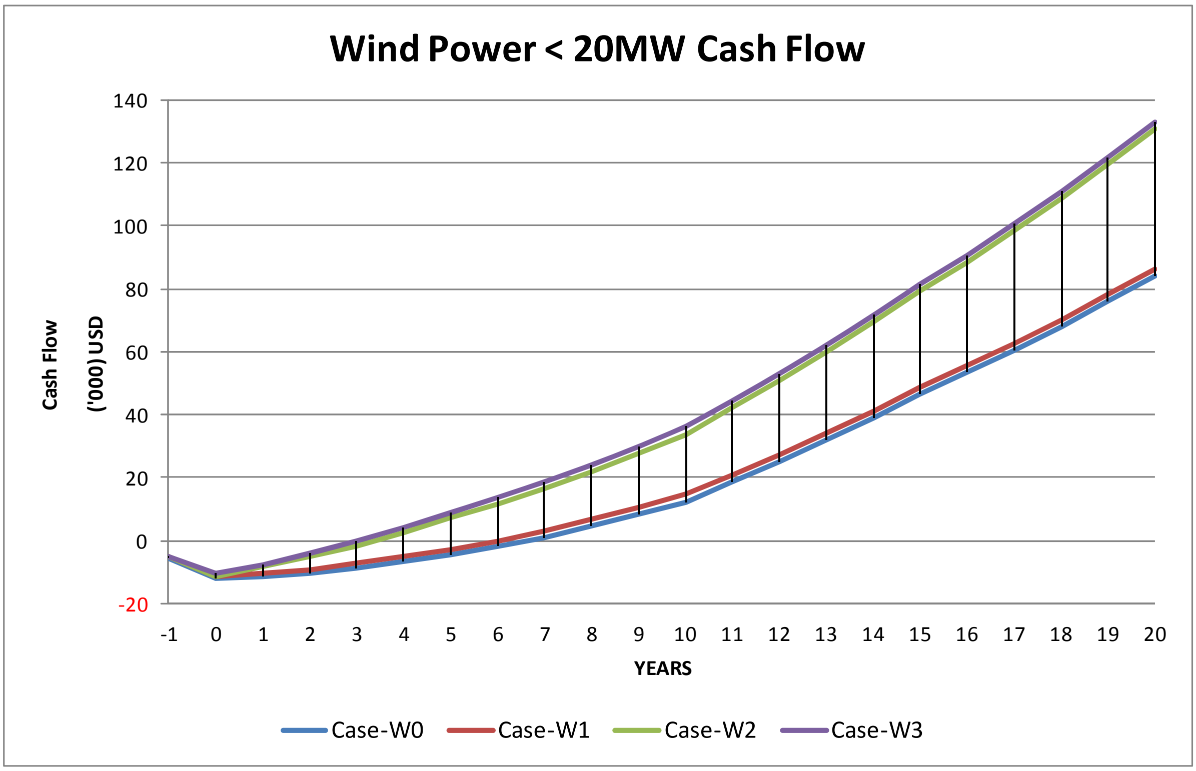
8.2.4.1 Cash Flow by Case

The following Figures show the results of cash flows prepared in accordance with the preconditions shown above. In addition, these cash flow statements are shown in Appendix -E.



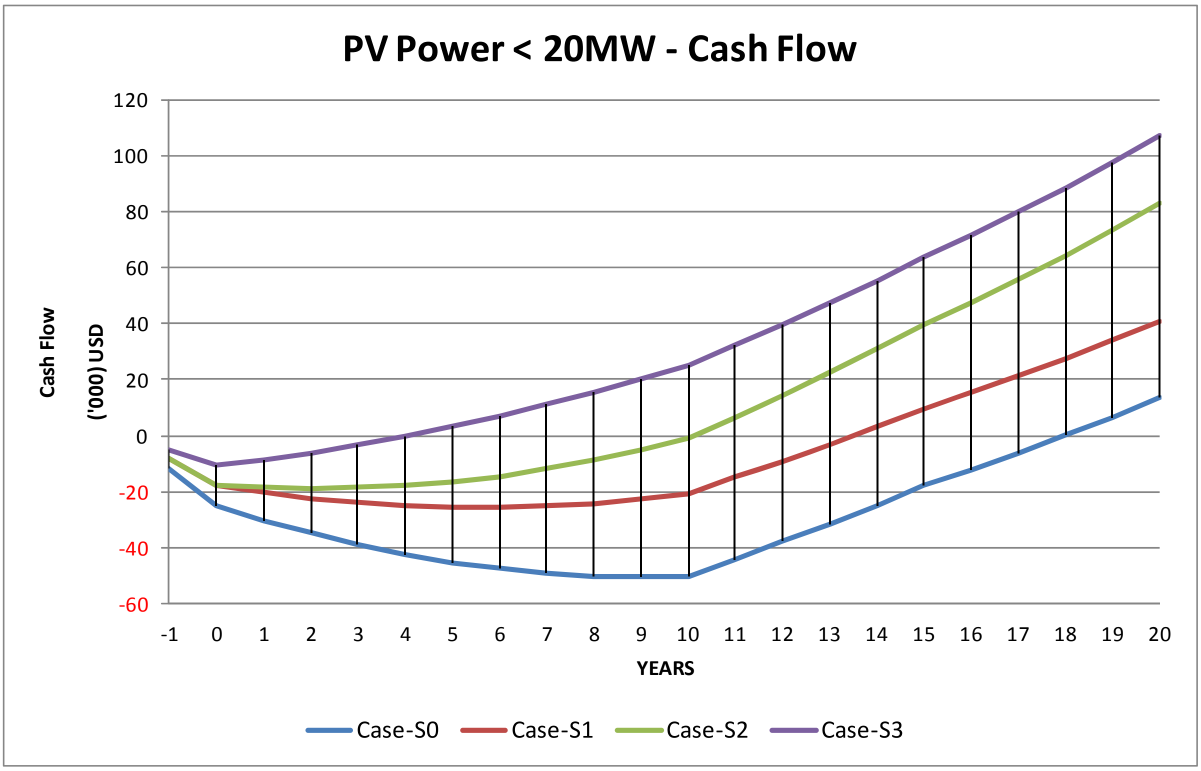
Source: JICA Study Team

Figure 8.2.3 Simulation Results for Small Hydropower



Source: JICA Study Team

Figure 8.2.4 Simulation Results for Wind Power



Source: JICA Study Team

Figure 8.2.5 Simulation Results for Solar PV (Grid Connected)

The above typical analysis is carried out by the assumption of electricity sales price at the $ 140/MWh. In El Salvador, sales price is determined by competitive bidding. Therefore unit price of $ 100/MWh in the option case is also carried out by sensitivity analysis in terms of price competitiveness.

All calculated outputs and evaluation results by cash flow are shown as follows. In addition, the evaluation was made using the following three categories based on the (B/C) of the financial indicator in the typical development pattern (electricity sales price $ 140/MWh):

- "A" means viable project, no need for special incentives. (B/C>1.5)
- "B" means viable project subject to site development conditions, high capacity factor to be installed at potential site or grid connection cost will be borne by third party. (B/C 1.0~1.5)
- "C" means difficult to develop the project without financial support or subsidy. (B/C<1.0)

An analysis was done taking as reference the energy sales price at $140 per MWh, however, an analysis was done taking as reference the energy sales price at $100 per MWh to obtain a price sensitization analysis and to achieve this way a better picture of their behavior.

Table 8.2.8 Evaluation Results by Case Study

Type of Energy	Case Study	Pre-conditions							Calculation Result						Overall Evaluation
		Plant Capacity (MW)	Capacity Factor (%)	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost		Tax Exemption (year)	A.Unit Price ($140/MWh)			B.Unit Price ($100/MWh)			
									NPV ($000)	FIRR (%)	B/C	NPV ($000)	FIRR (%)	B/C	
Small Hydro	Case-H0	5	50%	12,500	150	5	%	10	16,024	37.7%	2.05	8,294	24.2%	1.59	A
	Case-H1	4	50%	10,000	150	5	%	10	12,793	37.5%	2.04	6,609	24.1%	1.59	A
	Case-H2	3	50%	7,500	150	5	%	10	9,563	37.3%	2.04	4,925	24.0%	1.58	A
	Case-H3	2	50%	5,000	150	5	%	10	6,332	36.9%	2.02	3,240	23.7%	1.57	A
	Case-H4	1	50%	3,000	150	5	%	10	2,666	28.5%	1.74	1,120	17.7%	1.33	A
	Case-H5	0.7	50%	2,100	150	5	%	10	1,827	27.8%	1.71	745	17.2%	1.31	A
	Case-H6	0.5	50%	1,500	150	5	%	10	1,268	26.8%	1.68	495	16.5%	1.28	A
	Case-H7	0.3	50%	900	150	5	%	10	710	24.9%	1.61	246	15.1%	1.22	A
	Case-H8	0.2	50%	600	150	5	%	10	430	22.6%	1.52	121	13.5%	1.16	A
	Case-H9	0.2	40%	600	150	5	%	10	214	16.3%	1.27	-34	9.0%	0.96	B
	Case-H10	0.1	50%	300	150	5	%	10	151	17.4%	1.32	-4	9.8%	0.99	B
	Case-H11	0.1	60%	300	150	5	%	10	259	22.8%	1.53	73	13.6%	1.16	A
Wind	Case-W0	20	25%	36,000	-	22	$/MWh	5	15,796	19.6%	1.34	163	10.1%	1.00	B
	Case-W1	20	25%	34,000	-	22	$/MWh	5	17,384	21.2%	1.38	1,915	11.2%	1.04	B
	Case-W2	20	34%	34,000	-	22	$/MWh	5	33,365	31.9%	1.64	12,900	18.3%	1.27	A
	Case-W3	20	34%	32,000	-	22	$/MWh	5	34,954	34.5%	1.70	14,489	19.9%	1.31	A
Solar PV	Case-S0	20	18%	76,000	-	4	$/MWh	5	-26,811	1.7%	0.63	-38,621	#NUM!	0.45	C
	Case-S1	20	18%	54,000	-	4	$/MWh	5	-7,518	6.9%	0.86	-19,235	1.6%	0.63	C
	Case-S2	20	25%	54,000	-	4	$/MWh	5	7,889	13.2%	1.14	-8,299	6.5%	0.84	B
	Case-S3	20	25%	32,000	-	4	$/MWh	5	25,745	27.8%	1.70	10,677	17.3%	1.31	A

Source: JICA Study Team

8.2.4.2 Evaluation of Commercialization

The comments on financial viability for the development of renewable energy projects by case based on the simulation results are as follows:

1) Small Hydropower

Any case of SHPs with power between (0.3~5MW) may be developed with the above conditions. In other words, incentives and other subsidies are not necessary for the development of such projects. However, in some cases with powers between (0.1~0.2 MW), which is known as micro-hydro are more difficult to develop and are not very feasible for commercialization due to the magnitude of the costs of development. The development project of this scale requires a very big subsidy or exemption from costs for connecting to the network, and that are subject to the conditions of site development.

2) Wind Power

Commercialization is possible for all cases. This type of energy is not expected to reduce development costs such as for solar PV in future. However, development site conditions are greatly affected by the development of energy. Therefore site conditions are similar to the Metapan Project being planned in North-Western part of the country, this is because this type of energy would be developed by commercial sector.

3) Solar PV (Grid Connected) Power

Among the four cases, commercialization is possible only for Case “S2” and “S3”. Case “S3” is expected to have reduced development cost in 2020 prices and improved energy generation efficiency of the system by 25%. Therefore, the Solar PV power generation is difficult to develop by the private sector initiative at the present.

8.2.5 Factors for Increasing the Cost

In developing the above energy sources, it is necessary to consider the following factors that increase the cost in El Salvador:

1) Natural Disaster Prevention

Large-scale natural disasters such as hurricanes, earthquakes and volcanic eruptions have occasionally happened in El Salvador. Site selection for renewable energy development should need to consider such factors. In some cases, it is assumed that the costs for development become higher because of the need to install countermeasures against natural disasters.

2) Fostering of Maintenance Technology for New Power Systems

Small hydropower projects have been developed in El Salvador before; however, wind power and solar power systems will be newly introduced as power generation systems. The procurement for these new generation systems will be from abroad and performed while receiving technical assistance from suppliers such as installation works. It is necessary to train personnel on construction technology and proper maintenance for the new systems. These factors are expected to affect the development costs and maintenance costs for fostering technicians while obtaining technical guidance from a foreign manufacturer.

3) Spare parts procurement system

It is necessary to implement periodical inspection and replace consumables and parts according to the plans of routine inspection to avoid disrupt the operation failed due to power systems. To achieve this condition, it is necessary to develop the necessary parts procurement to be quickly and regularly procured for maintenance of power system through the local agencies in the country. This system could increase maintenance costs, but the constant operation of the power generation system is required for introduction of this procurement system.

4) The funding conditions

The power sector development in El Salvador has been led by the private sector. Private company can be procured necessary funding to develop a new project from public financial institutions including BCIE (Banco Centroamericano de Intecración Económica) in addition to the commercial banks. However, the annual interest rate is not less than 8%, which is considerably more expensive when compared to interest rates from foreign soft loans. This interest rate is one of the factors increasing cost burden. Need to consider creating a mechanism to procure soft loans from abroad.

8.3 Environmental Aspects

During the planning or design of a project, it is very important to take into account the various environmental and social factors, which are vital for the project's sustainability and viability. This chapter focuses on the environmental aspects such as protected areas, obstacles, and unforeseen impacts, as well as those subjects considered as priorities, which should be taken into account while implementing renewable energies. The final objective is to include all socio-environmental considerations while executing the projects.

8.3.1 Identifying barriers for the promotion of Renewable Energies

The Study Team has conducted various research and interviews with different agencies regarding renewable energy, taking into consideration the environmental and social aspects, as well as the current experiences and conditions of the projects existing in El Salvador. Based on this, the Study Team has identified the following obstacles which must be breached in order to promote the mentioned projects:

(1) Political Barriers

- Lack of a basic framework and a master plan for the development of renewable energy.
- Lack of incentive laws, which would promote renewable energies in relation to national socio-environmental measures.
- Lack of an environmental permit from the Ministry of the Environment and Natural Resources (MARN), for each renewable energy.

As a direct result of these obstacles, it is very difficult for any related institutions and even private sectors, to have the tools defined in order to implement power generation projects using renewable energy sources.

(2) Institutional Barriers

- Lack of MARN experts on renewable energy.
- Lack of a shared information system between the institutions involved with the environment, particularly regarding the environmental impacts and damages caused by renewable energy projects, as well as the progress made during the implementation of said assignment.

(3) Barriers to Project Implementation

- Expensive environmental studies, particularly of the environmental impact assessment (EIA), which prevent companies from risking their investments in this type of research.
- Poor distribution of land possession, mainly due to inadequate land planning and zoning, and lack of a socio-environmental perspective.
- Complex procedures (or red tape) in acquiring environmental and social permits. In many cases, the projects destined for rural areas do not proceed due to these processes.
- Lack of human resources specifically trained for environmental and social permits approval, particularly smaller companies and non-profit organizations.

As a result of these obstacles, it is increasingly difficult for the private sector involved with renewable energy to smoothly execute related projects while taking into consideration the various socio-environmental aspects.

8.3.2 Expected Impacts on the Socio-Environment due to the Implementation of Renewable Energies (Scoping)

Based on the strategic analysis conducted in this Study, the following tables 8.3.1 to 8.3.6 show scoping and impacts that are expected to affect the socio-environment as a result of the development of renewable energy in El Salvador:

Table 8.3.1 Scoping for Renewable Energy Projects <Small Hydropower (SHP)>

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
1	Population Resettlement	B-	C	[Construction Stage] - Possible resettlement of some families residing in the immediate vicinity of the project [Operation Stage] - A follow-up plan must be implemented.
2	Local Economy and Livelihoods	B+	B+	[Construction Stage] - Possibility of generating direct (construction labor) and indirect employment (sellers, restaurants, etc. within the vicinity of the construction site). [Operation Stage] - Reactivation of the industrial sector is expected as a result of energy cost reduction.
3	Land Use and Use of Local Resources	D	D	- Non-significant negative impacts are foreseen.
4	Social Capital and Local Organizations	D	D	- No significant negative impacts are foreseen, rather, possible benefits are expected for local residents.
5	Existing Infrastructure and Public Services	D	B+	[Operation Stage] - It is expected that electricity services in the neighboring areas of the project will be stabilized.
6	Ethnic Minorities and Indigenous Population	D	D	- No significant negative impact is foreseen
7	Unbalanced Distribution of Benefits and Damages by the Project	D	D	- No significant impact is foreseen. Possible benefits to local residents.
8	Local Conflict caused by Common Interests	C	C	- No local conflict is expected; however, a public poll will be conducted to become aware of the opinion of the people.
9	Cultural Heritage	C	D	[Construction Stage] - An inspection of the project site will be conducted by the Culture Secretariat
10	Right of Water Use	B-	B-	- Right of water use permits will be requested.
11	Infectious Diseases like HIV/AIDS	D	D	- Small or no impact at all is expected.
12	Working Conditions	D	D	- Small or no impact at all is expected.
13	Topography and Geography	B-	D	[Construction Stage] - Generation of negative impact to the topography and geography of the site is expected from engineering works.
14	Underground Water	D	D	- No negative impacts are expected to affect the groundwater
15	Soil Erosion	B-	D	[Construction Stage] - Possible effects on the soil because of erosion originating from earthworks through stripping.
16	Hydrology	C	C	- Negative impacts to the water resources are expected.
17	Flora and Fauna / Biodiversity	B-	B-	[Construction Stage and Operation Stage] - It is possible to affect the area´s flora, fauna and biodiversity.
18	Climate	D	D	- Non-significant negative impact is expected.

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
19	Landscape	B-	B-	[Construction Stage] - There is a possibility of affecting the landscape of the area due to earthworks, road works, etc. [Operation Stage] - There is a possibility of affecting the landscape of the area due to the height of the wind towers.
20	Protected Natural Areas	C	C	- Protected natural areas must be identified.
21	Control of Waste Disposal Sites	D	D	- Very little negative impact is expected since the planned waste disposal site will be the one expressly authorized by the corresponding agency.
22	Global Warming	D	D	- Little or none expected impact
23	Air Pollution	D	D	- No significant chemical gases are expected to pollute the air.
24	Water Pollution	D	D	- No significant chemical liquids are expected to pollute the water.
25	Soil Pollution	D	D	- No significant chemical liquids are expected to pollute the soil.
26	Solid Waste	D	D	- No significant amounts of solid waste.
27	Noise and Vibrations	B-	B-	[Construction Stage] - Noise and vibrations will be generated due to the operation of heavy machinery and different construction activities. [Operation Stage] - Noise generated from small activities.
28	Land Subsidence	D	D	- No impact is expected
29	Offensive Odors	D	D	- No impact is expected
30	Traffic Accidents	B-	D	[Construction Stage] Accidents are expected to some degree from ongoing and incoming vehicular traffic caused by the project and neighboring residents.

A: Significant impact expected
B: Moderate impact expected
C: There is no information, more research required
D: None or little impact expected
+: Positive
-: Negative
(Source: JICA Study Team)

Table 8.3.2 Scoping for Renewable Energy Projects <WIND>

	Components	Evaluation		Expected Impact
		Construction Stage	Operation Stage	
1	Population Resettlement	B-	C	[Construction Stage] - Possible resettlement of a few families which reside in the immediate vicinity of the site. [Operation Stage] - Follow-up plan must be implemented.
2	Local Economy and Livelihood	B+	B+	[Construction Stage] - Possible generation of direct (construction labor) and indirect employment (sellers, restaurants, etc. from the neighboring vicinities). [Operation Stage] - Reactivation of the industrial sector is expected as a result of energy cost reduction.
3	Land Use and Use of Local Resources	B-	D	[Construction Stage] - Agricultural and livestock areas will be affected. Part of the vegetation will be cut (mainly bushes).
4	Social Capital and Local Organizations	D	D	- No significant negative impacts are expected; furthermore, there may be some positive benefits to the local residents.
5	Existing Infrastructure and Public Services	D	B+	[Operation Stage] - It is expected that electricity services in the neighboring areas of the project will be stabilized.
6	Ethnic Minorities and Indigenous Communities	C	C	- Existing indigenous communities must be identified within the facility.
7	Unbalanced Distribution of Benefits and Damages by the Project	D	D	- No significant damages are expected. Possible benefits to local residents .
8	Local Conflict caused by Common Interests	C	C	- No local conflicts are expected; however, a public poll will be conducted to know the opinion of the community.
9	Cultural Heritage	C	D	[Construction Stage] - Project´s inspection will be conducted by the Culture Secretariat.
10	Right of Water Use	D	D	- No expected impact to water sources.
11	Infectious Diseases like HIV/AIDS	D	D	- No expected impact.
12	Working Conditions	D	D	- No expected impact.
13	Topography and Geography	B-	D	[Construction Stage] - Negative impacts to the topography and geography of the site (cut and fill works) are to be expected.
14	Groundwater	D	D	- No negative impacts to groundwater are expected.
15	Soil Erosion	B-	D	[Construction Stage] - Possible effects on the soil because of erosion originating from earthworks through stripping.
16	Hydrology	D	D	- No negative impacts are expected on the local hydrology.
17	Flora and Fauna / Biodiversity	B-	B-	[Construction Stage y Operation Stage] - It is possible that fauna and biodiversity will be affected, specifically the bird species.
18	Climate	D	D	- No negative impacts on the climate are expected.

	Components	Evaluation		Expected Impact
		Construction Stage	Operation Stage	
19	Landscape	B-	B-	[Construction Stage] - There is a possibility of negatively affecting the landscape of the area due to earthworks, road works, etc. [Operation Stage] - There is a possibility of negatively affecting the landscape of the area due to the height of the wind towers.
20	Protected Natural Areas	C	C	- Protected natural areas must be identified.
21	Control of Waste disposal Sites	D	D	- No impact is expected due to solid waste.
22	Global Warming	D	D	- No impact to the atmosphere is expected.
23	Air Pollution	D	D	- No negative impact on air quality is expected.
24	Water Pollution	D	D	- No negative impact on water quality is expected.
25	Soil Pollution	D	D	- No negative impact on soil is expected.
26	Solid Waste	D	D	- No negative impact due to solid waste generation is expected.
27	Noise and Vibrations	B-	B-	[Construction Stage] - Noise and vibrations are generated due to the operation of heavy machinery and construction works. [Operation Stage] - Noise generated due to tower operation. - Microwaves emission due to tower operation.
28	Land Subsidence	D	D	- No impact is expected
29	Offensive Odors	D	D	- No impact is expected
30	Traffic Accidents	B-	D	[Construction Stage] Accidents are expected to some degree from ongoing and incoming vehicular traffic caused by the project and neighboring residents.

A: Significant impact expected
B: Moderate impact expected
C: There is no information, more research required
D: None or little impact expected
+: Positive
-: Negative
(Source: JICA Study Team)

Table 8.3.3 Scoping for Renewable Energy Projects <SOLAR PV POWER>

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
1	Population Resettlement	D	D	- No negative impact is expected.
2	Local Economy and Livelihood	B+	B+	[Construction Stage] - Possible generation of direct (construction labor) and indirect employment (sellers, restaurants, etc. from the neighboring vicinities). [Operation Stage] - Reactivation of the industrial sector is expected as a result of energy cost reduction.
3	Land Use and Use of Local Resources	D	D	- No negative impact is expected
4	Social Capital and Local Organizations	D	D	- No negative impact is expected.
5	Existing Infrastructure and Public Services	D	B+	[Operation Stage] - It is expected that electricity services in the neighboring areas of the project will be stabilized specially those for public facilities such as schools and medical clinics.
6	Ethnic Minorities and Indigenous Communities	D	D	- No negative impact is expected.
7	Unbalanced Distribution of Benefits and Damages by the Project	D	D	- No negative impact is expected.
8	Local Conflict caused by Common Interests	C	C	- No local conflict is expected; however, a public poll will be conducted to determine the opinion of the community.
9	Cultural Heritage	C	D	[Construction Stage] - Project site inspection will be conducted by the Culture Secretariat.
10	Right of Water Use	D	D	- No negative impact is expected.
11	Infectious Diseases like HIV/AIDS	D	D	- No negative impact is expected.
12	Working Conditions	D	D	- No negative impact is expected.
13	Topography and Geography	D	D	- No negative impact is expected.
14	Groundwater	D	D	- No negative impact to underground water is expected.
15	Soil Erosion	D	D	- No negative impact is expected.
16	Hydrology	D	D	- No negative impact is expected.
17	Flora and Fauna / Biodiversity	D	D	- No negative impact is expected.
18	Climate	D	D	- No negative impact is expected.
19	Landscape	C	C	[Construction Stage and Operation] - Possible negative impact on the landscape due to the size of the solar panels.
20	Protected Natural Areas	D	D	- No negative impact is expected.
21	Control of Waste Disposal Sites	D	D	- No negative impact is expected.
22	Global Warming	D	D	- No negative impact is expected.
23	Air Pollution	D	D	- No negative impact to the atmosphere is expected.
24	Water Pollution	D	D	- No negative impact to water is expected.
25	Soil Pollution	D	D	- No negative impact to soil is expected.
26	Solid Waste	D	D	- No negative impact due to solid waste is expected.
27	Noise and Vibrations	D	D	- No negative impact is expected.

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
28	Land Subsidence	D	D	- No negative impact is expected.
29	Offensive Odors	D	D	- No negative impact is expected.
30	Traffic Accidents	D	D	- No negative impact is expected.

A: Significant impact expected
B: Moderate impact expected
C: There is no information, more research required
D: None or little impact expected
+: Positive
-: Negative
(Source: JICA Study Team)

Table 8.3.4 Scoping for Renewable Energy Projects <SOLAR THERMAL>

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
1	Population Resettlement	D	D	- No negative impact is expected.
2	Local Economy and Livelihood	B+	B+	Construction Stage] - Possible generation of direct (construction labor) and indirect employment (sellers, restaurants, etc. from the neighboring vicinities). [Operation Stage] - Reactivation of the industrial sector is expected as a result of energy cost reduction.
3	Land use and Use of Local Resources	D	D	- No negative impact is expected.
4	Social Capital and Local Organizations	D	D	- No negative impact is expected.
5	Existing Infrastructure and Public Services	D	B+	[Operation Stage] - It is expected that electricity services in the neighboring areas of the project will be stabilized specially those for public facilities such as schools and medical clinics, etc.
6	Ethnic Minorities and Indigenous Communities	D	D	- No negative impact is expected.
7	Unbalanced Distribution of Benefits and Damages by the Project	D	D	- No negative impact is expected.
8	Local Conflict caused by Common Interests	C	C	- No local conflict is expected; however, a public poll will be conducted to know the opinion of the community.
9	Cultural Heritage	C	D	[Construction Stage] - Project site inspection will be conducted by the Culture Secretariat.
10	Right of Water Use	D	D	- No negative impact is expected.
11	Infectious Diseases like HIV/AIDS	D	D	- No negative impact is expected.
12	Working Conditions	D	D	- No negative impact is expected.
13	Topography and Geography	D	D	- No negative impact is expected.
14	Groundwater	D	D	- No negative impact is expected.
15	Soil Erosion	D	D	- No negative impact is expected.
16	Hydrology	D	D	- No negative impact is expected.
17	Flora and Fauna / Biodiversity	D	D	- No significant negative impact is expected.
18	Climate	D	D	- No significant negative impact is expected.
19	Landscape	C	C	[Construction Stage and Operation] - Some negative impact on the landscape due to the size of the solar panels is expected.
20	Protected Natural Areas	C	C	- Protected natural areas must be identified.
21	Control of Waste Disposal Sites	D	D	- No significant negative impact is expected.
22	Global Warming	D	D	- No negative impacts to the atmosphere are expected.
23	Air Pollution	D	D	- No impact regarding pollution due to air emissions is expected.
24	Water Pollution	D	D	- No negative impacts to water are expected.

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
25	Soil Pollution	D	D	- No pollution due to contamination and spills on soil is expected.
26	Solid Waste	D	D	- No solid waste is expected from the construction works.
27	Noise and Vibrations	D	D	- No negative impact is expected.
28	Land Subsidence	D	D	- No negative impact is expected.
29	Offensive Odors	D	D	- No negative impact is expected.
30	Traffic Accidents	D	D	- No negative impact is expected.

A: Significant impact expected
B: Moderate impact expected
C: There is no information, more research required
D: None or little impact expected
+: Positive
-: Negative
(Source: JICA Study Team)

Table 8.3.5 Scoping for Renewable Energy Projects <GEOTHERMAL>

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
1	Population Resettlement	B-	C	[Construction Stage] - Possible resettlement of some families residing in the immediate vicinity. [Operation Stage] - Monitoring plan must be implemented.
2	Local Economy and Livelihood	B+	B+	[Construction Stage y Operation Stage] - Possible generation of direct (construction labor) and indirect employment (sellers, restaurants, etc. from the neighboring vicinities). [Operation Stage] - Reactivation of the industrial sector is expected as a result of energy cost reduction.
3	Land Use and Use of Local Resources	B-	D	[Construction Stage] - The agricultural and livestock areas will be affected. Parts of the vegetation mainly bushes will be affected. [Operation Stage] - No significant negative impact is expected or none at all.
4	Social Capital and Local Organizations	D	D	- No significant negative impact is expected. Rather, there are possible benefits for the locals.
5	Existing Infrastructure and Public Services	D	B+	[Operation Stage] - It is expected that electricity services in the neighboring areas of the project will be stabilized, especially within access roads.
6	Ethnic Minorities and Indigenous Communities	C	C	- Indigenous communities within the facilities must be identified.
7	Unbalanced Distribution of Benefits and Damages by the Project	D	D	- No significant damage is expected. Rather, there are possible benefits for the locals.
8	Local Conflict caused by Common Interests	C	C	- No local conflict is expected; however, a public poll will be conducted to determine the opinion of the community.
9	Cultural Heritage	C	D	[Construction Stage] - Project site inspection will be conducted by the Culture Secretariat.
10	Right of Water Use	B-	C	[Construction Stage] - Right of water use permits will be requested, not only during the construction Stage, but also during the well drilling stage.
11	Infectious Diseases like HIV/AIDS	D	D	- Few or no impact is expected.
12	Working Conditions	D	D	- Few or no impact is expected.
13	Topography and Geography	B-	D	[Construction Stage] - The generation of negative impacts due to cut and fill works are expected.
14	Groundwater	D	D	- No negative impact on groundwater is expected due to drilling, construction Works or even operation processes.
15	Soil Erosion	B-	D	[Construction Stage] - Possible effects on soil due to erosion as a result of the changes in the land where drilling platforms and plant facilities will be installed.

	Components	Evaluation		Expected Impacts
		Construction Stage	Operation Stage	
16	Hydrology	D	D	- Few or no significant effects are expected on the water resources.
17	Flora and Fauna / Biodiversity	B-	B-	[Construction Stage y Operation Stage] - It is possible that flora, fauna and biodiversity of the area will be affected.
18	Climate	D	D	- Few or no significant negative impacts are expected.
19	Landscape	B-	B-	[Construction Stage] - Possible negative impact to the landscape of the area due to plant construction. [Operation Stage] - During the operation stage, vapor emissions into the atmosphere will be observed.
20	Protected Natural Areas	C	C	- Protected natural areas must be identified.
21	Control of Waste Disposal Sites	D	D	- Few negative impacts are expected. Effort will be made to use the sites designated by the competent authorities.
22	Global Warming	D	D	- Few or no impacts are expected.
23	Air Pollution	B-	D	[Construction Stage and Operation] - Possible deterioration of air quality due to gas emissions by the worksite machineries (CO_2 y H_2S) and suspended dust particles from the construction itself.
24	Water Pollution	B-	D	[Construction Stage] - Possible contamination of water due to pollution and oil spills from the construction site.
25	Soil Pollution	B-	B-	[Construction Stage and Operation Stage] - Possible soil pollution due to geothermal water spills and pollutants.
26	Solid Waste	B-	D	[Construction Stage] - Solid waste will be generated from the works.
27	Noise and Vibration	B-	B-	[Construction Stage] - Noise and vibration caused by machineries for construction, as well as traffic due to heavy vehicles. [Operation Stage] - Noise generation from road operation.
28	Land Subsidence	B-	B-	- Possible land subsidence due to the extraction of thermal water.
29	Offensive Odors	B-	B-	[Construction Stage] - Offensive odors from gas emissions caused by construction machineries and well drilling. [Operation Stage] - Permanent offensive odors due to H_2S emissions within the central community.
30	Traffic Accidents	B-	D	[Construction Stage] - Possibility of traffic accidents within the site´s vicinity, mainly due to vehicular movements within the project caused by internal activities.

A: Significant impact expected
B: Moderate impact expected
C: There is no information, more research required
D: None or little impact expected
+: Positive
-: Negative
(Source: JICA Study Team)

Table 8.3.6 Scoping for Renewable Energy Projects <BIOMASS>

	Components	Evaluation		Expected Impact
		Construction Stage	Operation Stage	
1	Population Resettlement	B-	C	[Construction Stage] - Possible resettlement of some families residing in the vicinity. [Operation Stage] - Follow-up plan must be implemented.
2	Local Economy and Livelihood	B+	B+	[Construction Stage y Operation Stage] - Possible generation of direct (construction labor) and indirect employment (sellers, restaurants, etc. from the neighboring vicinities). [Operation Stage] - Reactivation of the industrial sector is expected as a result of energy cost reduction.
3	Land Use and Use of Local Resources	D	D	- No significant negative impact is expected.
4	Social Capital and Local Organizations	D	D	- No significant negative impact is expected.
5	Existing Infrastructure and Public Services	D	B+	[Operation Stage] - It is expected that electricity services in the neighboring areas of the Project will be stabilized
6	Ethnic Minorities and Indigenous Community	D	D	- No negative effects are expected on the indigenous communities.
7	Unbalanced Distribution of Benefits and Damages by the Project	D	D	- No major changes are expected at the site in terms of damages or benefits caused by the project. Plant has been proposed to be located in a small area.
8	Local Conflict caused by Common Interests	C	C	- No conflicts from the local residents are expected; however, a public poll will be conducted to confirm the opinions of the communities involved.
9	Cultural Heritage	C	D	[Construction Stage] - Project site inspection will be conducted by the Culture Secretariat.
10	Right of Water Use	C	C	- Right of water use should be identified and controlled.
11	Infectious Diseases like HIV/AIDS	D	D	- No impacts due to HIV are expected
12	Working Conditions	D	D	- Working conditions should not be affected.
13	Topography and Geography	B-	D	[Construction Stage] - Some negative impact, albeit insignificant, is expected on the topography and geography where the construction works are conducted.
14	Groundwater	D	D	- No significant negative impact to groundwater is expected,
15	Soil Erosion	B-	D	[Construction Stage] - Damages resulting from soil erosion will be sustained as a result of the earth removal activities, etc.
16	Hydrology	D	D	- No impacts are expected to the water resources within the area where the central source will be installed.
17	Flora and Fauna / Biodiversity	D	D	- No significant negative impacts to these components.
18	Climate	D	D	- Few or no expected impacts.
19	Landscape	D	D	- Few or no expected impacts.
20	Protected Natural Areas	C	C	- Protected natural areas must be identified.

	Components	Evaluation		Expected Impact
		Construction Stage	Operation Stage	
21	Control of Waste Disposal Sites	D	D	- Few negative impacts are expected, since the waste disposal site specifically authorized by the competent authorities will be used.
22	Global Warming	D	B-	[Operation Stage] - Possible negative impact due to methane gas emissions.
23	Air Pollution	B-	B-	[Construction Stage and Operation] - Air pollution due to gas emissions caused by the use of machineries within the site and suspended dust particles from all ongoing activities.
24	Water Pollution	B-	B-	[Construction Stage and Operation] - There is a possibility that drinking water quality will deteriorate due to oil and fuel spills from the machineries used.
25	Soil Pollution	B-	B-	[Construction Stage and Operation] - Possible deterioration of soil quality caused by oil and fuel spills from machineries.
26	Solid Waste	B-	B-	[Construction Stage and Operation] - Solid waste is expected from construction works as well as from the operation itself.
27	Noise and Vibration	B-	B-	[Construction Stage] - General noise and vibrations caused by the operation of construction machineries, and the eventual heavy vehicle traffic. [Operation Stage] - Noise caused by the overall operation of the central plant.
28	Land Subsidence	D	D	- No impact expected.
29	Offensive Odors	B-	B-	[Construction Stage] - Offensive odors caused by the emissions from combustion of gasses from the machineries as well as the creation of solid waste. [Operation Stage] - Offensive odors due to gas emissions caused by the combustion from plant operation.
30	Traffic accidents	D-	D	[Construction Stage] - No traffic accidents are expected within the site.

A: Significant impact expected
B: Moderate impact expected
C: There is no information, more research required
D: None or little impact expected
+: Positive
-: Negative
(Source: JICA Study Team)

8.3.3 Priorities for Renewable Energies within the Framework of Environmental and Social Considerations

As a result of the analysis of the existing obstacles and barriers in implementing renewable energy projects, as well as the EIA discussed above, the following priorities are recommended to promote the development of renewable energies in El Salvador:

(1) Priorities for Policies

- Energy policies in El Salvador must take into account the environmental and social framework.
- The General Electricity Law must be harmonized with various laws pertaining to the sector.
- Create a standard on power network interconnection of distributed resources, such as small hydroelectric power stations and photovoltaic solar energy.
- It is urgent to amend the Environmental Act and harmonize it with related laws.

(2) Priorities for Institutions

- It is essential to highly prioritize the issuance of guidelines for government institutions in order to establish a general pattern regarding renewable energies and their eventual implementation.
- Within the framework of the Environmental Act, Articles 6, 7, 8 and 9 must be observed, particularly regarding the System of National Environmental Management (SINAMA). An environmental unit must be created within SIGET or the CNE. Once the said unit is established, it must create the terms of reference (ToR) for renewable energy projects as a valuable input for the MARN, who will then need to endorse the said ToR. The objective of such procedures would be to optimize government resources and speed up the authorization processes for the ToR from projects regarding renewable energy sources.
- The government should be a part of the process of strengthening related knowledge by providing training for the personnel from involved government institutions in matters pertaining to renewable energies and the environment.
- Support exchange of information towards the transfer of technologies from the renewable energy resources, aiming to enrich the abilities of technicians to develop these projects.
- The government should make the most of the existing human resource of the country, specifically the professionals specializing in disciplines pertaining to renewable energy sources.
- Agreements with universities focused on projects regarding renewable energy sources, both at scientific and implementation levels.
- The government should support the provision of information regarding renewable energy resources, and should also provide guidelines for institutions involved with this subject. This is intended to enable its personnel to handle the information without discretion and within the framework of the Right to Information Act.

(3) Priorities for Project Implementation

Financial Priorities: Implement an adequate safeguarding system that will provide security to the investment in the renewable energy development sector; lower the high percentages on investments and increase economic incentives; and achieve reasonable rates, which would benefit the general population.

Chapter 9 Proposals for Promoting Renewable Energy use

9.1 Proposals for the development of Renewable Energy use

Based on the results of investigations and studies, some proposals are defined concerning the course that could take in the future renewable energy policy and the development of each energy source. The proposals discussed the different energy sources, which have been categorized in the following respects: (1) technical, (2) economic and financial (3) environmental like it is referred in Table 9.1.

Table 9.1.1 Recommendations on Future Directions of Development of Renewable Energy based on the Study Results

	Technical Aspect	Economic and Financial Aspect	Environmental Aspect
General	1. Each of the sources of energy (small hydropower, wind, solar PV, solar thermal, geothermal, biomass and biogas) differs from each other by their level of difficulty of exploitation. Therefore, it is necessary to perform proper preparation and studies to promote the introduction of renewable energy sources taking into consideration the level of maturity of each technology.	1. Interest rate of commercial bank is high as 8%, which is one of the barriers for preparation of development funds. As renewable energy development requires relatively high initial investment costs, it is necessary to consider establishment of low interest rate financing systems especially for renewable energy development.	1. Preparation of simplified procedures for obtaining environmental permit for renewable energy development that has less environmental impacts. 2. Clarification of the status of renewable energy development in the protected natural areas.
Small Hydropower	1. Confirmation of more accurate head (m) and discharge (m^3/sec) through site visits to the promising sites. 2. Preparation and maintenance of hydrological observation network and accumulation of hydrological data in a long term point of view.	1. For 100 kW to 200 kW class small hydropower, subsidy will be required to cover grid connection fee or to cover about one third of the construction cost to make the project viable. 2. For 0.3 MW to 5 MW class small hydropower, the project can be possibly developed without any subsidy.	1. Establishment of guidelines for river maintenance flow. 2. It is necessary to elaborate procedures and formats for environmental permit application especially for small hydropower.

	Technical Aspect	Economic and Financial Aspect	Environmental Aspect
Wind Power	1. Wind observation is required at promising sites which are identified by wind potential map. 2. Detailed assessment of wind power potential through Pre F/S or F/S. 3. Training of technical expert who can lead development and maintenance of wind power projects.	1. Under the current tax incentive measures that can be applied to projects up to 20 MW, development costs should be less than 1,700 US$/kW and plant factors should be more than 35% to make the project viable. 2. Monitoring of world-wide trends for technology development and cost levels are recommended.	1. It is necessary to elaborate procedures and formats for environmental permit application especially for wind power.
Solar PV	1. Solar radiation potential is relatively high, for example in San Salvador. 2. Need for pilot projects development to overcome technical barriers. 3. Training of technical expert who can lead development and maintenance of solar PV projects.	1. Under the current tax incentive measures that can be applied to projects up to 20 MW, development costs should be less than 1,600 US$/kW and plant factors should be more than 25% to make the project viable. 2. Monitoring of world-wide trends for technology development and cost levels are recommended.	1. It is necessary to elaborate procedures and formats for environmental permit application especially for solar PV.
Solar Thermal	1. Currently, high initial investment cost is a barrier for introduction. Monitoring of the latest world-wide trends for technology development and cost levels are necessary to decide the time for investment.	1. Standard size for solar thermal development ranges from 30 to 50 MW which is out of ranges for tax incentives application. To promote introduction, modification and enhancement of incentive schemes will be required.	1. It is necessary to elaborate procedures and formats for environmental permit application especially for solar thermal.
Geothermal	1. By 2017, it is important to develop geothermal power based on the development schedule prepared by LaGeo to reinforce base load for electricity. 2. Timely studies and investigations will be required to formulate development plans after 2017.	1. Considerations for public funds for new geothermal resources investigations to reduce financial burden and risks of private developers are required.	1. Simplification of environmental permit application procedures and expedition of required time.

	Technical Aspect	Economic and Financial Aspect	Environmental Aspect
Biomass	1. Expansion of installed capacity for power generation using bagasse. 2. Examination of potential for other biomass resources by region.	1. Collection of cost information on biomass resources utilization.	1. It is necessary to elaborate procedures and formats for environmental permit application especially for biomass.
Biogas	1. F/S for new and extension projects for landfill biogas. 2. Accumulation of know-how and data will be required for other type of biogas technologies such as animal waste or waste water, through implementation of pilot projects that use biogas (e.g. cattle waste or sewage)	1. Collection of cost information on biogas resources utilization.	1. It is necessary to elaborate procedures and formats for environmental permit application especially for biogas.

(Source: JICA Study Team)

9.2 Governmental support and incentives for developers of power projects that use renewable resource

As was also examined in section 9.1, the following items can be considered as support schemes by the government or incentive schemes for power companies:

(1) Necessity of low interest rate financing systems to improve cash flow of renewable energy development projects. For example, establishment of “Renewable Energy Development Funds.”

(2) Enhancement of target power development for the current tax incentive (by Decree 462). Enhancement from 30 to 50 MW class solar thermal or biomass power generation.

(3) Preparation of hydrological observation networks led by the government organizations.

(4) Observation of solar radiations or wind potential led by the government organizations.

(5) For wind, solar PV and solar thermal, training of technical expert is urgently required in an effective manner through coordination of government organizations, universities and public/private companies to be ready for actual introduction in the future.

Chapter 10 Renewable Energy Master Plan

10.1 Definition of Master Plan

Based on the studies and examinations made so far, descriptions are given on the Renewable Energy Master Plan. Master Plan was prepared for seven renewable energy sources for 15 year period from 2012 to 2026 as an Indicative Development Plan. Of the renewable energy sources there are energy sources that require further preparation periods prior to introduction. For such energy sources, references are provided for required items for examinations toward introduction.

10.1.1 Target Energy Sources for Master Plan Formulation

The following seven energy sources are considered for formulation of the master plan:

- Small Hydropower
- Wind Power
- Solar PV
- Solar Thermal
- Geothermal
- Biomass
- Biogas

As was examined in Chapter 8, there are energy sources that requires further examinations or pilot projects prior to introduction because the technologies or conditions of the market is still premature for introduction. For such energy sources, information was provided on: (1) current technical issues to be examined toward introduction; (2) action plans toward introduction and (3) introduction of examples of installation as references.

10.2 Indicative Development Plan

As was presented in Chapter 2, El Salvador applies an electricity supply system through transactions in an electricity market. State owned and private power generation companies play important roles in the electricity supply activities. Therefore, future development plans are very closely related with investment plans for those power generation companies.

In other countries that apply liberalized electricity market (Colombia in Latin America, for example), the government organization in charge of power sector policy preparation normally prepares an Indicative Development Plan for the next 15 years or so and announce the plan.

In this master plan, the same manner will be applied to prepare an Indicative Development Plan for the next 15 years (2012 to 2026).

An Indicative Development Plan should be updated in the certain time of the year by reflecting the investment plans or expansion plans prepared by state owned or private companies. For such update works, the latest information from state owned or private companies are prerequisite. To obtain such information, periodical information exchange occasions should be organized by the government organization in charge of power sector policy preparation. By using such occasions, confirmation on development directions and progress is recommended to formulate indicative development plans.

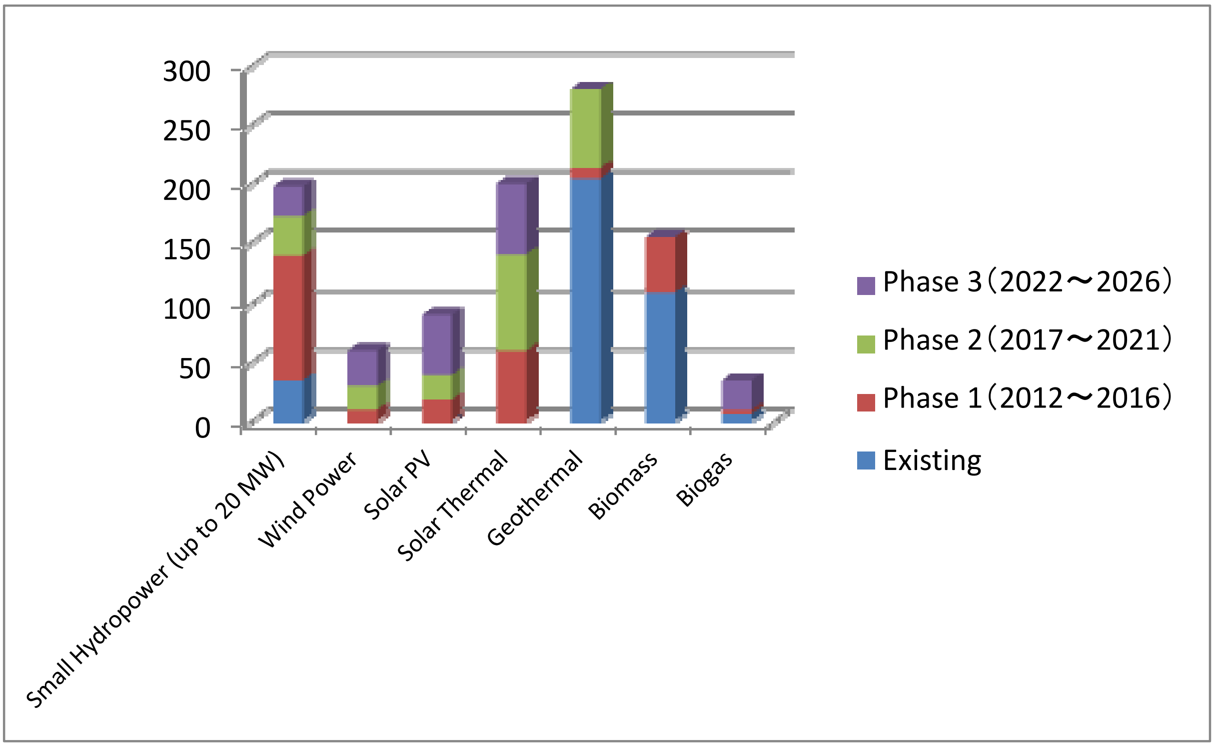
In this master plan study, renewable energy parts of the Indicative Development Plan for the next 15 years from 2012 to 2026 are presented. As the electricity supply system applies market mechanism, no prioritization were made for individual energy sources, but to present expected capacity of introduction by dividing the 15 year period from 2012 to 2026 into three, i.e., Phase 1 (2012 to 2016), Phase 2 (2017 to 2021) and Phase 3 (2022 to 2026).

An Indicative Development Plan is as shown in Table 10.1.1.

Table 10.2.1 Indicative Development Plan (2012 to 2026)

Type of Energy		Phase			
	Existing	Phase 1 (2012 to 2016)	Phase 2 (2017 to 2021)	Phase 3 (2022 to 2026)	Phase 1 to 3 Total
Small Hydropower (up to 20 MW)	35 MW	103.9 MW	33.5 MW	25.3 MW	162.7 MW
Wind Power	-	10 MW	20 MW	30 MW	60MW
Solar PV	0.5 MW	18 MW	21 MW	51 MW	90 MW
Solar Thermal	-	60 MW	80 MW	60 MW	200 MW
Geothermal	204.4 MW	5～9 MW	55～80 MW	-	60～89 MW
Biomass	109.5 MW	45 MW	-	-	45 MW
Biogas	6.3 MW	10 MW	-	25 MW	35 MW

(Source: JICA Study Team)



(Source: JICA Study Team)

Figure 10.1.1 Ratio of Energy Sources by Type in the Master Plan

For the above Indicative Development Plan, the followings are the remarks:

1) For small hydropower, Phase 1 projects were selected from: Under construction/concession projects, rehabilitation projects, projects with completed feasibility study or basic design or pre-feasibility study, with B/C (with bank loan) of more than 1.0. Phases 2 and 3 projects were selected considering economic viability and attractive size of the projects to private developers. Those projects with equal to or more than 250 kW in installed capacity, and with B/C equal to or large than 1.0, were selected.

2) For wind power, CEL has a plan to install total capacity of 72 MW. However, in reality, there is no actual installation schedule so far and the candidate locations for construction are limited. The figures in the indicative development plan are assumed figures that were confirmed through consultation with CNE.

3) For solar PV, CEL only has a plan to install about 18 MW. It was assumed that the plan to be implemented by 2016. For the development plan after 2016, the figures in the indicative development plan are assumed figures that were confirmed through consultation with CNE. Solar PV systems to be personally installed are not considered in the development plan.

4) For solar thermal, LaGeo and INE have development plans. LaGeo has a plan to implement by 2016. The indicative development plan was prepared from information derived from both companies to estimate future possibilities.

5) For geothermal, LaGeo (in charge of development) has a development plan up to 2017 only. Additional studies will be required for formulating further plans after 2017. On the other hand, another 60 to 90 MW will be expected to be developed by estimating in view of developable potential.

6) For biogas, the figures in the indicative development plan are assumed figures based on the existing development plans of Nejapa landfill biogas plant, i.e., short term expansion plan up to 10 MW and long term expansion plan up to 25 MW.

Detailed technical examinations in preparing the Indicative Development Plan are described in the next section.

10.3 Master Plan for Each Renewable Energy Source

Based on the technical and planning maturity of relevant energy sources, master plan was formulated for the following seven renewable energy sources:

- Small Hydropower (up to 20 MW)
- Wind Power
- Solar PV
- Solar Thermal
- Geothermal
- Biomass
- Biogas

Detailed descriptions for each energy sources are given hereunder:

10.3.1 Small Hydropower

Master plan for small hydropower was prepared in accordance with the workflow presented in Section 8.1.1 of Chapter 8. Based on information about the existing potential sites and the newly identified potential sites through desk studies, simple technical reviews was conducted through analysis of previous studies and verification of the newly found potential sites for small hydro, through the study of topographic maps, hydrologic analysis, cost estimate by formulas of Japanese guidelines, current unit cost in El Salvador and financial analysis. The size of the capacity is determined by optimizing the difference between benefit and cost (B-C). The master plan for development of small hydropower in three phases is considered for each five year from 2012 to 2027.

Scheduled development programs and the number of development sites for each phase are as presented in Table 10.3.1.1.

Table 10.3.1.1 Summary of Master Plan for Small Hydropower Development

Fase Phase	Condiciones Conditions	Nomber of Projects	Potencia Potential (MW)	Energía Energy (MWh/Año)	Plant Factor	Inversión Total Investment Cost (x 1,000 US$)	Costo/kW (US$)	Base del Inversionista (con préstamo del Banco) Investment Base (with Bank TIR FIRR (Average) (%)	 VAN NPV (Average) (x1,000 US$)	 B/C (Average)
Phase-I (2012-2017)	Under Const.,with B/D, F/S & Pre-F/S	59	103.9	436,100	48%	305,100	2,937	27.7%	4,500	1.58
Phase-II (2017-2022)	B/C >=1, P>=0.25 (MW), 50% of Potential	32	33.5	146,100	50%	92,500	2,761	29.3%	3,500	1.72
Phase-III (2022-2027)	B/C >=1, P>=0.25 (MW), 50% of Potential	32	25.3	89,200	40%	85,800	3,391	17.6%	1,400	1.33
TOTAL		123	162.7	671,400	47%	483,400	2,972	24.7%	3,248	1.52

(Source: JICA Study Team)

For formulation of master plan, the following criteria are adopted:

- Phase-I (2012-2017) : Under construction/concession projects, rehabilitation projects, projects with completed feasibility study or basic design or pre-feasibility study, with B/C (with bank loan) of more than 1.0 The potential sites in the environmentally protected areas (SANP) are excluded.
- Phase-II (2017-2022) : 50% of the potential sites with B/C (with bank loan) of more than 1.0 and with potential capacity of more than 250 kW. The potential sites in the environmentally protected areas (SANP) are excluded.
- Phase-III (2022-2027) : The remaining 50% of the potential sites with B/C (with bank loan) of more than 1.0 and potential capacity of more than 250 kW. The potential sites in the environmentally protected areas (SANP) are excluded.

Total of 123 sites (59 in Phase-I, 32 in Phase-II and 32 in Phase-III) are selected for the master plan The total capacity is estimated at 162.7MW (103.9 MW in Phase-I, 33.5 MW in Phase-II and 25.3MW in Phase-III). Total annual energy is estimated at 671.4 Wh/year (436.1 GWh/year in Phase-I, 146.1 GWh/year in Phase-II and 89.2 GWh/year in Phase-III). The total investment cost will be US$483.4 million.

Details of master plan formulation are described hereunder.

10.3.1.1 Workflow of Master Plan Formulation for Small Hydropower Projects

Study of nationwide potential of small hydropower was conducted in CEL-UCA 1989 Study. In 2002, some information such as investment costs and economic values were updated for several of potential sites of the CEL-UCA 1989 Study by UNDP/GEF-MARN (Transénergie, F. Lozano/J. Cottin). However, UNDP/GEF-MARN did not update all the potential sites of CEL-UCA 1989 Study. Therefore, some of the above potential information are already outdated and need updating.

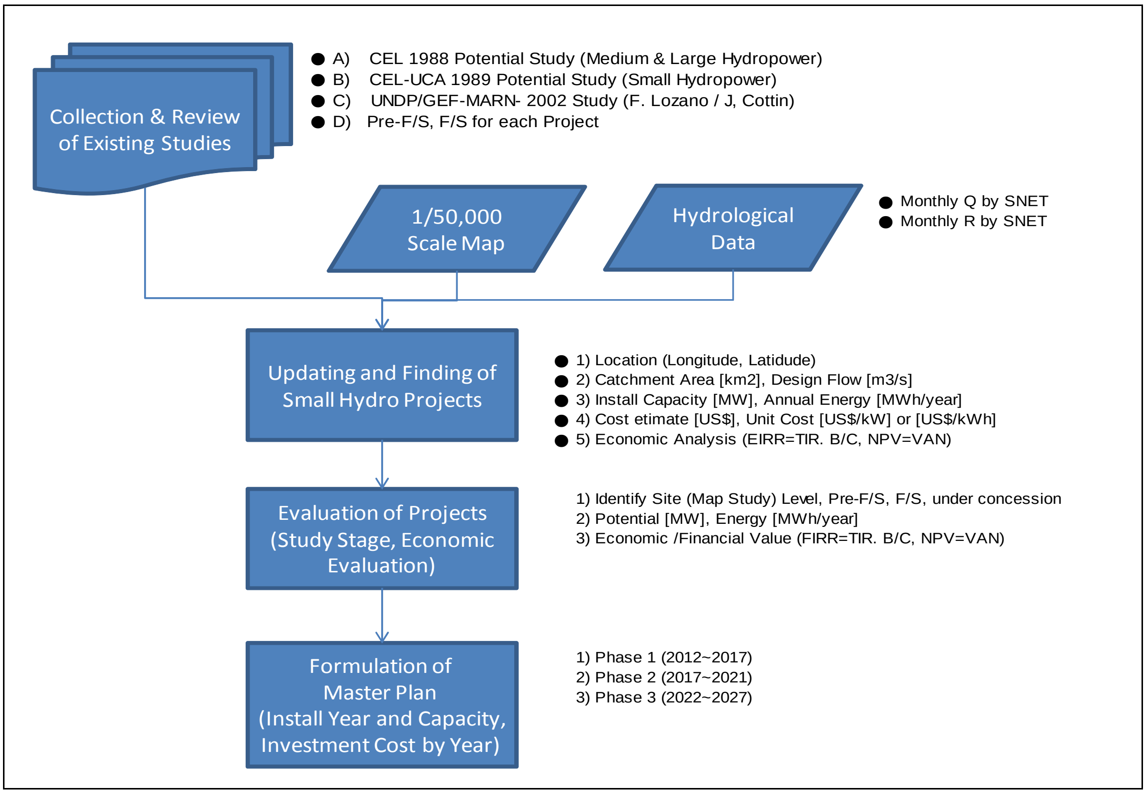
On the other hand, Pre-F/S or F/S was conducted for each hydropower project site, but nationwide study of potential small hydropower projects has not been updated. Therefore, updating of this comprehensive study of potential small hydropower projects is required.

To select viable sites among the identified potential sites mentioned above, technical, economical, financial and environmental feasibility were evaluated and updated.

Basic approach in the master plan formulation for the development of small hydropower with capacities less than 20 MW for 2012-2027 is described below.

A. Review and updating of potential installed capacity [MW] and average annual energy production [MWh/year] for each potential site by using results of previous studies, 1/50,000 scale topographic maps and recent hydrological data, etc.
B. Review and updating of investment cost [US$], benefit [US$] and financial values such as FIRR (TIR), NPV (VPN) and B/C for each potential site by using results of previous studies and recent economic values
C. Locating potential sites using 1/50,000 scale topographic maps
D. Estimation of the possible potential installed capacity [MW], average annual energy production [MWh/year], financial viability indicators such as FIRR (TIR), NPV (VPN) and B/C for each potential site by using results of previous studies and recent economic values, for each new potential site by using 1/50,000 scale topographic maps, recent hydrological data, and recent economic values
E. Project prioritization based on project status, such as study stage (potential survey, Pre-F/S, F/S, final design, under concession, etc.) and financial viability indicators (B/C)
F. Environmental impacts and viability evaluation

The workflow of master plan formulation for small hydropower development is shown in Figure 10.3.1.1.



(Source: JICA Study Team)

Figure 10.3.1.1 Workflow of the Master Plan Formulation for Small Hydropower

10.3.1.2 Review of Previous Study for Small Hydropower

For formulation of the master plan for small hydropower (with less than 20 MW capacity) from 2012 to 2027 in this study, potential of the identified sites were updated by the Study Team using 1/50,000 scale topographic maps, recent hydrological data and economic cost based on the following previous studies:

a). CEL 1988 potential study for medium- and large-scale hydropower

b). CEL-UCA 1989 potential study for small hydropower

c). UNDP/GEF-MARN 2002 Study (Transénergie, F. Lozano / J. Cottin)

d). Pre-F/S and F/S of each hydropower project

However, the factors that establish the project's potential, such as installed capacity [MW], annual energy output [MWh/year] and financial viability indicators of projects, at Pre-F/S and F/S levels or under construction and under concession levels, are not updated. Instead, values from previous studies are used.

Only the potential sites identified at map study level in previous studies, a), b) and c) mentioned above, are reviewed and re-evaluated using topographic maps, hydrological data and recent economic values.

10.3.1.3 Findings and Evaluation of New Potential Sites

Amongst the proposed potential sites in previous studies, such as the CEL-UCA 1989 Study, only the economically viable potential sites are presented in the final report. Most sites proposed in the CEL-UCA 1989 Study were identified through map studies and field investigations. In the JICA master plan study, new potential sites were also identified and evaluated using 1/50,000 scale topographic maps, hydrological data and recent economic cost data by the JICA Study Team. The project’s potential indicators, such as installed capacity [MW], annual energy output [MWh/year] and financial parameters are also evaluated using recent values.

10.3.1.4 Technical Evaluation of Potential Sites

For the evaluation and selection of small hydropower potential sites for the master plan study, technical evaluation was conducted. In the review of the proposed sites in existing studies, and in the search for new potential sites; map studies, hydrological study and financial evaluation were made for each potential site.

A. Map Study

i) Gross Head

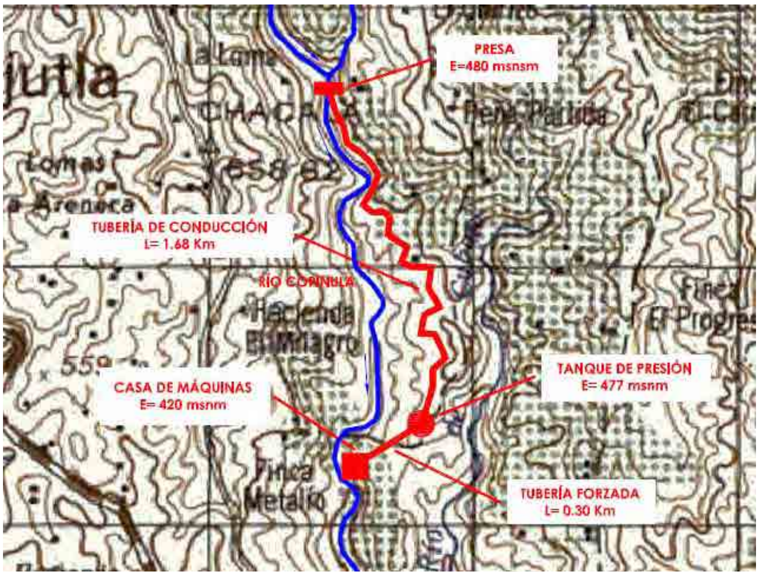
Topographic maps of 1:50,000 scale were used in the measurement and verification of gross head [m] on each potential site. New potential sites for small hydropower are also proposed by the JICA Study Team.

ii) Proposed Intake and Powerhouse Sites

Proposed intake and powerhouse sites in previous studies were reviewed and proposal for new intake and powerhouse sites were also prepared using the topographic maps.

iii) Length of Canal and Penstock

The length of the canal was measured following the contour lines until the proposed headtank site. The length of the penstock was measured between the proposed headtank and powerhouse site taking into account the slope. Example of a map study is shown in Figure 10.3.1.2.



(Source: INGENDEHSA S.A DE C.V)

Figure 10.3.1.2 Example of a Map Study for a Small Hydropower Layout

B. Hydrological Study

Daily mean discharge at proposed intake site for each potential site is estimated by using available daily mean discharge data at nearby hydrological station and monthly mean rainfall data at nearby rainfall stations as shown in Figure 10.3.1.3 and by the following equation:

$$\mathrm{Qd} = \mathrm{Qs}\,\frac{\mathrm{Ad} \times \mathrm{Rd}}{\mathrm{As} \times \mathrm{Rs}}$$

Where,

Qd: Estimated daily discharge at proposed intake site [m^3/s]

Qs: Observed daily mean discharge at nearby hydrological station [m^3/s]

Ad: Catchment area at proposed intake site [km^2]

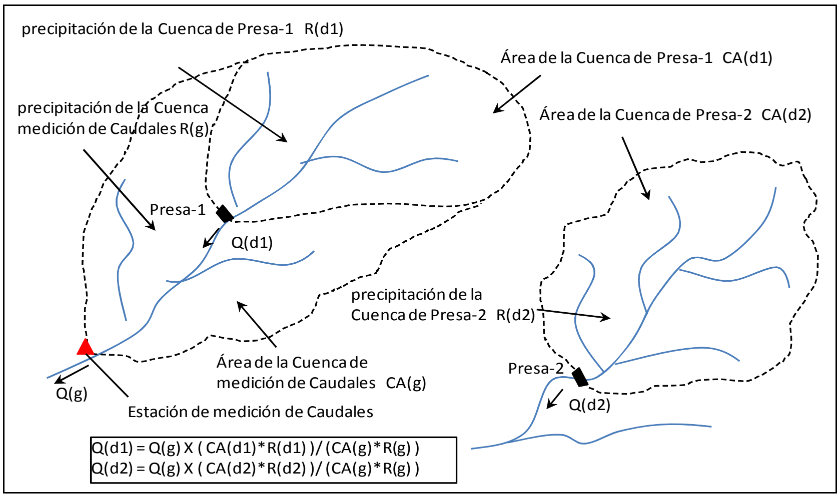
As: Catchment area at nearby hydrological station [km^2]

Rd: Monthly mean basin rainfall at proposed intake site [mm/month]

Rs: Monthly mean basin rainfall at nearby hydrological station [mm/month]

Monthly mean rainfall at proposed sites and hydrological stations are estimated using available rainfall data by SNET and Thiessen's Polygons.

After estimation of daily mean discharge at proposed intake sites, the flow duration curves of the daily discharge of available periods were created.



(Source: JICA Study Team)

Figure 10.3.1.3 Estimation of Discharge at Proposed Intake Site

C. Design Discharge

The design discharge for each potential site was determined from the results of the optimization study where site selection is based on the maximum benefit-cost value (B-C or NPV). The discharge is evaluated from 10% to 95% at 5% intervals of the flow duration curves for each proposed intake site. As this is a master plan level study, the river maintenance flow was not considered. River maintenance flow is normally examined at the Pre-F/S or F/S stages.

D. Power Output

The power output is estimated for each design discharge and head, using the following equations:

$$P = 9.81 \times \gamma_c \times Q \times H_e$$
$$H_e = H_g - H_l$$
$$\gamma_c = \gamma_t * \gamma_g$$

where,

P : Power output [kW]

Q : Design Discharge [m^3/s]

H_n : Gross Head [m] (Intake water level [El. m] - Tailrace water level [El. m])

H_e : Effective Head [m]

H_l : Head loss [m]

γ_c : Combined Efficiency

γ_t : Turbine Efficiency

γ_g : Generator Efficiency

The head loss H_l is estimated as follows:

$$H_l = (1/5000)*L_1 + (1/200)*L_2 + (1/5000)*L_3$$

where,

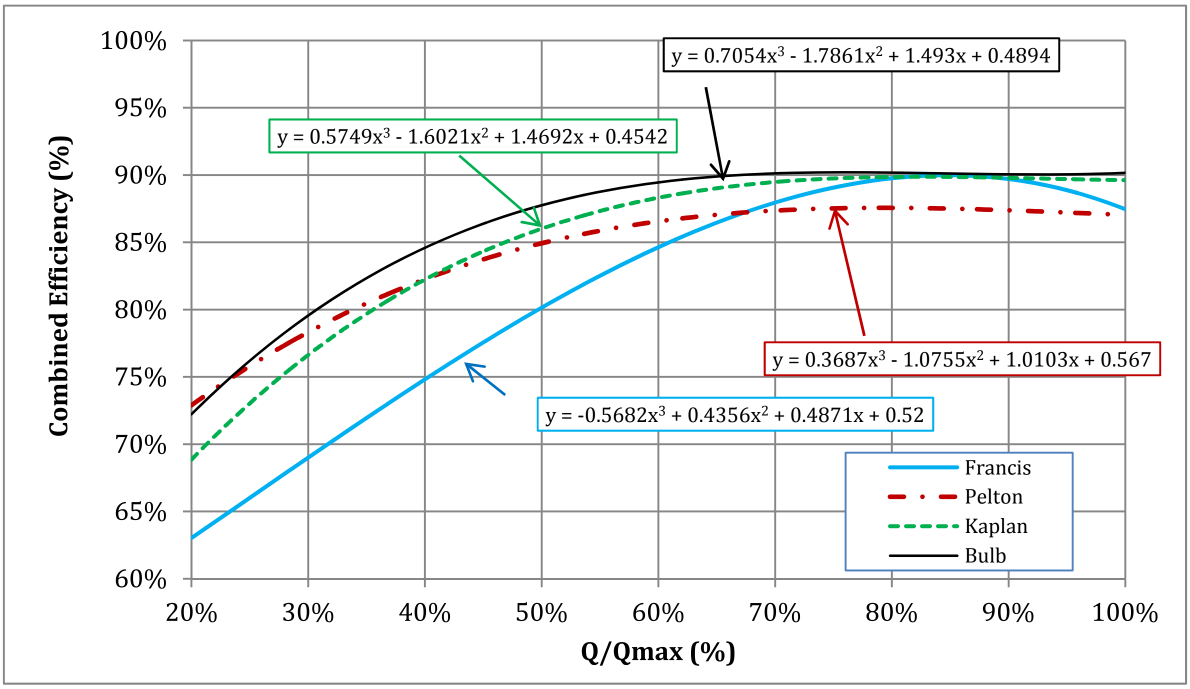
L_1 : Length of headrace channel[m]

L_2 : Length of penstock [m]

L_3 : Length of tailrace [m]

Note: this formula only can be used when we working Francis Turbine

The combined efficiency γ_c by turbine type is as shown in Figure 10.3.1.4.



(Source: "Guide Manual for Development Aid Program and Studies of Hydro Electric Power Projects": New Energy Foundation, Japan 1996)

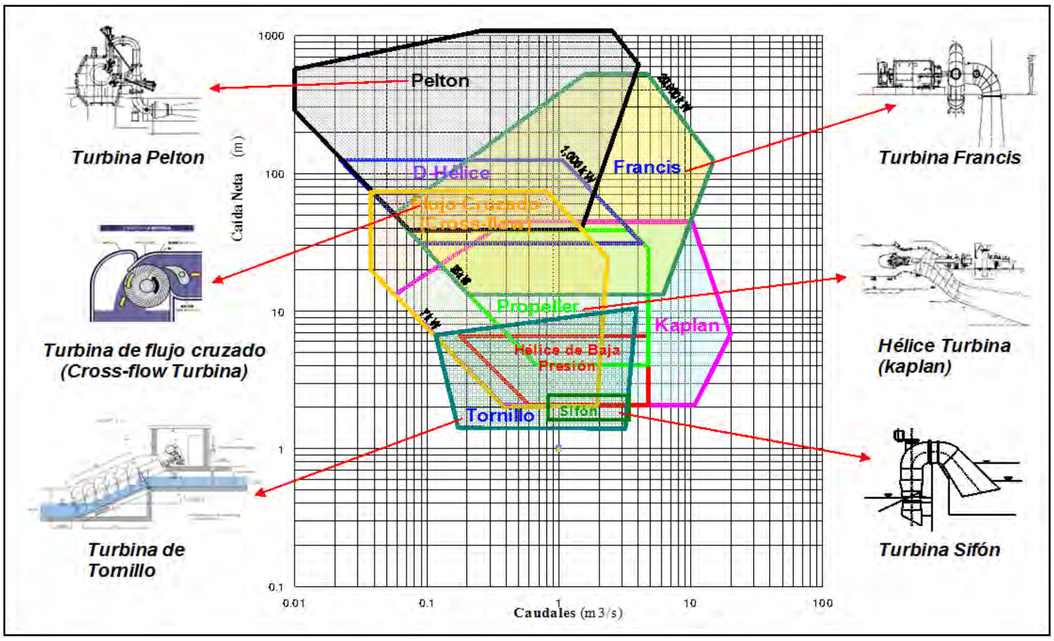
Figure 10.3.1.4 Combined Efficiency by Turbine Type

The type of turbine is selected for each design flow and effective head as shown in Table 10.3.1.2, but for simplified estimation, refer to Figure 10.3.1.5.

Table 10.3.1.2 Selection of Turbine Type

Type of Turbine	Head (m)	Discharge (m^3/s)
Cross-Flow	H<80 m	Q<1.0 m^3/s
Pelton	H>75 m	Q<2.0 m^3/s
Francis	H>30 m	Q>0.3 m^3/s

(Source: JICA Study Team)



(Source: Nippon Koei Co., Ltd.)

Figure 10.3.1.5 Turbine Selection Diagram

E. Energy

The average annual energy generation for each design discharge case is estimated using the flow duration curves described as follows:

- Flow below Q_{max} (design discharge) is divided into blocks partitioned by 5% steps as shown in Figure 10.3.1.6, which shows design discharge at 30% of year ($Q_{30\%}$) schematic as example.
- Volume of inflow for each block area A <a> through A <o> is obtained.
- Energy generation of each block is calculated. In this case ($Qd = Q_{30\%}$), the combined efficiency of the equipment is obtained from the ratio of the mean flow to the maximum plant discharge of each block by using Figure 10.3.1.4 above.

$E_a = P_{30\%} * 24*365*30\%$; $P_{30\%} = 9.8*Q_{30\%}*\eta_{30\%} * He$

$E_b = (P_{30\%} + P_{35\%})/2 * 24*365*5\%$; $P_{35\%} = 9.8*Q_{35\%}*\eta_{35\%} * He$

$E_c = (P_{35\%} + P_{40\%})/2 * 24*365*5\%$; $P_{40\%} = 9.8*Q_{40\%}*\eta_{40\%} * He$

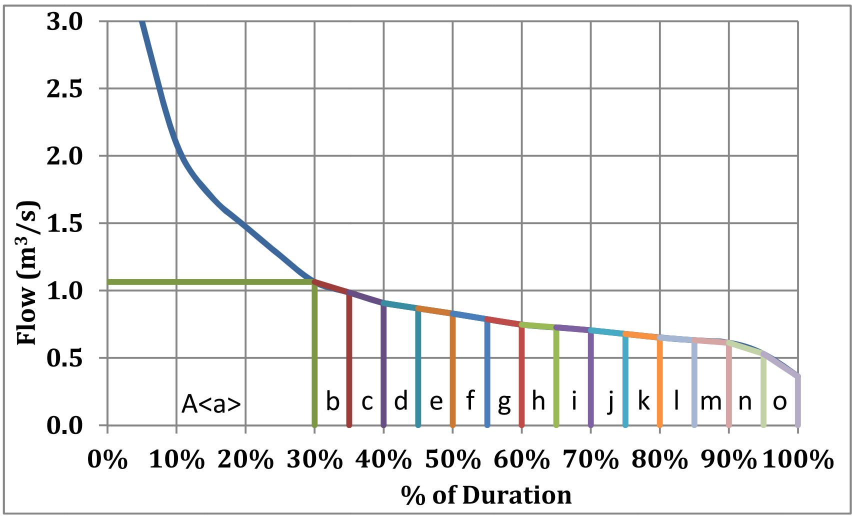
$E_c = (P_{40\%} + P_{45\%})/2 * 24*365*5\%$; $P_{45\%} = 9.8*Q_{45\%}*\eta_{45\%} * He$

(same as above for the 45% to 90% of flow duration)

$E_n = (P_{90\%} + P_{95\%})/2 * 24*365*5\%$; $P_{95\%} = 9.8*Q_{95\%}*\eta_{95\%} * He$

$E_o = (P_{95\%} + P_{100\%})/2 * 24*365*5\%$; $P_{100\%} = 9.8*Q_{100\%}*\eta_{100\%} * He$

Annual energy generation, E [kWh/year] = $E_a + E_b + E_c + E_d + \ldots + E_m + E_n + E_o$



(Source: JICA Study Team)

Figure 10.3.1.6 Calculation of Energy (Q_d=$Q_{30\%}$ case)

10.3.1.5 Cost Estimate of Potential Sites

A. Construction Cost Estimate

Example of a cost estimate is shown in Table S.1 of Appendix-S. The costs of civil works and hydraulic and electro-mechanical equipment for each potential site and design discharge case were estimated by using the equations in Tables S.2 and S.3 of Appendix-S, which were taken from the study results on existing hydropower stations in Japan (Source: Guide Manual for Development Aid Program and Studies of Hydro-Electric Power Projects: New Energy Foundation, Japan 1996).

The unit costs in civil works were based on current 2011 prices in El Salvador.

- Average height of intake weir (Hd) was assumed at 2.0 m for all potential sites. The crest width (Li) of intake weir was calculated using the following equation:

  $$Li = (Qmax * 198)/(Hd^2/7)$$

- Headrace channel assumes that the canal is constructed using conduction pipe. The unit costs of conduction pipes for each size are estimated by the following equation and Figure 10.3.1.7 (source: OTK Flowtite, Colombian company).

  Cost of Conduction Pipe [US$]:

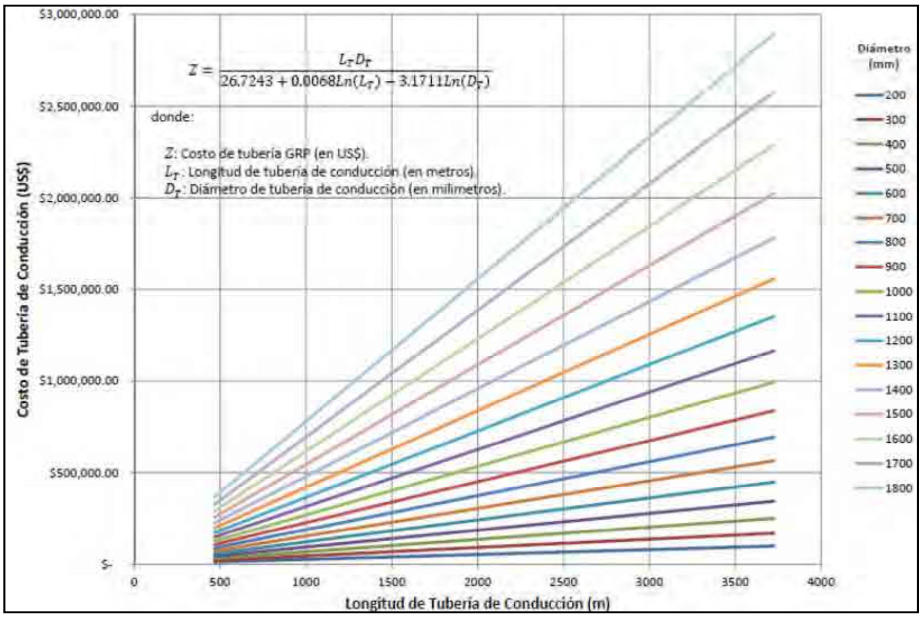
  $$Z= (Lt*Dr)/(26.7243+0.0068*Ln (Lt)- 3.1711*Ln (Dr))$$

  where:

  Z: Cost of Conduction Pipe [US$]

  Lt: Length of Conduction Pipe [m]

  Dr: Diameter of Conduction Pipe [mm]

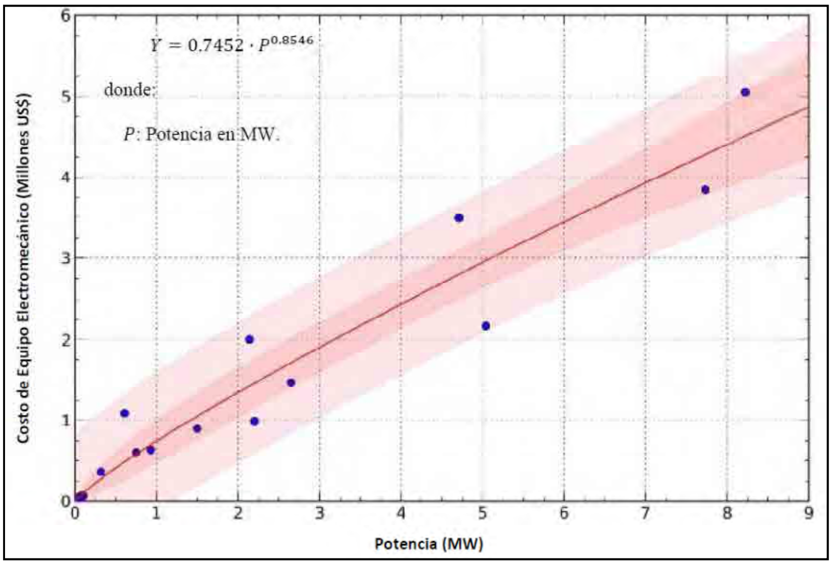


(Source: INGENDEHSA S.A DE C.V)

Figure 10.3.1.7 Cost of Conduction GRP Pipe

- Unit cost of electro-mechanical equipment (turbine and generator) was estimated using the following equation and Figure 10.3.1.8. (source: VOLK Wasserkraft WKV, German company)

Cost of Electro-mechanical Equipment [US$ Million] = 0.7452 * P[MW]^0.8546



(Source: INGENDEHSA S.A DE C.V)

Figure 10.3.1.8 Cost of Electro-mechanical Equipment

- The assumed length of transmission line (distribution) was 3.0 km for all potential sites. The unit cost of the distribution line used in the estimate was US$50,000/km.
- The assumed length of access road was 2.0 km for all potential sites. The unit cost of access road used was US$200,000/km for more than 500 kW and US$100,000/km for less than 500 kW.

B. Total Construction Cost

The estimated total construction cost is shown in Table S.4 of Appendix-S. This is based on the following assumptions:

- preparatory works (assumed 5% of civil works cost)
- environmental mitigation costs (assumed 1% of civil works cost)
- miscellaneous works of civil works (assumed 25% of civil works cost)
- administration & engineering fee (assumed 3% of direct cost)
- contingency (assumed 1% of direct cost)

10.3.1.6 Financial Evaluation of Potential Sites

A. General

The financial evaluation of small hydropower potential sites was carried out using the Net Present Value (NPV), Financial Internal Rate of Return (FIRR), and Benefit-Cost ratio (B/C). The project financial analysis "without" and "with" bank loan cases were carried out on the evaluation of the base case scenario of the project and on the more accurate financing cases using bank loan.

The IRR is expressed by the following equation:

$$\sum_{t=1}^{n}\frac{C_t}{(1+i)^t}-\sum_{t=1}^{n}\frac{B_t}{(1+i)^t}=0$$

Where:

C_t : Cost [US$]

B_t : Benefit [US$]

t : Year

n : Life of the project (=50 years)

i : Discount rate (if Cost=Benefit => i=Internal Rate of Return; IRR)

Net present value (NPV) is estimated as follows:

$$NPV=\sum_{t=1}^{n}\frac{B_t-C_t}{(1+i)^t}$$

The B/C is estimated as follows:

$$B/C=\frac{\sum_{t=1}^{n}\frac{B_t}{(1+i)^t}}{\sum_{t=1}^{n}\frac{C_t}{(1+i)^t}}$$

Generation cost is estimated as follows:

Generation cost [US$/kWh] = (Construction cost per kWh) * α

$$\text{Construction cost per kWh [US\$/kWh]} = \frac{\text{Construction cost (US\$)}}{\text{Annual energy generation (kWh)}}$$

$$\alpha = CRF + F_o = 0.082+0.05 = 0.132$$

$$CRF = \frac{i(1+i)^y}{(1+i)^y-1} = 0.082$$

where,

α: Annual cost factor

CRF: Capital recovery factor

i: Interest rate (assumed at *i* = 8%)

y: Service life (years) (assumed hydropower: 50 years)

F_o: O&M cost factor (assumed at 5%)

B. Condition of Project Financial Evaluation (without bank loan case)

The following assumptions were used in the project financial analysis of the ‘without bank loan’ case:

- Percentage of investors’ contribution: 100% (in this case, bank loan is not considered)
- Discount rate: 10%
- Construction period: 2 years (assumed)
- For the sale price of energy, this is based on the authorized average price of energy for distribution companies from 2008 to 2011, with a value of US$146.70/MWh (www.siget.gob.sv) and with 5.5% discount from the dealer, which is equivalent to US$140/MWh with an annual increase of 4% calculated on the basis of price changes for the period mentioned above.
- Operation and maintenance cost: 5% of total gross income and US$0.35/MWh for major maintenance
- Administrative expenses are assumed as follows:

	P>=1MW	1MW> P >=500kW	500kW> P >=200kW	P<200kW	Unit Cost (US$/month)
Engineer	1	1	0	0	US$1,800
Operator	2	2	1	1	US$500
Security guard	2	1	1	0	US$400
Accountant	1	1	0	0	US$500

- Annual increase in operation and maintenance costs and administration expenses: 5% (estimates based on average annual inflation in El Salvador)

- Annual insurance payment equivalent to US$1.5 per 1,000 (= US$0.0015) of investment cost and variable according to depreciable assets.
- Tax of municipality: US$0.216 per 1,000 of investment cost.
- Annuity to SIGET: US$0.51/MWh
- Registration Tax (CNR): US$11.43 per US$100,000 of investment cost (maximum US$11,430)
- Income tax: 25% from the 11 years of operation.

Example of result of project financial evaluation "without" bank loan case is shown in Table S.5 of Appendix-S.

C. Condition of Financial Evaluation (with bank loan case)

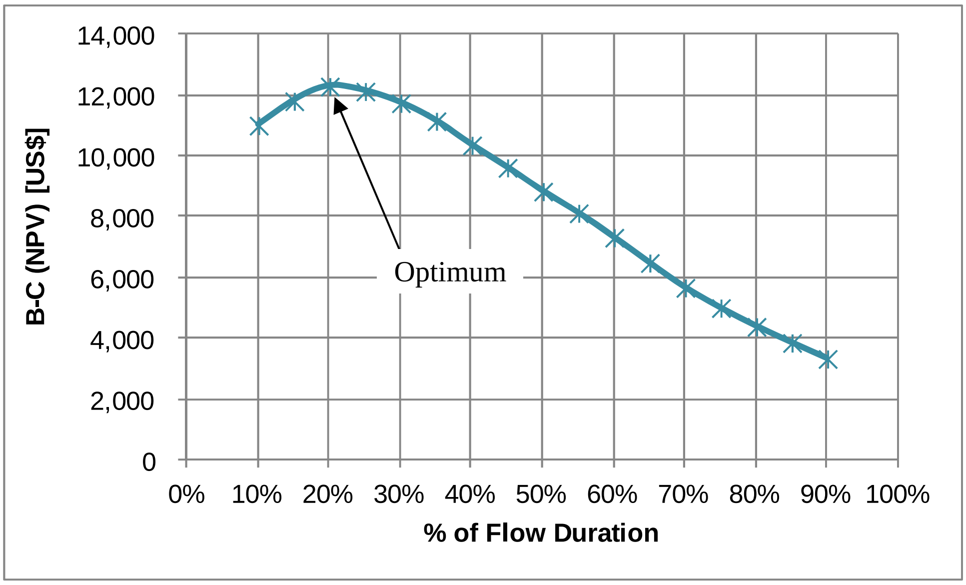
The following additional assumptions were used for financial analysis of the 'with bank loan' case. The assumption and calculation are the same with those applied in Chapter 8, Section 8.2.

- Percentage financed by banking institutions: 70%
- Percentage of investors' contribution: 30%
- Bank interest rate: 8.00%
- Funding period: 12 years (10 years plus 2 years of grace payment).

Example of project financial evaluation results for the 'with bank loan' case is shown in Table S.6 of Appendix-S.

10.3.1.7 Optimization of Design Discharge for Potential Sites

Design discharge was selected based on the optimum B-C value (or NPV) resulting from the project financial analysis of the 'with bank loan' case, as shown in Figure 10.3.1.9.

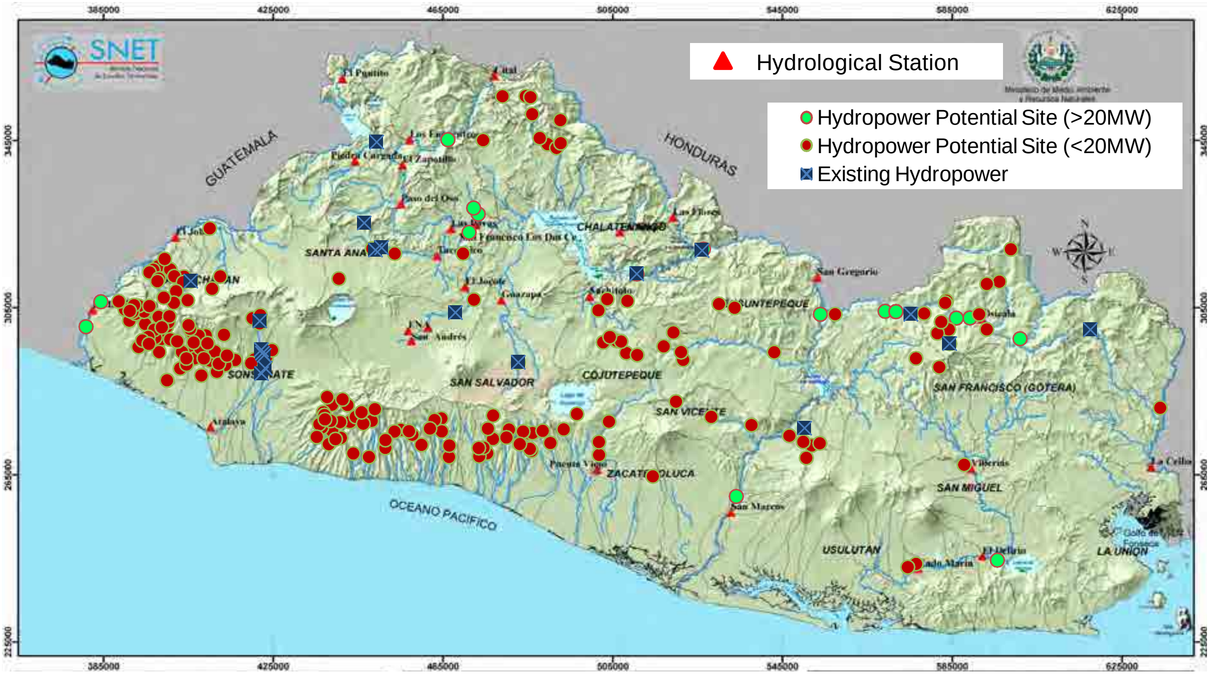


(Source: JICA Study Team)

Figure 10.3.1.9 Optimization of Design Discharge (Example)

10.3.1.8 Potential Sites for Small Hydropower Plants

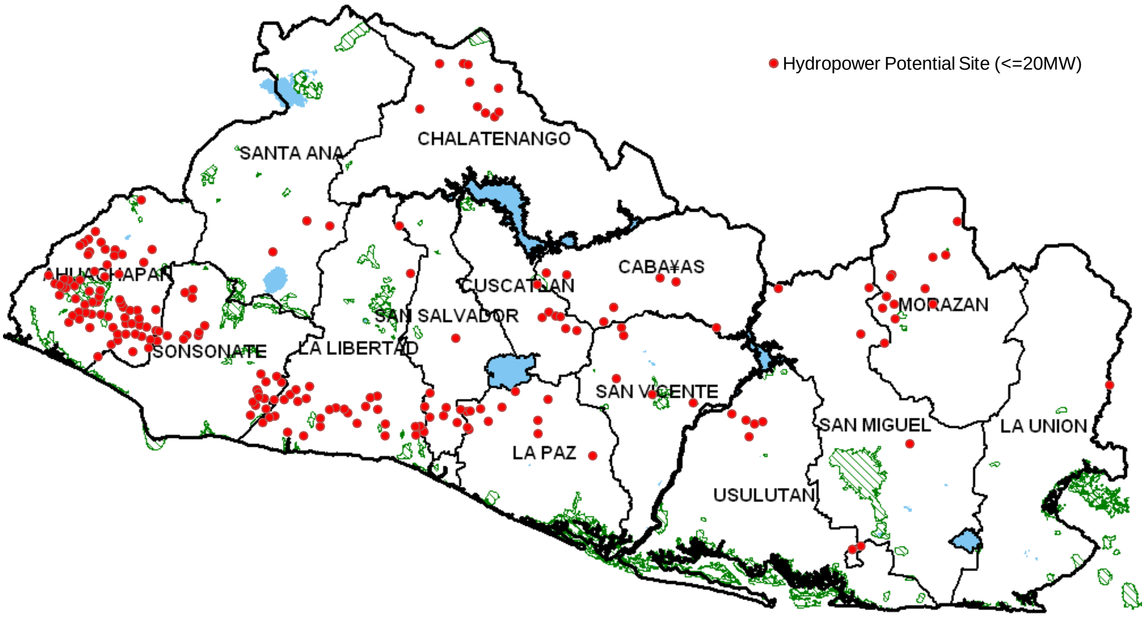
The evaluated small hydropower potential sites (< 20 MW) in El Salvador are shown in Table S.7 to S.8 of Appendix-S and Figure 10.3.1.10. There are 209 sites in total that were identified. The total capacity is estimated at 180.8MW and the estimated mean annual energy is 756 GWh. Most of the potential sites are located in the western region, especially in the Department Ahuachapán, Sonsonate and La Paz.



(Source: JICA Study Team). (Base map by SNET/MARN)

Figure 10.3.1.10 Location Map of Hydropower Potential Sites

There are 20 potential sites located in environmentally protected areas (Sistema Area Natural Protegida: "SANP") as shown in Figure 10.3.1.11, especially in Department Ahuachapán. According to MARN, private projects are not allowed in SANP. However, a government project is allowed to construct in SANP if necessary permits from MARN are obtained.



(Source: JICA Study Team). (Base map by SWERA, 2005)

Figure 10.3.1.11 Small Hydropower Potential Sites (<20 MW) and Environmentally Protected Area (SANP)

10.3.1.9 Master Plan for Small Hydropower

The list of small hydropower potential sites and the corresponding financial evaluation results are shown in Table S.8 of Appendix-S. In this list, if some information such as annual energy [MWh/year], cost [US$], or financial indicators (FIRR, NPV, B/C) from previous studies/projects (under construction/concession, rehabilitation projects, F/S, B/D, Pre-F/S) are not available, these values were estimated using the following assumptions:

- Annual energy was estimated using capacity [MW] and assumed plant factor of 50%.
- Cost estimate is based on the assumed unit cost of US$3,000/kW.
- Calculation of FIRR, NPV and B/C is based on the method mentioned in Section 10.3.1.6.

The evaluation resulted to a total of 152 potential sites with B/C (with bank loan case) of more than 1.0, as shown in Table 10.3.1.3. The total capacity is 171.8 MW and the annual energy is 712.6 GWh.

Table 10.3.1.3 Summary of Small Hydropower Potential Sites with B/C >= 1.0

	Number of Projects	Potential Capacity [MW]	Annual Energy [GWh/year]	Investment Cost [US$ Million]	Average Cost/kW [US$/kW]
TOTAL	152	171.8	712.6	528.5	3,077

(Source: JICA Study Team)

The master plan for small hydropower development for each 5-year phase between 2012 and 2027, the following criteria shown in Table 10.3.1.4 are adopted.

- Phase-I (2012-2017) : Under construction/concession projects, rehabilitation projects, and projects with completed feasibility study or basic design or pre-feasibility study and with B/C (with bank loan) of more than 1.0. The potential sites in the environmentally protected areas (SANP) are excluded.
- Phase-II (2017-2022) : 50% of the potential sites with B/C (with bank loan) of more than 1.0 and potential capacity of more than 250 kW .The potential sites in the environmentally protected areas (SANP) are excluded.
- Phase-III (2022-2027) : The remaining 50% of the potential sites with B/C (with bank loan) of more than 1.0 and potential capacity of more than 250 kW. The potential sites in the environmentally protected areas (SANP) are excluded.

Table 10.3.1.4 Criteria for Selection for Master Plan of Small Hydropower

Phase	Year	B/C (with bank loan)	Potential Capacity [kW]	Environmentally Protected Area (SANP)	% of Potential Sites
I	2012-2017	All projects under const./concession, with F/S or B/D or Pre-F/S and projects with B/C ≥ 1.0 from previous study results (*1)	all sizes (*1)	Excluded	-
II	2017-2022	B/C ≥ 1.0	≥ 250 kW	Excluded	50%
III	2022-2027	B/C ≥ 1.0	≥ 250 kW	Excluded	50%

Note *1): The projects include isolated rural electrification projects by NGO SABES.
(Source: JICA Study Team)

The selection criteria for projects under Phase-II and Phase-III(i.e., installed capacity of more than 250 kW and B/C of more than 1.0), are based on its economical and financial viability, development priority to meet the increasing national electricity demand, and its attractiveness in terms of size to private investors.

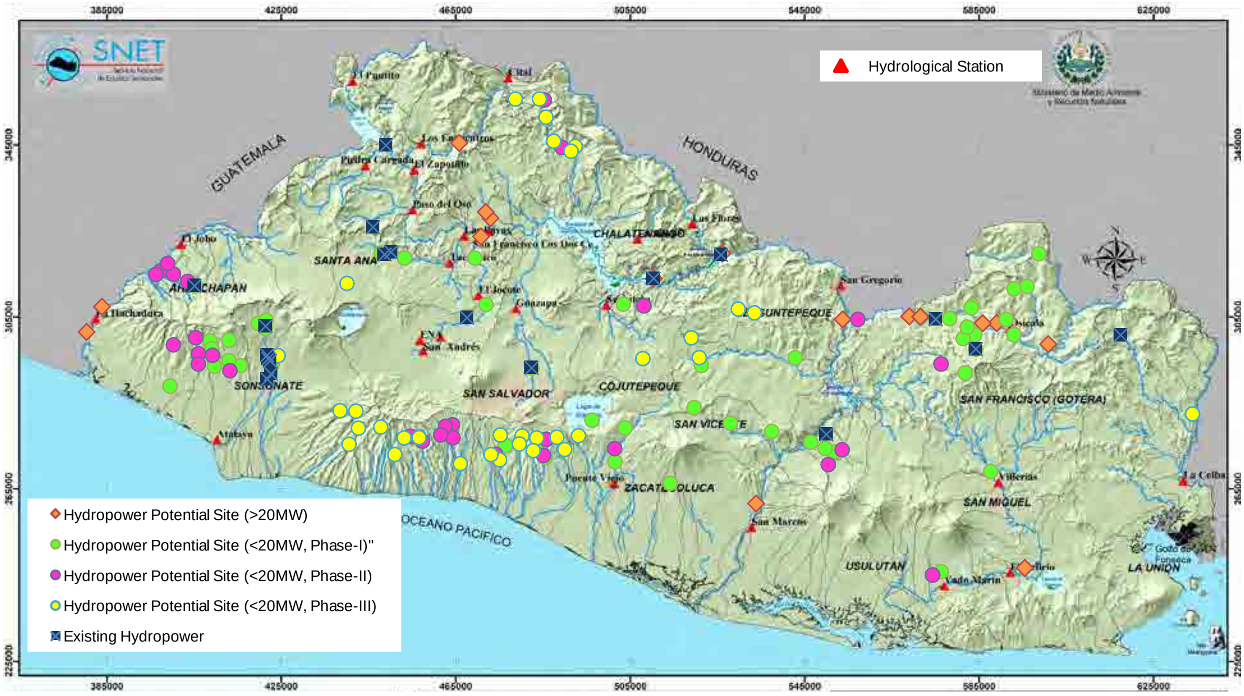
The formulated master plan for each phase is summarized in Table 10.3.1.5. The location map of selected potential sites for each phase is shown in Figure 10.3.1.12. The characteristics of selected sites on the master plan for the development of small hydropower are shown in Table 10.3.1.6.

Table 10.3.1.5 Summary of Master Plan for Small Hydropower Development

Fase Phase	Condiciones Conditions	Nomber of Projects	Potencia Potential (MW)	Energía Energy (MWh/Año)	Plant Factor	Inversión Total Investment Cost (x 1,000 US$)	Costo/kW (US$)	Base del Inversionista (con préstamo del Banco) Investment Base (with Bank		
								TIR FIRR (Average) (%)	VAN NPV (Average) (x1,000 US$)	B/C (Average)
Phase-I (2012-2017)	Under Const.,with B/D, F/S & Pre-F/S	59	103.9	436,100	48%	305,100	2,937	27.7%	4,500	1.58
Phase-II (2017-2022)	B/C >=1, P>=0.25 (MW), 50% of Potential	32	33.5	146,100	50%	92,500	2,761	29.3%	3,500	1.72
Phase-III (2022-2027)	B/C >=1, P>=0.25 (MW), 50% of Potential	32	25.3	89,200	40%	85,800	3,391	17.6%	1,400	1.33
TOTAL		123	162.7	671,400	47%	483,400	2,972	24.7%	3,248	1.52

(Source: JICA Study Team)

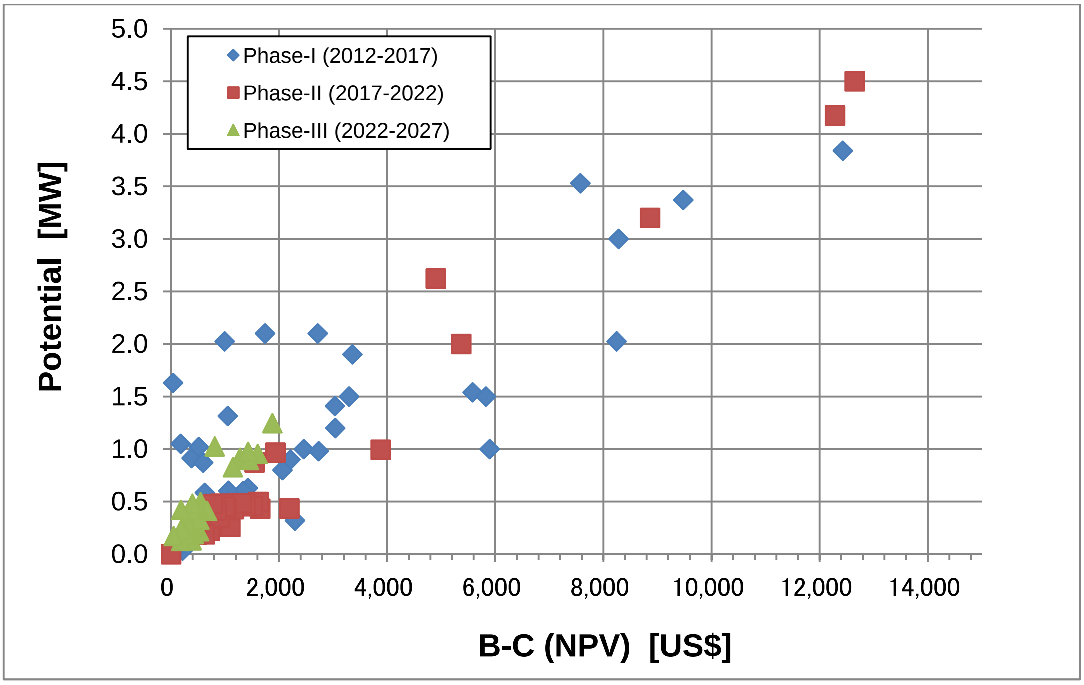
A total 123 sites (59 in Phase-I, 32 in Phase-II and 32 in Phase-III) are selected for the master plan of small hydropower development for the duration between 2012 and 2027. The total capacity is estimated at 162.7 MW (103.9 MW in Phase-I, 33.5 MW in Phase-II and 25.3 MW in Phase-III will be proposed for installation). Total annual energy is estimated at 671.4 GWh (436.1 GWh/year in Phase-I, 146.1 GWh/year in Phase-II and 89.2 GWh/year in Phase-III will be generated additionally). The estimated investment cost is US$483.4 Million in total.



(Source: JICA Study Team) (Base map by SNET/MARN)

Figure 10.3.1.12 Location Map of Selected Small Hydropower Potential Sites for Master Plan 2012-2027

Figure 10.3.1.13 shows the correlation between the B-C value (or NPV) and the potential capacity [MW] of selected small hydropower potential sites for the three phases. The projects under Phase-I and II have wide range of B-C values. The relationship between B-C and potential capacity [MW] of Phase-I and Phase-II projects seems linear. The B-C of Phase-III projects are, in general, smaller than the Phase-II projects.



(Source: JICA Study Team)

Figure 10.3.1.13 Relationship between B-C and Potential Capacity of Selected Small Hydropower Potential Sites by Phase

Table 10.3.1.6 Selected Small Hydropower Potential Sites for Master Plan (1/2)

No.	Nombre de Proyecto	Río	Departamento	Latitud	Longitud	Etapa del Proyecto	Potencia	Energía	Factor de planta	Inversión Total	Costo/kW	Generación de costos	Base del Proyecto (sin préstamo del Banco) Project Base (without Bank Loan)			Base del Inversionista (con préstamo del Banco) Investment Base (with Bank Loan)			Fase del proyecto
	Project Name	River	Department	Latitude	Longitude	Project Stage	Potential	Energy	Plant Factor	Investment Cost	Cost/kW	Generation Cost	TIR FIRR	VAN NPV	B/C	TIR FIRR	VAN NPV	B/C	Project Phase
				(N)	(W)		(MW)	(MWh/Año)		(x 1,000 US$)	(US$/kW)	(US$/kWh)	(%)	(x1,000 US$)		(%)	(x1,000 US$)		
1	El Calambre	Río El Calambre	Morazán	13.9928	88.0804	Construcción	0.058	311	61%	146	2,512	? 0.062	16.5%	82	1.17	? 39.4%	? 207	? 1.83	1
2	Mirazalco	Río Gran.d.e de Sonsonate	Sonsonate	13.8414	89.7456	Construcción	3.370	? 14,762	? 50%	9,969	2,958	? 0.089	? 19.6%	? 8,830	? 1.67	? 29.3%	? 9,475	? 1.76	1
3	Gualpuca	Río Gualpuca	Morazán	13.8333	88.2333	Financiamiento	1.000	6,155	70%	1,475	1,475	? 0.032	26.0%	614	1.70	? 90.5%	? 5,893	? 2.94	1
4	Ilopango Aguacayo	lago de Ilopanago	La Paz	13.6311	89.0334	Financiamiento	17.000	? 74,460	? 50%	? 51,000	? 3,000	? 0.090	? 19.7%	? 45,746	? 1.70	? 29.5%	? 49,047	? 1.80	1
5	San Luis IV	Rio Suquiapa	La Libertad	13.9942	89.4828	Bid Process	1.500	? 6,570	? 50%	? 5,250	? 3,500	? 0.105	? 16.3%	? 2,953	? 1.43	? 22.4%	? 3,293	? 1.50	1
6	Sumpul	Río Sumpul	Chalatenango	13.8300	89.7300	De Registro SIGET	16.200	64,043	45%	? 48,600	? 3,000	? 0.100	? 17.9%	? 35,075	? 1.58	? 25.8%	? 38,221	? 1.67	1
7	Sucio, Los Tetuntes	Río Sucio	La Libertad	13.8822	89.2594	De Registro SIGET	6.600	? 28,908	? 50%	? 19,800	? 3,000	? 0.090	? 19.5%	? 17,481	? 1.69	? 29.2%	? 18,762	? 1.78	1
8	La Joya	Río Acahuapa	San Vicente	13.6248	88.7383	De Registro SIGET	3.000	? 13,140	? 50%	? 9,000	? 3,000	? 0.090	? 19.2%	? 7,696	? 1.65	? 28.6%	? 8,279	? 1.74	1
9	San Francisco	Rio Tapuchina	Sonsonate	13.8482	89.7285	De Registro SIGET	1.000	? 4,380	? 50%	? 3,000	? 3,000	? 0.090	? 18.2%	? 2,261	? 1.53	? 26.4%	? 2,455	? 1.61	1
10	La Colmena (El Volcán)	Río El Volcán/Rio Sn Juan	San Miguel	13.7339	88.2375	De Registro SIGET	0.097	450	53%	290	2,986	? 0.085	15.3%	124	1.10	? 28.0%	? 259	? 1.63	1
11	Quebrada la Cueva / San Jose	Quebrada la cueva / San Jose	Morazán	13.7855	88.2146	De Registro SIGET	0.065	455	80%	294	4,527	? 0.085	13.2%	88	1.10	? 28.0%	? 262	? 1.63	1
12	Santa Rosa (El Riachuelo)	Río Riachuelo	San Miguel	13.8518	88.2707	De Registro SIGET	0.038	260	78%	180	4,737	? 0.091	11.8%	30	1.00	? 22.7%	? 116	? 1.43	1
13	Atehuecillas (Rehabilitation)		Ahuachapán	13.9228	89.8811	Rehabilitación	0.630	? 2,759	? 50%	? 1,890	? 3,000	? 0.090	? 17.6%	? 1,300	? 1.46	? 25.0%	? 1,422	? 1.53	1
14	San Esteban	Río San Esteban	San Miguel	13.5196	88.1829	Rehabilitación	0.751	3,287	50%	4,858	6,472	? 0.195	? 8.3%	? -689	? 0.88	? 8.6%	? -374	? 0.93	1
15	Cucumacayan (Reconversion)	Río Grande de Sonsonate	Sonsonate	13.7500	89.7167	Reconversion	2.300	17,895	89%	2,225	967	? 0.016	42.0%	261	1.76	? 164.1%	? 19,707	? 4.25	1
16	Acahuapa (Rehabilitation)		San Vicente	13.6583	88.8157	Rehabilitación	0.120	? 526	? 50%	? 360	? 3,000	? 0.090	? 18.2%	? 270	? 1.53	? 26.4%	? 294	? 1.60	1
17	Sapuyo (Rehabilitation)		La Paz	13.4941	88.8667	Rehabilitación	0.060	? 263	? 50%	? 180	? 3,000	? 0.090	? 16.6%	? 107	? 1.38	? 23.1%	? 119	? 1.44	1
18	Chorreron Jiboa	n.d.	La Paz			Factibilidad	2.000	? 8,760	? 50%	? 6,000	? 3,000	? 0.090	? 19.0%	? 4,979	? 1.62	? 28.1%	? 5,367	? 1.70	1
19	La Montañita		Morazan	13.8167	88.2167	Factibilidad	0.900	? 3,942	? 50%	? 2,700	? 3,000	? 0.090	? 18.2%	? 2,034	? 1.53	? 26.4%	? 2,208	? 1.61	1
20	El Sapo	Río Sapo	Morazán	13.9216	88.1056	Factibilidad	0.060	? 263	? 50%	? 180	? 3,000	? 0.090	31.0%	11,010	3.32	? 23.1%	? 119	? 1.44	1
21	San Luis III	Rio Suquiapa	Santa Ana	13.9942	89.4828	Factibilidad	0.600	? 2,628	? 50%	? 1,800	? 3,000	? 0.090	? 17.4%	? 1,218	? 1.45	? 24.8%	? 1,335	? 1.52	1
22	Sonzacate (Nahuizalco II)	Río Sensunapán	Sonsonate	13.7567	89.7153	Factibilidad	3.839	16,816	50%	9,450	2,461	? 0.074	22.3%	9,758	2.18	? 37.2%	? 12,427	? 2.00	1
23	Potrerillos	Quebrada Las Lajas	Morazán	13.8084	88.2417	Factibilidad	0.320	2,600	93%	976	3,049	? 0.049	18.4%	257	1.50	? 59.1%	? 2,292	? 2.52	1
24	Guanijiquil - Poza Hon.d.a	Río Sapo	Morazán	13.8500	88.1500	Factibilidad	0.131	510	44%	345	2,637	? 0.089	14.7%	140	1.43	? 26.7%	? 287	? 1.61	1
25	La Cabaña	Río Gran.d.e de San Miguel	Usulután	13.3019	88.2885	Factibilidad	0.980	4,300	50%	2,600	2,653	? 0.080	11.4%	181	1.40	? 31.4%	? 2,731	? 1.75	1
26	La Loma	Río Osicala	Morazán	13.8167	88.1333	Factibilidad	0.055	398	83%	270	4,905	? 0.089	16.0%	136	1.15	? 25.7%	? 212	? 1.56	1
27	El Progreso	Río Aruate	Morazán	13.8797	88.2216	Factibilidad	0.033	280	97%	200	6,061	? 0.094	11.8%	34	1.00	? 22.2%	? 124	? 1.42	1
28	Araute	Río Araute	Morazán	13.8751	88.2245	Factibilidad	0.033	284	98%	? 99	? 3,000	? 0.046	? 30.6%	? 206	? 1.98	? 54.9%	? 212	? 2.05	1
29	Cumaro	Río Cumaro	n.d.	13.9167	88.1333	Factibilidad	0.040	? 175	? 50%	? 120	? 3,000	? 0.090	? 15.0%	? 53	? 1.26	? 19.9%	? 61	? 1.30	1
30	El Naranjito	Río El Naranjito	Ahuachapán	13.7050	89.9333	Factibilidad	0.031	146	54%	97	3,124	? 0.087	10.3%	2	0.85	? 18.9%	? 44	? 1.26	1
31	Quezalapa	Río Quezalapa	Cuscatlán/Cabañas	13.8833	88.9667	Diseños Básicos	1.050	2,628	29%	? 3,150	? 3,000	? 0.158	? 9.9%	? -26	? 0.99	? 11.1%	? 178	? 1.05	1
32	Tihuapa 1	Río Tihuapa	San Salvador/La Paz	13.5883	89.1383	Diseños Básicos	1.315	3,870	34%	? 3,945	? 3,000	? 0.134	? 12.3%	? 794	? 1.16	? 15.1%	? 1,049	? 1.22	1
33	Tihuapa 2	Río Tihuapa	San Salvador/La Paz	13.5500	89.1333	Diseños Básicos	0.900	2,580	33%	? 2,700	? 3,000	? 0.138	? 11.6%	? 359	? 1.10	? 13.8%	? 534	? 1.16	1
34	San Simón 1	Río San Simón	Usulután	13.5619	88.5176	Diseños Básicos	0.900	2,040	26%	? 2,700	? 3,000	? 0.174	? 8.6%	? -304	? 0.91	? 9.1%	?- 130	? 0.96	1
35	San Simón 2	Río San Simón	Usulután	13.5699	88.5362	Diseños Básicos	0.915	2,484	31%	? 2,745	? 3,000	? 0.146	? 10.9%	? 201	? 1.06	? 12.6%	? 379	? 1.11	1
36	San Simón 3	Río San Simón	Usulután	13.5833	88.5667	Diseños Básicos	0.870	2,570	34%	? 2,610	? 3,000	? 0.134	? 11.9%	? 427	? 1.12	? 14.3%	? 596	? 1.18	1
37	Titihuapa 3	Río Titihuapa	Cabañas/San Vicente	13.6067	88.6500	Diseños Básicos	2.100	6,802	37%	? 6,300	? 3,000	? 0.122	? 14.2%	? 2,305	? 1.29	? 18.4%	? 2,713	? 1.36	1
38	Titihuapa 5	Río Titihuapa	Cabañas/San Vicente	13.7667	88.6000	Diseños Básicos	1.410	5,673	46%	? 4,230	? 3,000	? 0.098	? 17.2%	? 2,757	? 1.48	? 24.3%	? 3,031	? 1.56	1
39	Cuyuapa	Río Cuyuapa	Sonsonate	13.7500	88.8000	Diseños Básicos	1.020	2,840	32%	? 3,060	? 3,000	? 0.142	? 11.2%	? 315	? 1.08	? 13.2%	? 513	? 1.13	1
40	Suquiapa	Río Suquiapa	Santa Ana	13.9833	89.4333	Diseños Básicos	3.530	13,630	44%	? 10,590	? 3,000	? 0.102	? 17.2%	? 6,886	? 1.51	? 24.2%	? 7,571	? 1.59	1
41	Gr. Chalatenango	Río Gr. Chalatenango	Chalatenango	14.7167	89.0833	Diseños Básicos	1.630	3,680	26%	? 4,890	? 3,000	? 0.175	? 9.3%	? -279	? 0.95	? 10.1%	? 37	? 1.01	1
42	Sucio 3	Río Sucio	La Libertad/San Salvador	13.9833	89.2833	Diseños Básicos	2.025	11,149	63%	? 6,075	? 3,000	? 0.072	? 23.5%	? 7,849	? 1.91	? 38.1%	? 8,242	? 2.01	1
43	Polorós		La Unión	13.8050	89.8083	Diseños Básicos	2.025	5,250	30%	? 6,075	? 3,000	? 0.152	? 11.2%	? 597	? 1.08	? 13.1%	? 991	? 1.14	1
44	Huiza 2	Río Huiza	La Libertad/San Salvador	13.5500	89.2333	Diseños Básicos	2.100	6,009	33%	? 6,300	? 3,000	? 0.138	? 12.4%	? 1,330	? 1.17	? 15.3%	? 1,738	? 1.24	1
45	Santo Domingo (Presa 1 & 2 &3)	Río Tepechapa/ Río Cacahuata/ Quebrada El Camote	Sonsonate	13.7497	89.7838	Pre Factibilidad	1.540	7,885	58%	2,958	2,881	? 0.087	23.4%	3,969	2.29	? 35.9%	? 5,579	? 1.92	1
46	Chacala Los Apantes (Presa 1 & 2)	Río Chacala / Río Los Apantes	Ahuachapán	13.8037	89.8484	Pre Factibilidad	1.500	8,126	62%	4,498	3,124	? 0.094	22.0%	3,492	2.14	? 36.8%	? 5,825	? 1.95	1
47	Santa Rita	Río Jiboa	La Páz	13.6143	88.9630	Pre Factibilidad	8.357	36,603	50%	21,220	2,539	? 0.076	21.7%	20,688	2.11	? 36.3%	? 27,052	? 2.00	1
48	Milingo (Reconversion)	Río Acelhuate	San Salvador	13.7443	89.1619	Pre Factibilidad	0.800	? 3,504	? 50%	2,225	2,781	? 0.084	42.0%	261	1.76	? 28.8%	? 2,061	? 1.66	1
49	Copinula I	Río Copinula	Ahuachapán	13.7864	89.8444	Pre Factibilidad	0.603	2,641	50%	2,155	3,573	? 0.107	14.1%	653	1.35	? 19.6%	? 1,059	? 1.37	1
50	San José Loma	Río Jiboa	La Páz	13.5411	88.9845	Pre Factibilidad	1.901	8,327	50%	7,797	4,101	? 0.123	13.1%	1,804	1.26	? 18.3%	? 3,354	? 1.37	1
51	Cara Sucia (Presa 1 & 2)	Río Mistepe / Río Maishtapula	Ahuachapán	13.8286	89.9814	Pre Factibilidad	0.584	2,559	50%	2,560	4,382	? 0.132	11.1%	201	1.09	? 14.6%	? 624	? 1.19	
52	San Pedro II	Río San Pedro	Ahuachapán	13.7603	89.8080	Pre Factibilidad	0.397	1,739	50%	1,641	4,134	? 0.124	11.0%	117	1.08	? 18.1%	? 685	? 1.35	1
53	Copinula II	Río Copinula	Ahuachapán	13.7482	89.8388	Pre Factibilidad	0.487	2,132	50%	2,266	4,655	? 0.140	10.0%	-7	1.00	? 15.5%	? 653	? 1.25	1
54	Qbda El Naranjito al Naranjo		Ahuachapán	13.7050	89.9333	Pre Factibilidad	0.080	? 350	? 50%	? 240	? 3,000	? 0.090	? 17.4%	? 162	? 1.45	? 24.7%	? 177	? 1.52	1
55	Qbda El Singual, al Cuyapo		Morazan	13.8333	88.2333	Pre Factibilidad	0.058	? 254	? 50%	? 174	? 3,000	? 0.090	? 16.5%	? 102	? 1.37	? 22.9%	? 113	? 1.43	1
56	Venecia Prusia	n.d.	n.d.			Pre Factibilidad	1.200	? 5,256	? 50%	? 3,600	? 3,000	? 0.090	? 18.5%	? 2,804	? 1.56	? 27.0%	? 3,037	? 1.64	1
57	Las Pilonas	Río Huiza	San Salvador	13.5762	89.2177	Pre Factibilidad	1.100	2,961	31%	3,268	2,971	? 0.145	9.9%	-17	0.99	? 12.8%	? 489	? 1.12	1
58	Copinula	Río Copinula	Ahuachapán	13.7862	89.8445	Pre Factibilidad	0.241	1,055	50%	1,371	5,691	0.171	5.2%	-400	0.67	? 10.9%	? 67	? 1.04	1
59	Santa Emilia I	n.d.	n.d.			Pre Factibilidad	0.500	? 2,190	? 50%	? 1,500	? 3,000	? 0.090	? 17.0%	? 946	? 1.41	? 23.8%	? 1,044	? 1.47	1
60	Santa Emilia II	n.d.	n.d.			Pre Factibilidad	0.500	? 2,190	? 50%	? 1,500	? 3,000	? 0.090	? 17.0%	? 946	? 1.41	? 23.8%	? 1,044	? 1.47	1
61	Torola	Río Torola	San Miguel	13.8501	88.4663	Inventory	4.321	18,667	49%	4,710	1,090	0.033	26.0%	1,530	1.78	? 89.7%	? 18,607	? 3.20	2
62	Copinula III	Río Copinula	Ahuachapán	13.7721	89.8431	Inventory	0.463	3,187	79%	1,636	3,533	0.068	24.9%	2,364	2.02	41.4%	2,470	2.11	2
63	La Calzadora I	Quebrada La Calzadora	Usulután	13.5667	88.5000	Inventory	0.432	2,300	61%	1,308	3,028	0.075	22.6%	1,564	1.85	36.0%	1,648	1.94	2
64	Los Hervideros I	Río Los Hervideros	Ahuachapán	13.9550	89.9534	Inventory	0.993	5,457	63%	2,934	2,954	0.071	23.2%	3,688	1.85	37.3%	3,878	1.93	2
65	Los Hervideros II (Presa 1 & 2)	Río El Molino / Río Nejapa	Ahuachapán	13.9484	89.9264	Inventory	0.435	3,136	82%	1,902	4,372	0.080	21.5%	2,064	1.80	33.6%	2,187	1.89	2
66	Malancola	Río Jiboa	La Páz	13.5695	88.9850	Inventory	4.175	17,688	48%	10,926	2,617	0.081	21.3%	11,575	1.79	33.0%	12,282	1.88	2
67	Gran.d.e de San Miguel, Sn Juan	Rio Gran.d.e de San Miguel	Usulután	13.2947	88.3068	Inventory	4.500	19,710	50%	? 13,500	? 3,000	0.132	? 19.4%	? 11,773	? 1.67	? 29.0%	? 12,647	? 1.76	2
68	Gn.d.e de San Miguel, San José	Rio Gran.d.e de San Miguel	Usulután	13.2947	88.3068	Inventory	3.200	14,016	50%	? 9,600	? 3,000	0.132	? 19.3%	? 8,240	? 1.65	? 28.7%	? 8,861	? 1.74	2
69	Chilama I (Presa 1 & 2)	Río Chilama / Río Siguapate	La Libertad	13.6212	89.3309	Inventory	2.623	7,840	34%	5,197	1,981	0.087	19.5%	4,562	1.64	29.1%	4,898	1.73	2

Note: Italicized numbers are estimated values n.d.: no data
(Source: JICA Study Team)

Table 10.3.1.6 Selected Small Hydropower Potential Sites for Master Plan (2/2)

No.	Nombre de Proyecto	Río	Departamento	Latitud	Longitud	Etapa del Proyecto	Potencia	Energía	Factor de planta	Inversión Total	Costo/kW	Generación de costos	Base del Proyecto (sin préstamo del Banco) Project Base (without Bank Loan)			Base del Inversionista (con préstamo del Banco) Investment Base (with Bank Loan)			Fase del proyecto
	Project Name	River	Department	Latitude	Longitude	Project Stage	Potential	Energy	Plant Factor	Investment Cost	Cost/kW	Generation Cost	TIR FIRR	VAN NPV	B/C	TIR FIRR	VAN NPV	B/C	Project Phase
				(N)	(W)		(MW)	(MWh/Año)		(x 1,000 US$)	(US$/kW)	(US$/kWh)	(%)	(x1,000 US$)		(%)	(x1,000 US$)		
71	La Calzadora II	Quebrada La Calzadora	Usulután	13.5347	88.5294	Inventory	0.457	2,434	61%	1,677	3,670	0.091	19.0%	1,401	1.63	28.2%	1,509	1.72	2
72	EL Jabio	Rio Gran.d.e de Sonsonate	Sonsonate	13.7532	88.2887	Inventory	2.000	8,760	50%	? *6,000*	? *3,000*	0.132	? *19.0%*	? *4,979*	? *1.62*	? *28.1%*	? *5,367*	? *1.70*	2
73	El Rosario II	Río El Rosario	Ahuachapán	13.7754	89.8729	Inventory	0.498	2,606	60%	1,848	3,711	0.093	18.6%	1,460	1.60	27.2%	1,580	1.69	2
74	San Sebastián	Río Tihuapa	La Páz	13.5544	89.1366	Inventory	0.480	2,317	55%	1,656	3,449	0.094	18.4%	1,276	1.59	26.8%	1,383	1.67	2
75	Chilama II	Río Chilama	La Libertad	13.5929	89.3300	Inventory	0.457	2,343	59%	1,695	3,708	0.095	18.2%	1,273	1.57	26.4%	1,383	1.66	2
76	El Molino I	Río El Molino	Ahuachapán	13.9325	89.8960	Inventory	0.260	1,876	82%	1,345	5,175	0.094	18.2%	1,010	1.57	26.4%	1,097	1.65	2
78	El Refugio	Río Las Lajas	La Libertad	13.5569	89.2385	Inventory	0.465	2,243	55%	1,649	3,545	0.097	17.9%	1,191	1.55	25.8%	1,298	1.64	2
79	Los Toles	Río Los Toles	Ahuachapán	13.9715	89.9386	Inventory	0.428	2,035	54%	1,503	3,511	0.097	17.8%	1,065	1.54	25.5%	1,163	1.62	2
80	El Peñon	Río Gran.d.e de San Vicente	La Libertad	13.5855	89.3947	Inventory	0.486	2,212	52%	1,645	3,384	0.098	17.7%	1,157	1.54	25.4%	1,263	1.62	2
81	Guayapa V	Río Guayapa	Ahuachapán	13.9476	89.9636	Inventory	0.486	2,310	54%	1,741	3,582	0.099	17.5%	1,192	1.53	25.0%	1,304	1.61	2
83	El Charrerón	El Chorrerón	La Libertad	13.6178	89.3460	Inventory	0.418	1,903	52%	1,476	3,531	0.102	16.9%	927	1.48	23.8%	1,023	1.56	2
84	Santa Lucía	Río Tamanique	La Libertad	13.5962	89.4202	Inventory	0.966	3,609	43%	2,541	2,630	0.093	17.6%	1,766	1.49	25.2%	1,931	1.56	2
85	El Rosario I	Río El Rosario	Ahuachapán	13.7531	89.8731	Inventory	0.423	2,155	58%	1,800	4,255	0.110	15.9%	949	1.42	21.7%	1,065	1.49	2
87	Asesesco (Presa 1 & 2)	Río Asesesco / Río Viejo	Cabañas	13.8793	88.9226	Inventory	0.435	2,105	55%	1,767	4,061	0.111	15.8%	917	1.41	21.5%	1,032	1.49	2
88	Miramundo	Qda. Miramun.d.o	Chalatenango	14.3268	89.1353	Inventory	0.480	1,877	45%	1,567	3,265	0.110	15.8%	814	1.41	21.5%	916	1.48	2
89	Tilapa II	Río Gran.d.e de Chalatenango	Chalatenango	14.2237	89.0976	Inventory	1.925	6,402	38%	5,234	2,719	0.108	15.9%	2,762	1.40	21.7%	3,100	1.48	2
90	El Faro (Presa 1 & 2)	Río Los Leones / Río La Máquina	La Libertad	13.5990	89.3561	Inventory	0.426	1,750	47%	1,476	3,465	0.111	15.6%	739	1.39	21.1%	834	1.47	2
91	Santa María	Río Tihuapa	La Páz	13.5893	89.1307	Inventory	0.874	3,264	43%	2,494	2,854	0.101	16.2%	1,384	1.40	22.2%	1,545	1.46	2
93	San Pedro I	Río San Pedro	Ahuachapán	13.7386	89.8057	Inventory	0.344	1,944	65%	1,685	4,899	0.114	15.3%	791	1.37	20.5%	900	1.45	2
95	El Caoba	Río El Naranjo	Ahuachapán	13.7948	89.9263	Inventory	0.451	2,156	55%	1,898	4,209	0.116	15.1%	863	1.36	20.2%	986	1.44	2
96	El Rosario IV	Río El Rosario	Ahuachapán	13.8103	89.8788	Inventory	0.313	1,496	55%	1,290	4,122	0.114	15.2%	592	1.36	20.2%	675	1.43	2
98	Tizapa II	Río Tempisque	Cuscatlán	13.7917	88.9461	Inventory	0.418	1,907	52%	1,701	4,069	0.118	14.9%	732	1.34	19.7%	842	1.42	2
99	San Isidro	Río Sensipa	La Libertad	13.6160	89.4840	Inventory	0.477	1,782	43%	1,600	3,354	0.118	14.7%	669	1.33	19.4%	772	1.41	3
101	Loma de San Juan	Río Huiza	San Salvador	13.5449	89.2304	Inventory	0.954	3,837	46%	3,278	3,436	0.113	14.8%	1,391	1.32	19.5%	1,603	1.39	3
103	Los Pozos	Río Los Pozos	Chalatenango	14.3289	89.1455	Inventory	0.827	2,791	39%	2,276	2,752	0.107	14.9%	996	1.31	19.8%	1,143	1.38	3
104	Los Pueblos II	Río de Los Pueblos	Cabañas	13.8643	88.6869	Inventory	1.247	4,627	42%	4,075	3,267	0.116	14.5%	1,610	1.30	18.9%	1,873	1.37	3
105	El Jícaro (Presa 1 & 2)	Río Chuluma/Grand. de San Vicente	La Libertad	13.5933	89.4021	Inventory	0.496	1,851	43%	1,736	3,500	0.124	14.1%	632	1.29	18.3%	744	1.36	3
106	Guarumo	Río Guarumo	Cabañas	13.7670	88.8046	Inventory	0.897	3,647	46%	3,192	3,559	0.115	14.4%	1,233	1.29	18.8%	1,440	1.36	3
107	Guascoran	Rio el Sauce	La Unión	13.6446	87.7524	Inventory	12.500	38,000	35%	? *38,000*	? *3,040*	0.132	? *13.7%*	? *12,482*	? *1.28*	? *17.6%*	? *14,942*	? *1.35*	3
111	Agua Fría	Río Agua Fría	Cabañas	13.8100	88.8215	Inventory	0.974	3,960	46%	3,678	3,776	0.122	13.7%	1,187	1.25	17.5%	1,425	1.31	3
112	Chilama III	Río Chilama	La Libertad	13.5367	89.3142	Inventory	0.934	3,756	46%	3,491	3,738	0.122	13.6%	1,101	1.24	17.3%	1,327	1.31	3
113	Tehuechode	Río Chichicalapa	San Salvador	13.5926	89.1514	Inventory	0.339	1,267	43%	1,243	3,667	0.129	13.2%	352	1.23	16.7%	433	1.29	3
114	Tizapa IV	Río Ajuluco	Cuscatlán	13.7649	88.9248	Inventory	0.265	1,284	55%	1,268	4,786	0.130	13.2%	351	1.22	16.6%	433	1.29	3
115	Quezalate	Río Quezalate	La Libertad	13.5989	89.2288	Inventory	0.495	1,651	38%	1,679	3,391	0.134	13.0%	437	1.21	16.2%	546	1.28	3
116	El Anonal	Río El Zonte	La Libertad	13.5565	89.4540	Inventory	0.481	1,794	43%	1,835	3,815	0.135	13.0%	474	1.21	16.2%	593	1.28	3
117	Mizata I	Río Mizata	La Libertad	13.5786	89.5516	Inventory	0.421	1,727	47%	1,776	4,217	0.135	12.9%	445	1.21	16.0%	560	1.27	3
118	Los Pueblos I	Río de Los Pueblos	Cabañas	13.8726	88.7215	Inventory	0.412	2,081	58%	2,176	5,281	0.138	12.8%	524	1.20	15.9%	665	1.27	3
119	El Cutal	Río Teostrife	Chalatenango	14.2258	89.0690	Inventory	0.445	1,618	42%	1,675	3,764	0.136	12.8%	401	1.20	15.8%	509	1.26	3
121	El Silencio	Río Comalapa	La Páz	13.5940	89.1084	Inventory	0.287	1,178	47%	1,201	4,184	0.134	12.7%	281	1.19	15.7%	358	1.25	3
122	Concepción Los Planes	Río Comalapa	La Páz	13.5674	89.0916	Inventory	0.450	1,680	43%	1,766	3,924	0.138	12.6%	396	1.18	15.5%	510	1.25	3
124	El Escalón	Río Aquiquisquillo	La Libertad	13.5564	89.2489	Inventory	0.420	1,567	43%	1,641	3,908	0.138	12.6%	367	1.18	15.5%	474	1.25	3
125	Cuitapán	Río Cuitapán	San Salvador	13.5969	89.1825	Inventory	0.422	1,575	43%	1,659	3,930	0.139	12.5%	362	1.18	15.4%	469	1.24	3
126	Río Ceniza (Presa 1 & 2)	Río Ceniza	Sonsonate	13.7712	89.7030	Inventory	0.330	1,780	62%	1,898	5,751	0.140	12.4%	401	1.17	15.3%	524	1.24	3
127	Papaleguayo (Presa 1 & 2)	Río Papaleguayo/ Río El Patashte	San Salvador	13.5649	89.1588	Inventory	0.278	1,143	47%	1,198	4,308	0.138	12.3%	241	1.16	15.1%	318	1.23	3
131	San Benito (Presa 1 & 2)	Río Huiza / Río Texis	La Libertad	13.5925	89.4340	Inventory	0.483	1,613	38%	1,807	3,742	0.148	11.8%	276	1.13	14.1%	393	1.19	3
132	Tecomate	Río Cuitapan	San Salvador	13.5794	89.1882	Inventory	0.421	1,572	43%	1,758	4,176	0.147	11.8%	269	1.13	14.1%	383	1.19	3
133	Tilapa III	Río Gran.d.e de Chalatenango	Chalatenango	14.2371	89.1150	Inventory	0.480	1,619	39%	1,817	3,785	0.148	11.8%	276	1.13	14.1%	393	1.19	3
135	Ayacachapa III	Río Ayacachapa	Sonsonate	13.6506	89.5371	Inventory	0.312	1,166	43%	1,275	4,088	0.144	11.8%	199	1.13	14.2%	282	1.19	3
136	Ayacachapa II	Río Ayacachapa	Sonsonate	13.9282	89.5561	Inventory	0.448	1,495	38%	1,674	3,737	0.148	11.7%	250	1.12	14.1%	358	1.19	3
138	Tilapa I	Río Gran.d.e de Chalatenango	Chalatenango	14.2154	89.0780	Inventory	1.025	3,680	41%	3,954	3,858	0.142	11.6%	552	1.11	13.9%	808	1.17	3
139	Apancoyo II	Río Apancoyo	Sonsonate	13.6516	89.5709	Inventory	0.416	1,388	38%	1,589	3,819	0.151	11.4%	193	1.10	13.5%	296	1.16	3
144	Mizata II	Río Mizata	La Libertad	13.6137	89.5317	Inventory	0.270	1,109	47%	1,288	4,771	0.153	11.1%	118	1.08	13.0%	202	1.14	3
149	Talquezalar	Río Talquezalar	Chalatenango	14.2894	89.1316	Inventory	0.421	1,238	34%	1,501	3,565	0.160	10.7%	88	1.05	12.3%	185	1.11	3
150	El Cedro	Río Pepetapa	La Páz	13.5974	89.0623	Inventory	0.336	1,119	38%	1,348	4,012	0.159	10.7%	78	1.05	12.3%	165	1.11	3
156	San Ignacio	Río San Ignacio	Chalatenango	14.3288	89.1968	Inventory	0.441	1,269	33%	1,636	3,711	0.170	10.0%	5	1.00	11.3%	111	1.06	3
	Totales						**180.759**	**756,000**	**48%**	**586,000**	**3,242**	**0.105**							**123**
																		Phase-I	**59**
																		Phase-II	**32**
																		Phase-III	**32**

Note: Italicized numbers are estimated values. n.d.: no data
(Source: JICA Study Team)

10.3.1.10 Recommendations for Realization of the Master Plan

A. Site Reconnaissance and Detailed Study for Next Step

The level of precision of some parameters used in preparing the Master Plan, such as flow rate or the cost estimation, is not the one obtained in a field research or a feasibility study. The study used limited hydrological data and the 1/50,000 scale map to estimate necessary figures. For the realization of the master plan, the following field surveys and detailed studies are required.

When a site is classified as worthy of further detailed study, it is important to conduct a site reconnaissance along the proposed waterway route and alternative routes of a development site. Using 1:50,000 or 1:100,000 scale topographic maps, the differences between the topographic map and the actual topography, the geological conditions, existing facilities, and road conditions are to be verified in the site reconnaissance for each structure site. The results are inputted back to the study in preparation of the development plan. The following features should be carefully examined during the site reconnaissance.

- Topography: Topographic maps of 1:50,000 - 1:100,000 scale used in the reconnaissance study are of less reliable accuracy. The intake site topography and headrace route must be confirmed at the site as those features shown in the map may differ from the actual situation. Longitudinal and cross-sectional profiles of the penstock route are drawn based on the topographic map and an approximate location is confirmed at the site.
- Geology: The geological features at the intake site, and upstream and downstream of the site are surveyed. The condition of the foundation rock is confirmed from the outcrop of bedrock to determine its suitability as an intake weir site. The geology of the proposed headrace or penstock route and powerhouse site is checked from outcrops, vegetation, and landslide or slope failure.
- River flow: Flow at the intake site should be measured by using current meter or float.
- Riverbed deposit: Riverbed deposit is checked and the result is used to estimate future sedimentation behind the intake weir.
- Access road conditions to each site: As the availability of an existing road that will serve as access to the site during construction has significant effect on the project construction cost and construction schedule, existing navigable roads are checked on the site with the aid of a topographic map.
- Construction materials: For a concrete weir, the method of supplying concrete and locating a quarry site for aggregates are investigated at the site.
- Transmission line: The route of transmission or distribution lines that will transmit the electric power generated at the planned powerhouse is confirmed.
- Environmental survey: It is necessary to investigate the area for environmental restriction zones such as environmentally protected areas, natural parks, wildlife reserves, reserve forest, cultural assets, and houses, farms and existing water utility facilities, especially in the areas affected by the power plant. Water use for irrigation or drinking, fishery, etc., should be investigated during the site reconnaissance.

The plan is reviewed based on the data acquired from the site reconnaissance, and a final plan for site reconnaissance stage should be prepared. As a result of the review, if the development plan is judged to go for the next step of the study, pre-feasibility study and feasibility study should be conducted, and an investigation schedule should be prepared prior to the study.

In case there is no runoff gauging station at the intake site or in the adjacent areas, it is essential to install one and start runoff recording immediately.

B. Government Support in the Study, Design and/or Investment

To meet the objectives of the Master Plan it is required to facilitate the support of the government of El Salvador in various stages of the project development. Some aspects to consider are related to the land acquisition for the development of the projects, the feasibility studies and final design. Further, the government's support is required to simplify the process of obtaining the required permits.

The approval of the environmental permit should comply with the time periods established by law. It is estimated that if the 60 days (demanded by the art. 24 of the Environment Act) passed and if there is no environmental resolution, the project related to the use of renewable resources should be automatically approved.

Within the requirements of obtaining the Environmental Permit, there are commitments from the developer of the project for social development and local communities that are adjacent to the project site, these agreements should be notarized in the presence of a lawyer, and registered in the FISDL.

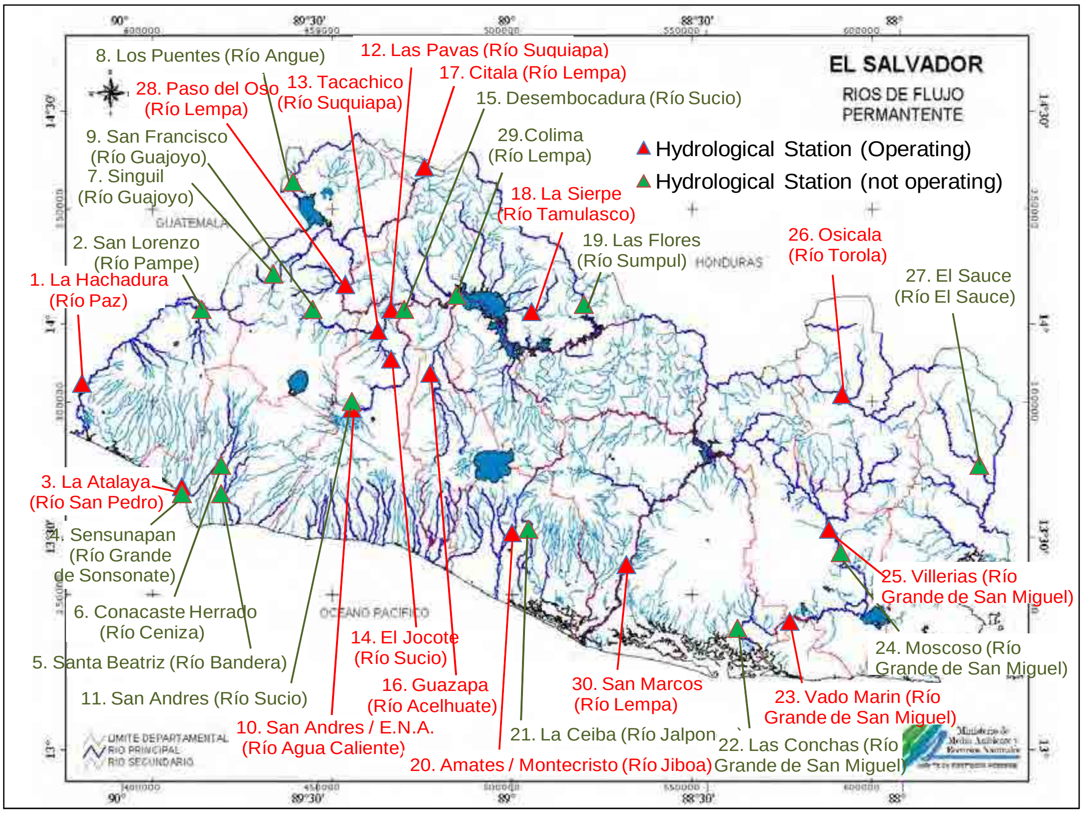
As part of the process of free competition and the implementation of existing regulatory frameworks for renewable energy, it is recommended to promote training and disclosure mechanisms relating to the topics and to be oriented to the developers of small hydro.

C. Nationwide Hydrological Observation System

Location map of hydrological stations by SNET is shown in Figure 10.3.1.14. Most of the observation stations were stopped from 1985 to 1992 during the period of the civil war. After the civil war, some of the stations resumed operations. The locations of hydrological stations are distributed partially. The number of hydrological stations is insufficient in the following areas:

- Department Ahuachapán: eastern part
- Department La Libertad: southern part
- Department San Salvador: southern part
- Department Chalatenango: northwest part
- Department San Miguel: northern part
- Department Morazán: all area
- Department La Unión: all area
- Department Cuscatlán: all area
- Department Cabañas: all area
- Department San Vicente: all area

Noteworthy, is the absence of hydrological stations in the departments of Cuscatlán, Cabañas and San Vicente.



(Source: Prepared by JICA Study Team based on the mean monthly discharge data of SNET)

Figure 10.3.1.14 Location Map of Hydrological Stations by SNET

Hydrological data is basic and essential information for the country, not only for hydropower development planning, but also for water resources such as irrigation, water supply, flood and/or draught control, or environmental protection and monitoring.

The long-term discharge observation data at the nearest station is required for planning of small hydropower projects. Thus, it is required to immediately build a nationwide network of hydrological and meteorological observation systems. The automatic telemeter hydrological observation system is suitable for monitoring of river flow.

D. Determination of River Maintenance Flow

In this master plan study, river maintenance flow was not considered in estimating the design discharge, power output [kW] and energy [kWh/year].

In El Salvador, most of the major hydropower plants are requested to release water, as a minimum, 10% of daily discharge for small hydropower, from intake weir site to downstream, as “river maintenance flow” for environmental and social purposes.

Study on the state of river utilization

As hydropower plants use river water, river utilization, such as for drinking, irrigation and industrial water supply, fisheries, and inland transport activities must be investigated during project planning.

The construction of the intake weir may sometimes result to inundation of houses and farmland, and consequently, the construction of a power facility decreases the river flow between the intake and tailrace sites. Therefore, water utilization facility in the project area should be carefully studied using available topographic maps and field investigation.

If there is water use between proposed intake site and powerhouse, the required discharge volume of water for utilization must be released downstream from the intake weir.

River Maintenance Flow (Caudal Ecologico)

River maintenance flow should be considered for cases where the length of the waterway of the proposed hydropower is long (more 1 km). The following items are recommended to satisfy the required minimum river maintenance flow for river ecology:

- 10% of daily discharge
- 10% of annual average discharge throughout the year
- 0.1~0.3 $m^3/s/100\ km^2$ (Japanese Guidelines for Hydropower)
- Minimum discharge throughout the year
- Necessary discharge for fishes, fauna and flora, landscape and river ecology

The acceptable and rationalized rate of river maintenance flow is as required and established by MARN.

10.3.2 Wind Energy

In this chapter, the permissible capacities of wind and solar energy in El Salvador are estimated. And also, procedures for wind monitoring and key issues on the construction of wind turbines are explained. Moreover, the technical aspects of operation and maintenance are explained. General implementation schedule of wind power projects and the project application processes in El Salvador are studied. As an example of wind power development in Central America, the current situation of wind power projects in Costa-Rica is studied.

10.3.2.1 Selection of Potential Sites

In the study, a nationwide wind potential map is prepared and several wind potential sites are identified on the map. The wind potential map and potential sites are explained in Chapter 7.

10.3.2.2 Allowable Capacity for Introduction to the Grid

The power output from wind turbine and solar PV system comes with large fluctuations of the power output depending on meteorological conditions. Because there is fluctuation of the daily load on the demand-side, it is necessary to adjust the power output depending on the current consumption of electricity to ensure stable supply of power. Therefore, it is necessary to conduct a review of the maximum allowable capacity for grid interconnection. However, in El Salvador, it is difficult to carry out simulation of the power network for analysis of the power grid that is interconnected with the wind and solar PV systems.

In the study, the allowable capacity of the wind power for grid interconnection was examined using an algebraic method of Tohoku Electric Power. In addition, the high penetration ratio of wind power to the interconnected power grid in European countries was taken into account. In the calculation, it is assumed that the maximum allowable capacity for grid interconnection can include both the wind and solar PV. This was considered because the fluctuation of power output from wind is larger than that of solar PV. Short-term fluctuations in the power output from wind and solar PV, such as those with 20-minute intervals, are very difficult to predict. On the basis of accumulated data from Tohoku Electric Power operations, the fluctuation in the power demand and the power output from wind turbine is estimated as shown below.

- Power demand fluctuation rate： 1.13% of national demand
- Wind power output fluctuation rate： 23% of wind capacity
- Lowest monthly peak demand： 864 MW (March 2010)
- Wind capacity (assumption） : 60 MW

Maximum allowable capacity for grid interconnection is examined by using an algebraic equation to the data mentioned above.

- Demand fluctuation ＝864 MW × 1.13% = 9.7 MW
- Output fluctuation ＝60 MW × 23% = 13.8 MW

The following shows the total fluctuation of demand and wind power output. The fluctuation becomes larger with any increase in wind power output.

$$\text{Total Fluctuation} = \sqrt{(\text{Demand fluctuation})^2 + (\text{Output fluctuation})^2} = 16.9\ \text{MW}$$

The maximum value to satisfy the lower equation is the allowable wind output fluctuation.

$$\sqrt{(\text{Load Frequency Control})^2 + (\text{Permissible error})^2} \geq \sqrt{(\text{Demand fluctuation})^2 + (\text{Allowable wind output fluctuation})^2}$$

$$16.9\ \text{MW} \geq \text{Allowable wind output fluctuation}$$

Assuming the grid interconnection of wind and solar PV as 60 MW of the 864 MW total installed capacity of the national power grid (maximum demand, January 2010 at 14:30H), the total fluctuation and allowable wind power output fluctuation values are almost the same. Therefore, the maximum allowable capacity of wind and solar power can be estimated at 60 MW in El Salvador. This value is approximately 7% of the assumed national power demand.

Therefore, it is desirable that the concentrated large-scale wind farm or solar PV systems be introduced progressively. In addition, when concentrated large-scale wind or solar PV systems are interconnected to the national grid in the future, it is necessary to re-examine the maximum allowable output capacity of wind and solar PV based on the result of the operating conditions of the actual installed power generation system.

The penetration ratio of wind power generation is high in European countries. The ratio in Denmark is around 21.9%, that of Spain is 16% and Germany is 9.4%. As for high penetration ratio in those countries, this is because wind power fluctuations can easily be absorbed by European countries that are bound together by a common power network. In Central America, wind power, with a total capacity of 62.8 MW, was introduced in Costa Rica, and the penetration ratio is approximately 4.2%. The maximum allowable capacity for grid interconnection will increase with the improvement of the smoothing technology for power output, such as battery storage.

Depending on the improvement of the future power demand and the selection of the technologies to be introduced, maximum allowable capacity may increase.

As for renewable energies, such as wind or solar PV power, power fluctuations easily happen depending on meteorological conditions. Therefore, implementation of technology to limit power fluctuations is necessary. A large-sized accumulator for charging power and smoothing the power output is required to mitigate the power fluctuations. However, the price of the accumulator is still expensive and thus, difficult to install in all wind power generators due to its high cost.

10.3.2.3 Consideration on Technical Aspects

A. Preparation Schedule

In El Salvador, grid connected wind turbines have not been installed yet. Therefore, it is necessary to prepare an action plan for the future implementation of wind power projects. In this Chapter, the planning process for wind power development is explained. The implementation planning for wind power generation varies depending on the purpose and business-scale.

In El Salvador, two types of application are being considered. The first case being considered is to sell all the generated power while the other case is to consume the generated power at a certain facility and sell any excess to power distribution companies such as CAESS, AES-CLESSA, EEO, DEUSEM, DELSUR, EDESAL, B&D and Abruzzo. It is a requirement for wind power developers to discuss this with the power distribution companies in El Salvador. Adjustment of technical issues on grid connected system and the selling price of generated power will also be discussed. Wind power project is one of the most economically feasible technologies amongst all renewable energy sources.

Submission of applications to concerned organizations is necessary before the implementation of the project. Since there are no wind projects implemented in El Salvador yet, there are no examples that can be used as a reference for project implementation. Therefore, the following procedures are suggested by the Ministry of Environment and Renewable Resources (MARN). The process of wind power development is similar to that of small hydro. However, since there is no previous experience on environmental impact assessment of wind power in El Salvador, it is difficult to predict the duration of the preparation schedule for application.

APPLICATION PROCEDURE

Step 1: The applicant surveys and identifies a project that utilizes renewable resources to generate electricity in a certain place.

Step 2: The applicant prepares the pre-feasibility study.

Step 3: Once the pre-feasibility study is conducted, the applicant receives environmental and technical forms from the Ministry of Environment and Renewable Resources (MARN). Then, it is filled-out and submitted to MARN together with all the required attachments.

Step 4: As MARN receives both the environmental and technical forms and all the required attachments, the next procedure is to qualify the project by category: a) “b1”, there is no need for an Environmental Impact Assessment (EIA) but compliance to certain conditions is required. b) “b2”, the project needs EIA and therefore Terms of Reference (TOR) are provided.

Step 4a: If the project has been classified by MARN as "b1", proceed directly to step 13.

Step 4b: If the project has been classified by MARN as “b2", then proceed to step 5.

Step 5: It is considered appropriate to inform the power distribution company about the project.

Step 6: The MARN will appoint an environmental inspector to study the proposed project site. The inspector verifies current conditions and collects necessary details for the TOR.

Step 7: After the inspection, the MARN will provide TOR to the applicant.

Step 8: Based on the TOR, the applicant will now prepare the EIA.

Step 9: The applicant submits the EIA to MARN.

Step 10: The applicant will need to revise the EIA if there are comments from MARN. It is necessary to revise the EIA until it is approved.

Step 11: Once the EIA is approved, MARN will issue the approval documents and inform the applicant of the necessity for an environmental bond.

Step 12: The applicant submits the environmental bond to the MARN.

Step 13: The applicant conducts the feasibility study for all the required technical issues.

Step 14: A copy of the feasibility study will be submitted to the local Electric Power distribution company.

Step 15: The local Electric Power distribution company reviews and evaluates the technical aspects of national grid interconnection.

Step 15a: If necessary, the applicant should correct the electrical issues in the feasibility study and submit it to the utility company for approval.

Step 15b: If there are no further remarks or recommendations, the electric power company issues technical approval.

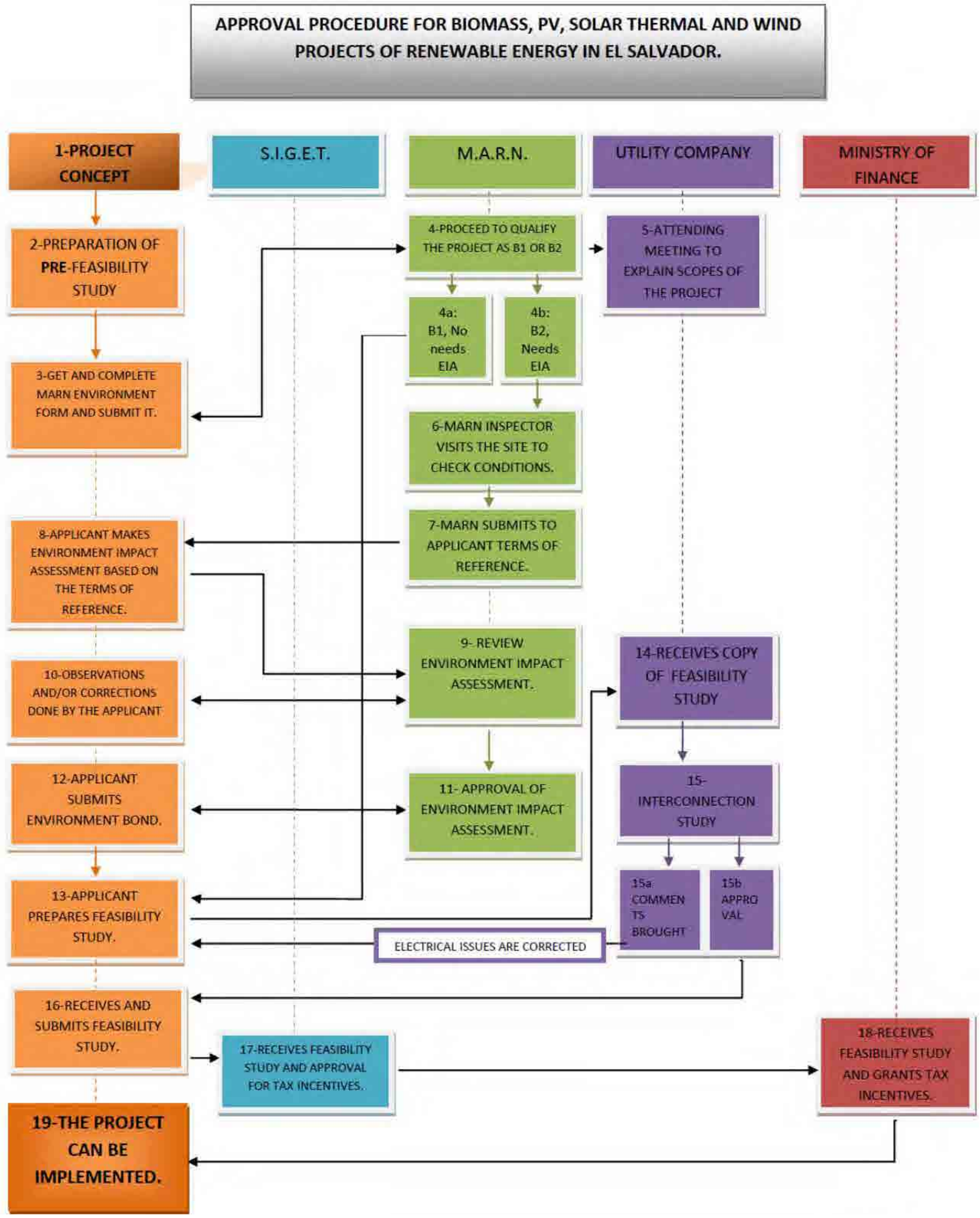
Step 16: The applicant submits the feasibility study approved by the power distribution company to SIGET.

Step 17: SIGET reviews the feasibility study and issues approval of the document.

Step 18: The Ministry of Finance receives the feasibility study approved by SIGET and grants tax exemption for the project.

Step 19: After all of the preparatory works are complete, the project can then begin construction.

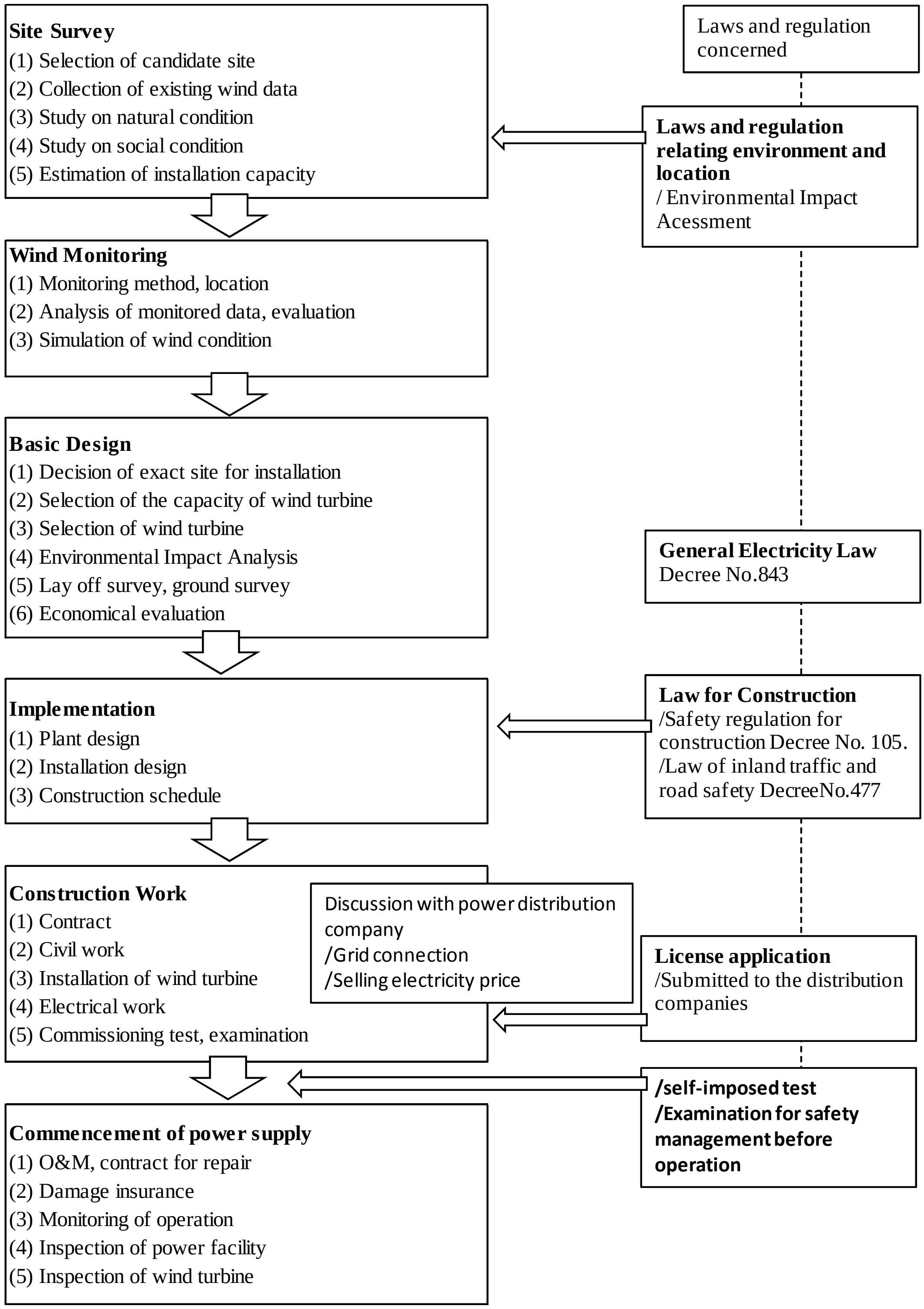
The following figure shows the preparation process for wind power projects. The same procedure can be applied for Biomass, Solar PV and Solar Thermal projects.



(Source: JICA Study Team)

Figure 10.3.2.1 Work Flow for Preparation of Wind Power Projects

The following figure shows the project implementation flowchart. In initial stage of the project, site survey and wind monitoring have to be conducted. On the basis of these results, the basic design and implementation plan will be prepared and after these are completed, construction will commence. After construction, power will be supplied after testing and commissioning.



(Source: JICA Study Team)

Figure 10.3.2.2 Process of Wind Power Development

B. Wind Potential Evaluation

a. Measurement Plan

The main objective of wind monitoring is to identify potential wind development areas that also possess other desirable qualities of a wind energy development site. In El Salvador, nationwide wind potential map is already prepared. Therefore, it is easy to identify good wind potential areas for wind monitoring. There are three steps in the wind monitoring works:

- Identification of potential wind development areas;
- Inspection and ranking of candidate sites; and
- Selection of actual tower location(s) within the candidate sites.

For the wind development plan, it is necessary to prepare measurement methodologies for wind monitoring. The following features should be specified in the preparation.

- Measurement parameters
- Equipment type, quality, and cost
- Number and location of monitoring stations
- Sensor measurement heights
- Minimum measurement accuracy, duration, and data recovery
- Data sampling and recording intervals
- Data storage format
- Data handling and processing procedures
- Quality control measures
- Format of data reports

b. Examination of Wind Power Potential

Wind analysis will be conducted to evaluate the wind characteristics based on the results of wind monitoring at candidate sites. On the basis of the results, power outputs from wind turbines are estimated. Consequently, installed capacity for the project will be decided.

b1. Monitoring Duration

The minimum monitoring duration should be one year, but two or more years will produce more reliable results. One year is usually sufficient to determine the diurnal and seasonal variability of the wind.

Inter-annual variability of the wind can also be estimated by comparing the data monitored at long-term reference stations such as airport and meteorological stations. The data recovery for all measured parameters should be at least 90% over the program's duration, with any data gaps kept to a minimum at less than a week.

b2. Wind Monitoring

In general, wind monitoring stations for wind power development are installed for a limited period only. Permission for the wind monitoring stations should be acquired from the land owner. The following table shows the basic parameters which should be examined in the evaluation.

Table 10.3.2.1 Basic Parameters

Measured Parameters	Recorded Values
Wind Speed (m/s)	Average Standard Deviation Maximum/Minimum
Wind Direction (degrees)	Average Standard Deviation Maximum Gust Direction
Temperature (°C)	Average Maximum/Minimum
Barometric Pressure (hPa)	Average Maximum/Minimum
Solar Radiation (W/m^2)	Average Maximum/Minimum

(Source: NREL Wind Resource Assessment Handbook)

Wind Speed

Wind speed data is the most important indicator of a site's wind energy resource. Multiple measurement heights are encouraged for determining a site's wind shear characteristics, conducting turbine performance simulations at several turbine hub heights, and for backup.

Wind Energy

The amount of energy in wind is a function of its speed and mass. At higher wind speed, more energy is available. Wind energy is the rate at which energy is available, or the rate at which energy passes through an area per unit time. The following formula shows the power that can be generated from wind.

$$P = \frac{1}{2}\rho A V^3$$

P: wind power (W)

ρ : Air density (kg/m^3)

A: Swept area (m^2)

V: Wind velocity (m/s)

Wind Direction

Wind direction frequency information is important in identifying preferred terrain shapes and orientations and in optimizing the layout of wind turbines in a wind farm. Prevailing wind directions have to be defined.

Temperature

In most locations the average near ground level ambient temperature (at 2 to 3 m) falls within 1°C of the average at hub height.

Vertical Wind Speed

Wind speed and power varies with the height above ground level. However, it is difficult to measure wind speed at the exact hub height especially at 80 meters. Therefore, it is necessary to measure wind speed at different heights to estimate that of the higher levels. Therefore, wind speed has to be monitored in at least two different heights.

The following equation illustrates how to use the power law method where V_0 is the wind speed at the original height, V is the wind speed at the new height, H_0 is the original height, H is the new height and α is the wind shear exponent.

$$V = \left(\frac{H}{H_0}\right)^{\alpha} V_0$$

V_0:	Wind speed at original height
V:	Wind speed at new height
H_o:	Original height
H:	New height
α:	Wind shear exponent

Table 10.3.2.2 Wind Shear Exponent

Terrain	Wind Shear Exponent α
Coastal areas	0.11
Cut grass	0.14
Short-grass prairies	0.16
Crops, tall-grass prairies	0.19
Scattered trees and hedges	0.24
Trees, hedges, a few building	0.29
Suburbs	0.31
Woodlands	0.43

(Source: Wind Power)

If wind speeds are monitored at different heights, it is possible to calculate the wind shear exponent using the following equation:

$$\alpha = \frac{\text{In}\left(\frac{V}{V_0}\right)}{\text{In}\left(\frac{H}{H_0}\right)}$$

Barometric Pressure

Barometric pressure is used together with air temperature to determine air density. However, it is difficult to measure accurately in windy environments because of the dynamic pressures induced when wind flows across an instrument enclosure. An indoor or office environment is the preferred location for a pressure sensor. Therefore, most resource assessment does not measure barometric pressure but instead use data taken by SNET stations that is then adjusted for elevation.

b3. Monitoring Height

Typical wind monitoring heights for both wind speed and direction are 40 m, 25 m, and 10 m. However, hub height goes higher with increased wind turbine capacity. In general, the typical hub height of a 1 MW wind turbine is about 60 meters, and that of 2 MW class is around 70 to 80 meters. Therefore, it is necessary to monitor wind speeds as close to the hub height as possible.

Ambient temperature, barometric pressure and solar radiation are monitored 2 to 3 meters above ground level.

b4. Placement of wind monitoring tower

Two important guidelines should be followed when choosing the location for the monitoring tower:

- Place the tower as far away as possible from local obstructions to the wind
- Select a location that is representative of the majority of the site.

Siting a tower near obstructions such as trees or buildings can adversely affect the analysis of the site's wind characteristics. The presence of these features can alter the perceived magnitude of the site's overall wind resource, wind shear, and turbulence levels. As a rule, if sensors are near an obstruction, they should be located at a horizontal distance no closer than 10 times the height of the obstruction in the prevailing wind direction.

c. Evaluation

c1. Monitoring

The following table shows the list to be evaluated based on the results of wind monitoring. For each evaluation item, the purpose and procedures for wind monitoring are stated.

Table 10.3.2.3 List of Wind Power Data forEvaluation

	Items	Term	Purpose	Procedure
Wind Condition	Average Wind Speed (m/s)	Annual Monthly	Evaluation of wind speed	Average Wind Speed ＝Sum of all hourly averaged value in of monitoring term / No. of data
	Wind Speed Frequency Distribution(%)	Annual	Evaluate characteristic of wind speed by wind speed frequency distribution	A wind speed class is established every 1m/s and calculates the relative frequency of each class
	Wind Direction Frequency Distribution (%)	Annual	Clarify prevailing wind direction	All wind direction is divided into 16 direction and accumulate in mean wind direction
	Directional Wind Speed (m/s)	Annual	Clarify prevailing wind direction to consider siting of wind turbines	An arithmetic average based on hour mean wind speed is calculated every direction
	Wind Speed Directional Frequency Distribution (%)	Annual	Clarify prevailing wind direction to consider siting of wind turbines	Relative frequency of each wind speed class (1m/s step) is calculated every azimuth
	Diurnal Wind Speed (m/s)	Diurnal Annual	Time variability of wind speed is evaluated for operational plan of the wind turbines	The average hourly wind speed of each month is calculated and clarifies the transaction by chart
	Turbulence intensity	Annual	Fluctuation properties of the wind speed and the direction with large wind speed fluctuation is clarified	It is calculated for the wind speed for all azimuth direction and each direction. Intensity of turbulence =standard deviation of wind speed / mean wind speed
	Vertical Wind Speed	Annual	Power index to predict wind speed at certain height is calculated and clarified vertical distribution of the wind speed	Each monitoring height and the wind speed are substituted for following formula and calculate it by a least squares $V/V1 = (Z/Z1)^{1/n}$
Wind Energy	Utilization Factor	Annual	Operational conditions of the wind turbine are clarified	It accumulates from the high wind speed side in wind speed relative frequency and calculates cumulative relative frequency. Utilization Factor = Cumulative relative frequency higher than cut-in wind speed - Cumulative relative frequency higher than cut-out wind speed
	Power Availability (Annual Power Output) ($kWh/m^2/year$)	Annual Monthly	Amount of power output that can be acquired from wind power generation is evaluated	It is accumulated in annual power output at every wind speed based on power curve of wind turbine and wind speed relative frequency.
	Capacity Factor	Annual Monthly	Possibility of the introduction of the wind power generation is evaluated	Capacity factor = power output / (reted power output x operational hours)

(Source: Guidebook for Wind Power Introduction / NEDO)

c2. Evaluation of Monitored Data

Suitable wind characteristics for wind power development are high average wind speed, steady wind direction and small intensity of turbulence.

Average Wind Speed

The sites where annual average wind speeds **exceed 6 m/s at 30 m** above ground level are acceptable for wind power development.

$$\text{Average Wind Speed (m/s)} = \frac{\text{Sum of all hourly averaged value withinthe monitoring period (m/s)}}{\text{Number of monitored data}}$$

Relative frequency of wind direction

If the relative frequency of annual wind direction is **more than 60% in the wind axis**, the wind direction can be considered as stable. (Wind axis is defined as the direction of the prevailing wind and the two immediate directions on both sides, and the symmetric directions of these three directions. In total, 6 azimuths out of the 16 azimuth angles are designated as the wind axis. The following figure shows an example of wind-axis (SSW, SW, WSW and ENE, NE, NNE) marked by the red line.)

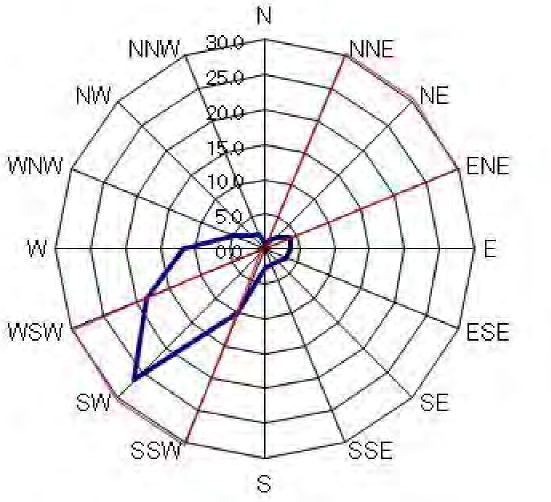


Figure 10.3.2.3 Wind-axis

Turbulence intensity

The intensity of turbulence is greatly affected by the topographic features. Therefore, it is difficult to standardize. It is generally within the range of **approximately 0.1-0.3** depending on the topographic features. Candidate locations can be reviewed if the turbulence intensity is larger than that of the IEC standard or it is necessary to consult with manufacturers for the selection of appropriate wind turbines.

$$\text{Intensity of turbulence} = \frac{\text{standard deviation of wind speed (m/s)}}{\text{mean wind speed (m/s)}}$$

c3. Evaluation of Output Energy

Wind Energy Density

Annual wind energy density has to be more than **240 W/m at 30 meters above ground level**.

$$\text{Wind Energy Density (W/m}^2) = \frac{1}{2}\frac{\rho \sum V^3}{T_0}$$

ρ : Air Density (W/m^3)

V: Hourly average wind speed (m/s)

T_0: Hours in the period

Wind energy Density is wind energy which available in unit area (m^2). Wind density can be calculated using the gas law as a function of change in temperature and pressure as shown in the following equation. For example, air density at standard temperature of 15 ^{0}C at sea level is 1.225 kg/m^3

$$\rho = \frac{P}{RT}$$

P: Air pressure (N/m^2)

R: Gas Content (287.04 J/kgK)

T: Temperature in Kelvin

Capacity Factor of Wind Turbine

Annual **capacity factor** has to be **more than 20%.**

$$\text{Annual Capacity Factor (\%)} = \frac{\text{Annual Power Output (kWh)}}{\text{Rated Power Output (kW)} \times 8760\ \text{(hr)}} \times 100$$

Utilization factor should be **around 90 to 95%** to account for repair system failures. Correction factor is 95% for flat land, 90% for complex terrain.

Annual Power Output (kWh) = Annual Power Output ×Utilization Factor ×Correction Factor

Operation rate expresses rate of system operation for power generation by hour. With the value that divided the total operation hours of wind turbine by annual hours, it is calculated by accumulation of relative frequency of wind speed from cut-in to cut-out wind speed. When a wind characteristics curve (cumulative relative frequency) is available, it is calculated by the following expressions.

Operation Rate (%) = Cumulative relative frequency higher than cut-in wind speed

— Cumulative relative frequency higher than cut-out wind speed

Power output correction factor has to be 95% in flat regions and 90% in complex terrains.

C. Basic Design

a. Determination of Exact Site for Installation

a1. Wind Potential

In El Salvador, the wind potential map is available. Therefore, it is easy to identify the wind potential area by using the map. The preparation process for the wind potential map is written in Chapter 7.

a2. Natural Environment

Wind condition is heavily dependent on surrounding terrain and circumstances. It is therefore necessary to study the local climatic features. Wind energy development should be located so as to optimize the aesthetic qualities of the surrounding landscape and those of the wind energy development itself.

b. Consideration of Natural and Social Conditions

It is necessary to consider the wind characteristics of the surrounding areas of the installation site to achieve maximum effect from the introduction of wind power generation. As for the location of the wind power turbines and power plant, these can be in mountain ranges, plains, coastal areas and sometimes parks or urban districts, and so on. In addition, it is necessary to consider other natural conditions that may damage the facilities and structures such as, lightning or damage from salt water. It is also necessary to consider the condition of the access road for bringing in materials or heavy machines during construction and the availability of potable water and electric power supply that will be needed during construction. In addition, compliance to local regulations, securing official licenses and permits to comply with land use policies (prohibited area; timber, farm land, urban district, park), is required. It is necessary to examine the environmental impacts such as noise, vibration, electromagnetic interference, landscape and the impact to the local ecosystem. In the technical aspect, considerations for meteorological conditions (i.e. hurricane, turbulent flow and lightning) of the site where installation is planned are important. During these past few years, there were few cases of problems with regards to landscape and ecosystem issues (the bird strike of particularly rare raptors). Therefore, consideration must be given to the concerns of local inhabitants and organizations. The summarized installation requirements that should be considered in the installation of the wind turbines are shown in the next table.

Table 10.3.2.4 List of Items to Consider in Advance

	Items	Issues to consider
Natural Condition	Wind Condition (speed /direction)	A site where the annual average wind speed exceeds 5 to 6 m/s at 30 meters above ground level is suitable for wind power projects. Additional consideration is necessary for areas with high incidence of hurricanes.
	Wind Flow	It is necessary to conduct additional studies at sites where turbulent flow caused by complex terrain is strong. For the installation of several wind turbines, it is necessary to consider the wake effects of wind and interference between the wind turbines caused by their placement.
	Lightning	Lightning produces a large energy surge during discharge. It is necessary to consider suitable countermeasures at areas with frequent lightning occurrence.
	Damage from salt water	It is necessary to take measures for mitigation of damage from salt water on structures near in coastal areas.
	Dust (Blowing sand)	It is necessary to be take measures to mitigate damage from dust or wind-blown sand in coastal areas.
	Geology, Slope	It is necessary to consider the ground gradient and other topographic features.
Social Condition	Prohibited territory	It is necessary to consider prohibited territories, such as natural parks and the nature conservation areas.
	Land use	It is necessary to consider the current land-use policy at candidate site
	Transmission / Distribution line, Transformer	It is necessary to consider the location of transmission lines, distribution lines and transformers.
	Road, Bridge, Port	It is necessary to consider the road conditions, such as road width and curvature for transportation of materials, wind turbines and equipment. It is necessary to pay special attention to the material (space and weight) restrictions of the bridge and the harbor.
	Noise	It is necessary to pay attention to the distance from the nearest households.
	Electromagnetic radiation	It is necessary to pay attention to the distance and direction to important radio aids so as to minimize interference.
	Bioecology	It is necessary to consider the effect on animals and plants in nature.
	Landscape	It is necessary to pay attention on its influence on the landscape.

(Source: JICA Study Team)

C. Selection of Wind Turbine

Plans for the placement of the wind turbines based on the estimated most suitable installed capacity will be established through the following procedures:

<u>Estimation of power output</u>

Total power output from wind turbines will be assumed based on the available project implementation budget and other considerations such as distance, capacity and main load of the power transmission and distribution grid.

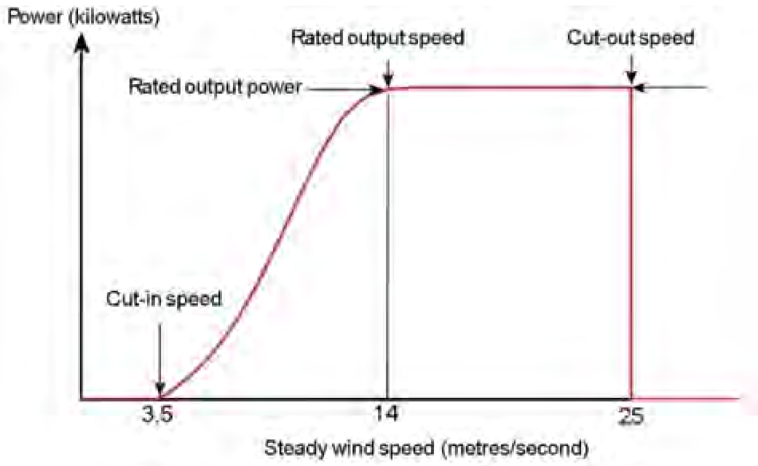
On the basis of the power output curve which will be provided by the manufacturers, power output of the wind turbine is estimated. The manufacturers estimate the power output of their turbine under the standard condition of hub-height wind speed, Rayleigh distribution, air density at sea level and 15 ^{0}C.

When wind speed is stronger than the cut-in wind speed, the wind turbine starts generating power. Power output of wind turbine is controlled by pitch or stall when wind speeds reach the rated value. Rotor is stopped to prevent damage and to stop power generation when wind speeds are too strong. The following figure shows the typical wind turbine power output with steady wind speed. Cut-in, cut-out and rated output speed depends on the performance of the wind turbines. In general, the following wind speed values are applied:

Cut-in wind speed : 3～4 m/s

Rated wind speed : 12～16 m/s (dependent on the performance of wind turbine)

Cut-out wind speed : 24～25 m/s



(Source: UK wind power program)

Figure 10.3.2.4 Power Curve of Typical Wind Turbine

The following table shows the power output from a typical wind turbine. Average power output from wind turbines is calculated using the power curve by multiplying the power output with wind probability at each wind speed. The following equation shows annual power output at wind speed Vi (m/s).

$$\text{Annual Power Output (kWh)} = \sum (P_i \times f_i \times 8760\ (h))$$

P_i : Power output (kW) at Vi (m/s)

f_i : wind probability (%) at Vi (m/s)

Table 10.3.2.5 Estimation of Power Output

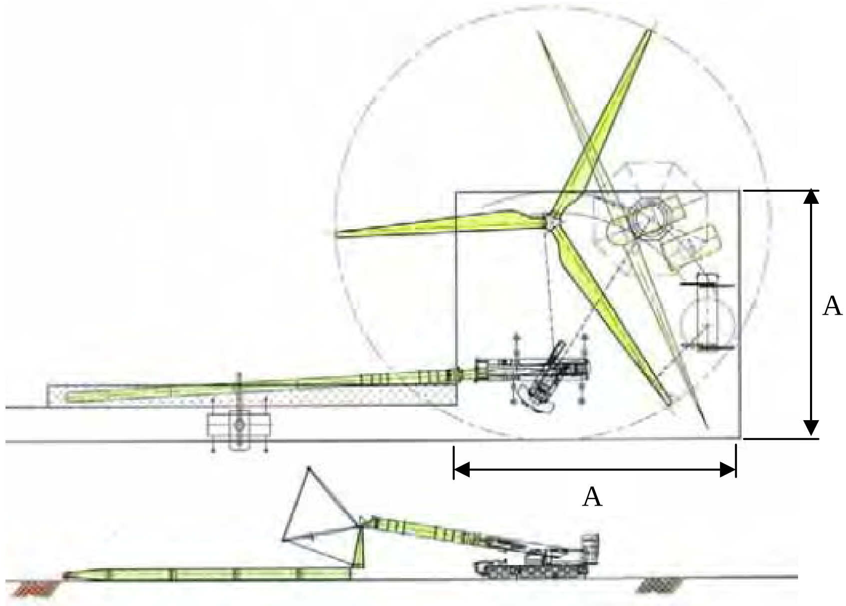
V (m/s)	Power Curve (kW)	Wind Probability (f)	Net kW
0	0	0.885%	0.00
1	0	6.803%	0.00
2	0	12.238%	0.00
3	18	15.383%	2.77
4	55	16.015%	8.81
5	102	14.564%	14.86
6	157	11.847%	18.60
7	255	8.730%	22.26
8	367	5.872%	21.55
9	487	3.622%	17.64
10	595	2.056%	12.23
11	677	1.077%	7.29
12	735	0.521%	3.83
13	779	0.233%	1.82
14	797	0.097%	0.77
15	801	0.037%	0.30
16	788	0.013%	0.10
17	769	0.004%	0.03
18	749	0.001%	0.01
19	733	0.000%	0.00
20	717	0.000%	0.00
21	705	0.000%	0.00
22	701	0.000%	0.00
23	700	0.000%	0.00
24	702	0.000%	0.00
25	0	0.000%	0.00
		100.00%	132.87

(Source: JICA Study Team)

D. Implementation Plan

a. Construction Area

In areas where the introduction of wind power generation is planned, the field selected based on the natural and social conditions is recommended as the site where construction of the wind power generation facility is possible. In the case of installation of a single wind turbine, the field with the most suitable wind characteristics should be selected in the available area. Occupancy dimensions where wind turbine is assembled on ground and installed are shown below.



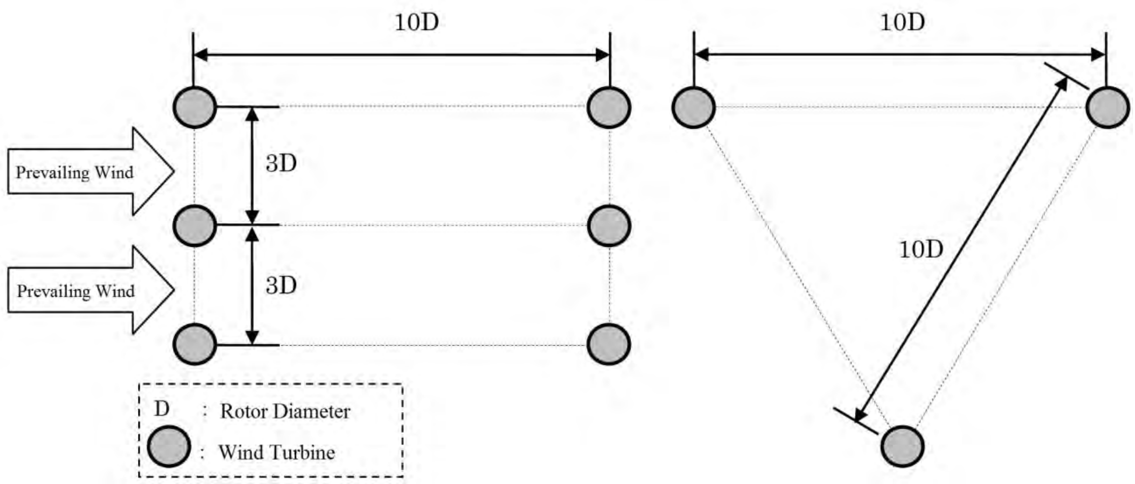
(Source: Guidebook for Wind Power Introduction: NEDO)

Figure 10.3.2.5 Required Occupancy Dimensions during Construction

500 kW Class:	A=50 m×50 m
1,000 kW Class :	A=65 m×65 m
2,000 kW Class :	A=85 m×85 m

On the other hand, it is necessary to consider the prevailing wind direction at the installation site in deciding the layout if multiple wind turbines will be installed. The disturbed area of wind characteristics formed leeward of the wind turbine is called the wake area. If another wind turbine is installed in the wake area, the amount of power output from that wind turbine decreases greatly. The wake area is confirmed by experimentation and actual measurement. It is approximately 3 times the rotor (D)diameter perpendicular to the wind direction, and it is approximately 10 times in the leeward direction. Therefore, construction should be avoided in these wake areas where multiple wind turbines are installed.

In the area where the general direction of the wind is clearly defined, the wind power generation facility is designed with a rectangular layout of $10D \times 3D$. In the area where the general direction of the wind is not clearly defined, the wind power generation facility is designed in a triangular layout of $10D \times 10D$ x $10D$. A concrete layout example is shown in the figure below.



(Source: Guidebook for Wind Power Introduction: NEDO)

Figure 10.3.2.6 Layout of Multiple Wind Turbines

b. Heavy-Duty Vehicle

It is necessary to complete the installation of wind turbines without problems during the implementation period. In this period, construction of foundations, assembly of equipment, installation of towers, wiring and site preparation have to be completed. Therefore, it is necessary to establish a construction plan and work schedule for safety purposes. It is necessary to consider the following issues: For the construction of wind turbine, a trailer for transportation of materials and a crane truck for tower installation will be required. It is necessary to investigate road conditions such as the width of the road, slope, curve, weight limit of bridge and so on, to determine if the site will be accessible for these types of heavy-duty vehicles. Truck crane and crawler crane will be used for the installation of the wind turbines. However, a 2000 kW class wind turbine can be installed by a truck crane if the nacelle can be divided into several parts and if the length of the tower is shorter. For installing multiple wind turbines, assembly and disassembly of crawler crane for every wind turbine takes much time. It will be more economical and faster to move the crawler crane to next location instead of taking it apart and assembling it again. In this case, it will be necessary to widen the existing road for transporting the crane. Therefore, calculating any additional costs will be necessary. The land use restrictions for the installation works will also have to be confirmed at the same time. The following table shows the summarized information of heavy-duty vehicles needed for wind turbine installation.

Table 10.3.2.6 Heavy-Duty Vehicle for Wind Installation

	Item	unit	600kW	1,000kW	2,000kW
Specification of Wind Turbine	Weight of Nacelle	ton	35	45	65
	Diameter of rotor	m	45 - 50	60	80
	Length of blade	m	22 - 25	30	40
	Weight of tower	ton	40 - 80	80 - 120	150 - 250
	Length of tower	m	35 - 50	50 - 70	60 - 100
Heavy Duty Vehicle	Transportation (blade)		pole trailer	pole trailer	pole trailer
	Transportation (nacelle)		low-floor trailer	low-floor trailer	low-floor trailer
	Installation		Sub Crane 50t	Sub hydraulic Crane 100t	Sub hydraulic Crane 120t
			Main Crane 200t	Main hydraulic Crane 550t	Crawler Crane 650t

(Source: Guidebook for Wind Power Introduction: NEDO)

E. Implementation Schedule

Enough space of leveled land area is required for assembling the blades, tower construction and the main jib assembly of the truck crane. After construction of foundations for the wind power generation facility is completed, it will be necessary to conduct schedule adjustment with other work schedules. Depending on the model of wind turbine, there is a method to attach each piece of blade to the nacelle directly without assembling the blade on the ground. In addition, there is a method of construction involving the use of special lifts instead of the large-scale crane truck. In this case, the land area prepared for construction work becomes smaller. As for the installation work of the switchboard and cubicle, electrical works and other related works may be carried out during the same period. Therefore, schedule adjustment is necessary for each work starting from the planning phase of the works. For conveyance and lifting of heavy materials, it is necessary to be careful about loading and hoisting loads. In addition, it is necessary to be careful about changes in the wind speed while the crane is operating. Construction work under hazardous conditions is never allowed. It is necessary to take preventive measures against unauthorized persons entering the construction zone except for persons concerned with the project. In addition, it is necessary to pay attention to the technical specifications of the works.

The construction period takes approximately around three months for a wind turbine from commencement of civil engineering work to the end of the trial run. The work schedule is a standard term so that the schedule varies with the capacity of wind turbine and the process of installation. For the installation of large-scale wind farms, e.g. 10 turbines of 2,000 kW class, the usual construction period required will be more than 12 months. However, in this case, construction period varies with construction conditions greatly.

Table 10.3.2.7 Implementation Schedule

N	Schdule of Wind Turbine Construction		1st Month			2nd Month			3rd Month			4th Month		
	Milestone		●Groundbreaking				●Receive electricity					●Hand over		
1	Civil Works	Road and Land Construction	■											
		Construction of Basement	■	■	■	■	■	■	■					
		Maintains the area of the generating plant						■						
2	Electrical Works	Wireing for interconnection			■	■								
		Installation of switchboard and the cubicle			■	■								
		Wiring and Grounding Works	■	■	■	■	■	■	■					
3	Wind Turbine (including transportation)	Assembly and Installation of Tower							■					
		Assembly and Installation of nacell and rotor							■					
		Installation and the wiring of the control unit							■					
4	Monitoring device	Installation of monitoring devices			■	■	■	■	■	■				
5	Comissioning Test	Examination by Manufacture (adjustment)								■				
		Self-imposed test				■	■	■	■	■				
		Testing Operation									■			

(Source: Guidebook for Wind Power Introduction: NEDO)

F. Operation and Maintenance

a. Operation & Maintenance

Maintenance inspection is essential in maintaining the high operating rate of the wind turbine generator. For O&M, daily monitoring of operations, periodic and regular maintenance and modification, and the repair of equipment are required. Monitoring of operation with daily inspection contributes to the detection of problems early. Objectives of maintenance and repair are to operate the facility safely under stable conditions. It is necessary to maintain the high operational rate of wind turbines, so rehabilitation works will have to be conducted promptly after the maintenance works. Generally, maintenance means periodic inspection. And maintenance service means investigation and rehabilitation works on parts that are close to failure and problems that occur irregularly. The contractual agreement for the operations and maintenance should be reviewed. The O&M cost is one of the important factors when selecting the model to evaluate economical efficiency. In anycontract agreement, it is necessary to consider the highly specialized nature of the works. It is recommended to carry out negotiations with the manufacturer or a specialized O&M company in consideration of the items which are shown in the following table.

Table 10.3.2.8 Operation and Maintenance

List	Items to be Considered
Contract for monitoring of operation	1) Monitoring items, contents, issues and frequencies have to be clarified. 2) Qualifications and conditions to be monitored have to be clarified. 3) Duty of the monitor, working condition and monitoring area has to be clarified. 4) Selection between monitoring methods, such as remote or direct monitoring. 5) Framework corresponding to emergency cases has to be made clear. The cases in which a monitoring personnel communicates are made clear. 6) Periodic reports for the owner: term (week, month, year), item, reporting method and disclosed data are confirmed.
Contract for maintenance (Periodic Inspection)	1) Facility for maintenance (wind turbine, electrical equipment, others), contents, maintenance period, cost, necessity of assistance, traveling expenses and transportation are decided. 2) Work fulfillment condition is clarified. 3) Maintenance contractual guarantee conditions for the inspection part. 4) Confirmation of road accessibility for equipment and service engineer. And assignment of road responsibility is clarified. 5) Dissolution and renewal conditions of the contract are clarified. 6) If the maintenance contractor is different from the equipment supplier, term charge out, guarantee conditions, warranty area and condition and availability of a spare item are clarified. 7) Availability and delivery of consumable supplies. 8) Target term is made clear.
Contract for maintenance (irregular inspection)	1) Target range of the service (a product, work, and conveyance), contents, time of service, cost, necessity of assistance, contents of warranties is clarified. 2) Setting of the repair duration considering re-arrangement of heavy machinery when non-conformity occurs due to large-sized equipment, transportation and procurement of parts. 3) Service procedure (from whom, until when, who, what) . 4) Confirmation of road accessibility for equipment and service engineer. And assignment of road responsibility is clarified.
Contract for repair (modification, repair)	1) Modification, purpose of the repair, effect, term and costs are clarified. 2) Modification, coverage for the repair result, term and substance are clarified. 3) Necessity of securing access road for heavy-duty machines for modification and repair are clarified. Assignment of the work responsibility is clarified. 4) If enforcement of modification and repair is different from an equipment supplier, necessary items such as the coverage of the equipment supplier and the modification of conditions are made clear. 5) If enforcement of modification and repair is different from an equipment supplier,

	condition and range of disclosed information from owner company are clarified.
Spare parts	1) Consumables, spare parts, replacement period and price are clarified. 2) Supplemental spare parts stocked by operating company, aged consumables, new model. 3) Necessity of exchange of spare parts. The defrayal of costs is made clear.
Tools and fixture	1) The scope of supply, cost and compensation by the operating company have to be clarified. 2) The scope of supply, cost and compensation by the company in charge of O&M have to be clarified. 3) Necessity of special fixture, availability, cost, operation is clarified.
Right of access	Monitoring operations by owner company, maintenance, right-of-access to wind turbine is disclosed to the service company.
Training	1) Training of owner company by the equipment supplier: contents, term and limitation of operation are clarified. 2) Training for the engineer of the owner company for primary correspondence: contents and the defrayal of costs are clarified. 3) Training of operation monitoring company by owner company: term and limitation operation are clarified. 4) The training of the maintenance company by owner company: contents and operating range are clarified. 5) Training of the service firm by owner company: contents and operating range are made clarified.
Restriction of debt	1) If supplier conducts modification or exchange of equipment without the agreement of the proprietor: responsibility and charge-out of the supplier for non-conformity which accrued are clarified. 2) If proprietor modifies it without the agreement of the supplier: responsibility and charge-out of the system owner for non-conformity which accrued are clarified. 3) Dissolution of maintenance service, manifestation of reclamation contents.

(Source: Guidebook for Wind Power Introduction: NEDO)

The wind turbine generator has many mechanical parts, and periodic inspections such as refilling of the lubricating oil or the exchange of consumable supplies are required.

The company-in-charge of O&M and the owner company commits to a maintenance agreement together for the purpose of improving the operating efficiency in carrying out mechanical and electrical inspections. The periodic inspections vary according to the manufacturer, but quarterly inspections are recommended by most manufacturers. The inspection costs for a 2000 kW capacity wind turbine is around US$50,000.00 per year. Visual inspection will be conducted for the cables, blades and tower booms. Lubricating oil refilling, terminal strapping, bolt dip, and braking system will also be inspected. It is necessary to change the oil for braking valve unit, gear box, oil hydraulic brakes regularly.

Table 10.3.2.9 Periodic Inspection

Item	Contents of Inspection
Visual Inspection (4 times/year)	All parts are checked in appearance (discoloration, nasty smell, extraordinary noise, modification, fissuring).
	Inspection for rusted or corroded parts.
	Rainwater encroachment.
	Inspection of each department's fluorescent light fittings.
Inspection of Oil (2 times/year)	Changing canned grease for each bearing part.
	Grease refilling of each bearing part and revolving superstructure of nacelle.
	Confirmation of oil quantity in gear box of the yaw control system.
	Pitch gear box oil quantity of the oil hydraulic brake unit will be checked.
Inspection on Mechanical Parts (1 time/year)	Tightening of the tower foundation bolt, abnormality can be determined from the basement surface.
	Tightening of the bolts of the blades.
	Securing of the bolts in the tower foundation except the blade.
	Changing the oil of the yaw gear box.
	Changing the oil of the pitch gear box.
	Changing the oil of the oil hydraulic brake unit.
Inspection on Electrical Parts (1 time / year)	Inspection and adjustment of each sensor switch of wind turbine.
	Connection of the main circuit is confirmed.
	Each parameter of the wind turbine is confirmed.
	Performance testing of all parts.
	Testing of protective system.

(Source: Guidebook for Wind Power Introduction: NEDO)

G. Experience of Other Countries in Central America (Costa Rica)

In Central America, wind power development has been implemented in Costa Rica. Around 63 MW of wind turbine capacity is currently operating in the country.

Installation of a wind farm with a total capacity of 12.8 MW was completed at Los Santos, San José in September 2011. During the preparation stage, transportation from port to candidate sites of the wind farm was confirmed. In the installation process, the foundation of the wind turbine was constructed by Costa Rican companies. And for installation, a crane truck with a 275-ton capacity was used. In total, GAMESA's (Spanish company) 15 wind turbines with a capacity of 850 kW each are installed. The tower has a height of 44.55 m with a 52 m rotor diameter.

The project cost is shown in the table below. In Costa Rica, kW cost of wind power project is US$1,975/kW.

Table 10.3.2.10 Table of Wind Farm in Costa Rica

No.	PROJECT NAME	LOCATION	POTENTIAL (MW)	INVESTMENT (US$)
1	GUANACASTE 1ST STAGE	GUANACASTE PROVINCE	25	$88,000,000.00
2	GUANACASTE 2nd STAGE	GUANACASTE PROVINCE	25	
3	VALLE CENTRAL	Los Santos, San José	12.8	$36,000,000.00
TOTAL			**62.8**	**$124,000,000.00**

(Source: JICA Study Team, based on the expansion plan of ICE Costa Rica)

10.3.2.4. Master Plan

A master plan of wind power development from 2012 to 2026 is required in this study. However, this is only the plan by CEL. Thus, the following development plan was compiled for implementation from 2012 to 2016 based on information from CNE. On the other hand, the CEL plan only points out the possibility of further wind development plan.

Wind power development plan of CEL will be revised continuously. Therefore, wind power development plan will have to be revised for several years. CNE has to coordinate with CEL and other institutions to update the Master Plan.

10.3.2.5 Recommendations to institute the Master Plan

1. Installation of monitoring systems for the most important parameters presented in this study. It is recommend to monitor wind potential at the potential sites which are shown in Figure 7.1.5 and Table 7.1.5

2. Strengthen the ability of experts or institutions for data collection, analysis and evaluation of wind monitoring.

3. There are technical regulations on protection of electrical works. However, it is necessary to define the regulation on unintentional operation for wind turbines.

4. It is necessary to consider regulations on wind power capacity for grid interconnection to avoid increase of fluctuation.

5. It is necessary to transfer the technology on O&M skills, wind monitoring and simulation of grid

connection as a part of human development in El Salvador.

6. It is necessary to clarify to wind development sites not only based on wind potential but also surrounding condition for grid interconnection such as distance to distribution lines, access roads and households.

Table 10.3.2.11 Master Plan of Wind Development

Year	Capacity (MW)	Power Production (MWh/year)
2012 to 2016	10	21.9
2017 to 2021	20	43.8
2022 to 2026	30	65.7

(Source: JICA Study Team)

10.3.3 Solar PV Power

In this Chapter, key issues on construction, technical aspects of operation and maintenance are explained. System structure, site surveys, equipment plans and sample implementation schedule for MW-class solar photovoltaic(PV) systems and O&M work items are explained. There is an existing solar PV system with 100 kW of installed capacity in El Salvador, and the installation project cost is used as a reference in this report. For the Master Plan, review of installation schedule every five-year duration is recommended. As for the rooftop solar PV, details are explained in Chapter 7.

10.3.3.1 Selection of Potential Sites

Nationwide solar potential map which was prepared by SWERA is explained in Chapter 4. This map shows the high solar irradiation in the country, especially at the central region of El Salvador.

10.3.3.2 Allowable Capacity for Introduction to the Grid

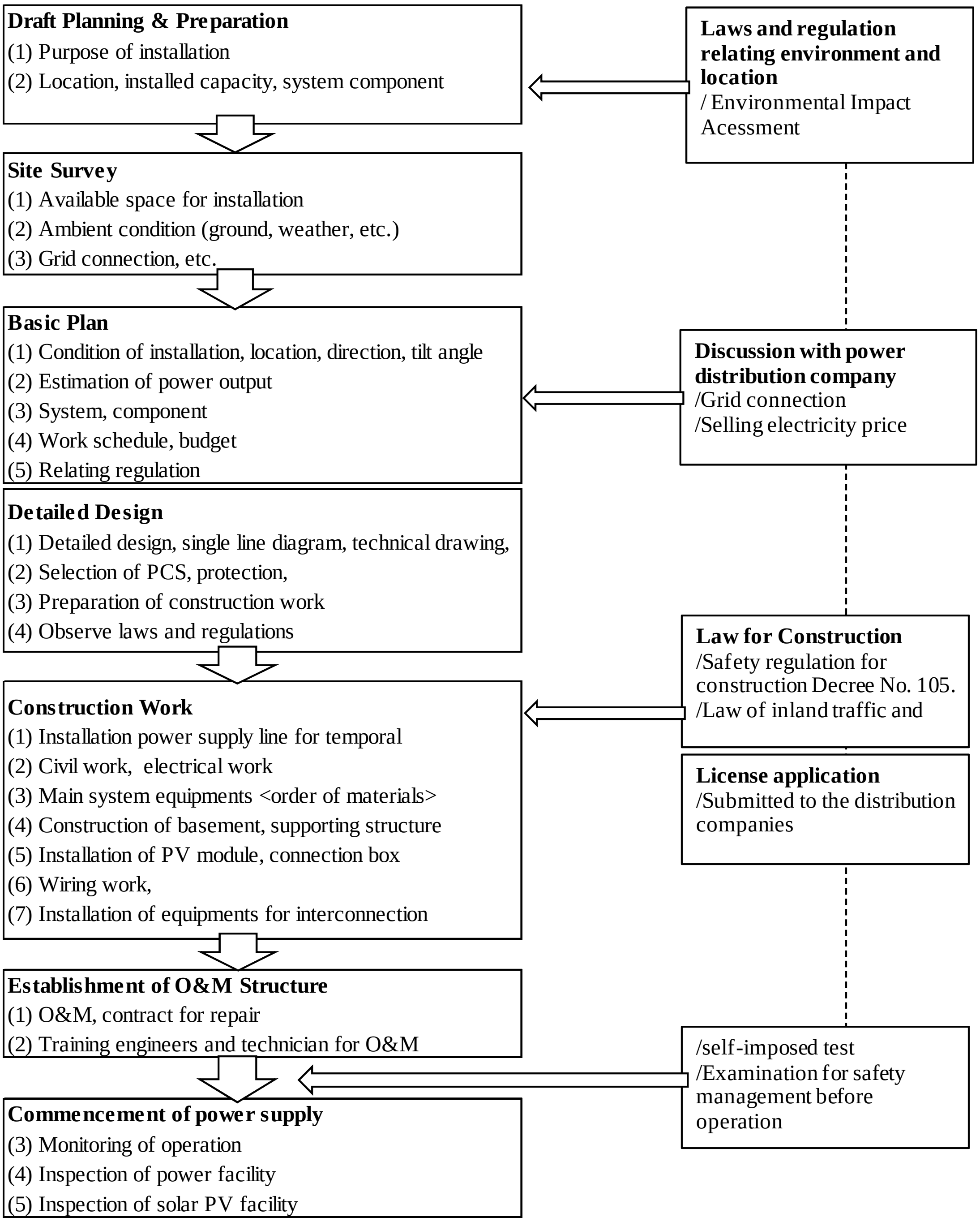
The allowable capacity for wind and solar energy sources is explained in Section 10.3.2.2. The power output from solar PV comes with large fluctuations of power output depending on meteorological conditions. In the study, allowable capacity of the wind and solar power for grid interconnection was examined using the algebraic method of Tohoku Electric Power. The result shows a 60-MW maximum allowable capacity for the grid-interconnected solar PV and wind systems. This value is approximately 7% of the lowest national monthly maximum power demand in 2010. Depending on the improvement of the future power demand and the selection of the technologies to be introduced, maximum allowable capacity may increase. It is necessary to re-examine the maximum allowable capacity of wind and solar energy when concentrated large-scale wind or solar PV systems are interconnected with the national grid in the future.

10.3.3.3 Consideration on Technical Aspects

A. Preparation

The preparatory works for solar PV systems follows the same methodology mentioned in Section 10.3.2.2. Work flow for the preparation of solar PV projects is the same as that for wind power projects as shown in Figure 10.3.3.1.

Figure 10.3.3.1 shows the flowchart of the project implementation. During the initial stages of the project, concept plan and basic design of solar PV installation will be considered. On the basis of these results, the basic design and implementation plan will be prepared. The solar PV system will then be constructed based on the prepared plans, before commissioning tests are conducted. After completion of the project implementation process, power will be supplied to the grid.



(Source: JICA Study Team)

Figure 10.3.3.1 Process of Solar PV Power Development

B. Evaluation of Solar PV Potential

a. Examination of Solar Irradiation

Nationwide solar irradiation map was created under the SWERA Project and solar irradiation is currently being monitored at several locations. Meteorological data are available at SNET (Servicio Nacional de Estudios Territoriales). Solar irradiation, ambient temperature and other data are available in the website of NASA on Surface Meteorology and Solar Energy, (http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi). If solar irradiation data are not available from the actual site, the data can be obtained from this website. The following table shows solar irradiation data which was collected under the SWERA Project.

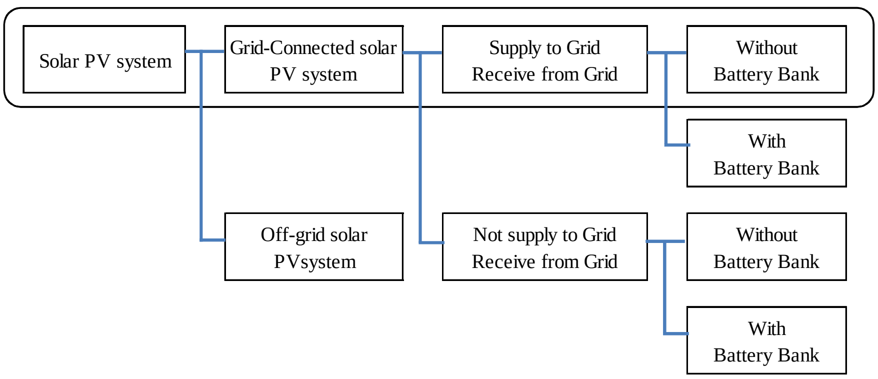
Table 10.3.3.1 Solar Irradiation Data for El Salvador (kWh/m^2/day)

Monitoring Station	Monitoring Period	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Los Planes de Montecristo	1980-1983	5.2	5.0	4.5	3.6	4.1	5.2	4.7	3.8	4.4	4.6	4.6	3.6	4.9
Chalatenango	1984-1987, 1989-2000, 2002	5.0	5.6	5.3	5.1	5.0	5.5	5.5	4.8	4.7	4.3	4.3	4.3	4.6
Nueva Concepción	1980-1984, 1986	5.4	5.7	5.5	5.2	5.2	5.4	5.4	5.0	4.9	4.7	4.6	4.6	4.9
Ahuachapán	1980-1 984	5.4	5.7	5.5	5.0	4.7	5.2	5.0	4.3	4.5	4.6	4.5	4.3	5.0
La Unión	1980, 1985	5.1	5.4	5.3	4.8	5.0	5.3	5.2	4.8	4.7	4.5	4.4	4.4	4.7
Estación Matriz	1980-1984	5.6	6.2	5.9	5.2	5.3	5.9	5.6	4.9	4.8	5.0	4.8	4.8	5.1
San Salvador	1983, 1984, 1985, 1986, 1987	5.4	5.7	5.4	4.9	5.0	5.5	5.2	4.6	4.8	4.8	4.8	4.6	4.9
Beneficio La Carrera	1980, 1983, 1984	5.4	5.5	5.2	4.8	4.8	5.4	5.4	5.0	4.8	4.8	4.7	4.7	4.9
Apastepeque	1980	5.2	5.3	5.1	4.8	4.7	5.1	5.1	4.6	4.5	4.6	4.4	4.4	4.6
La Galera	1980-1982	4.9	5.1	4.8	4.1	4.0	4.5	4.3	3.5	3.7	3.7	3.9	3.5	4.4

(Source: SWERA)

C. System Structure

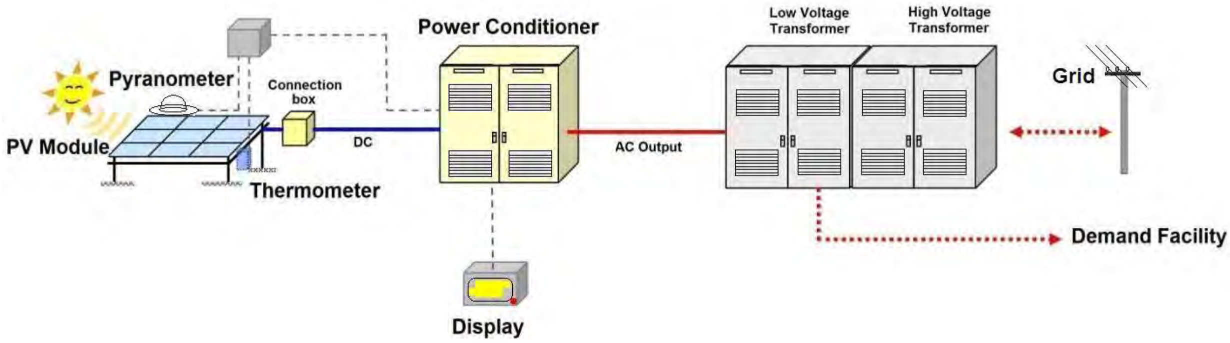
There are various configurations of solar PV systems. The solar PV systems are roughly classified into two types, one is a grid-connected PV system and the other is an off-grid PV system. In general, large-scale solar PV systems, those without battery banks of several hundred kW and over, are used as centralized solar PV stations. If the power flow is controlled at the connection point or the PV system is introduced as a disaster-proof concept, the power generator needs to be temporarily charged over a certain period, and discharged for power supply during other periods. For this purpose, the storage batteries should be connected to the main circuit for charging and discharging.



(Source: JICA Study Team)

Figure 10.3.3.2 Types of Grid-connected PV Systems

In a basic solar PV system, the PV module generates DC power, then passing through junction boxes DC power is collected at the collection box, before supplying power to the PCS. The PCS converts the collected low voltage DC power to AC power. For large solar PV systems, a transformer converts the high voltage AC power, before supplying electricity to grid.

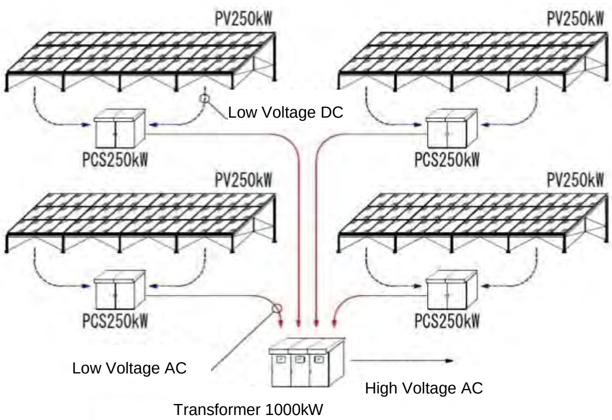


(Source: JICA Study Team)

Figure 10.3.3.3 Example of a Grid-connected Solar PV System

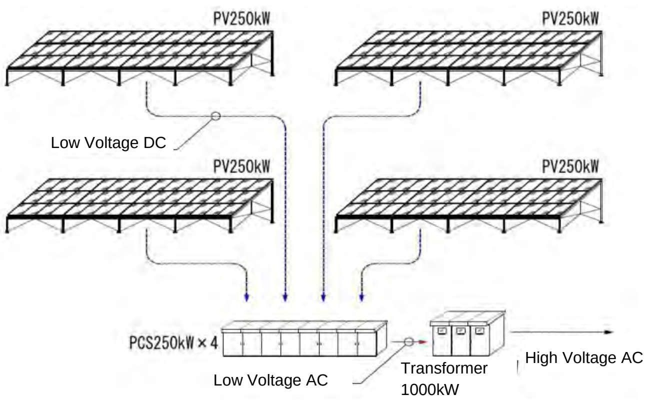
In general, voltages of power output from most PCSs are as low as 210 V or 420 V. For solar PV systems with large capacities, it is necessary to consider the location of PCS (Power Conditioning System) to reduce power losses. There are two types of layout for PCS, one is the distributed system and the other is the concentrated system. The following figure shows sample solar PV systems with 1.0 MW total capacity. In many centralized solar PV systems, PCS with a 250-kW capacity is applied for cost effectiveness and availability of various types.

For the layout of distributed PCS system, a transformer is installed at the center of the PCSs or on locations that facilitate maintenance services. As for a concentrated PCS system, a transformer is installed beside a PCS to reduce the distance of AC distribution line. It is possible to improve efficiency if manufacturers produce units which consist of both a PCS and a transformer.



(Source: Guidelines for the Introduction of Large-scale Solar PV Systems: NEDO)

Figure 10.3.3.4 Layout of Distributed PCS System



(Source: Guidelines for the Introduction of Large-scale Solar PV Systems: NEDO)

Figure 10.3.3.5 Layout of Concentrated PCS System

Most large-scale grid-connected solar PV systems are built as power stations that are operated by electric power companies or independent power producers (IPP). The system basically consists of multiple sets of PV arrays, junction boxes, collection boxes, and PCSs. In some cases, the system is equipped with storage batteries to reduce the impact of grid connection on the commercial power system (changes in the voltage and frequency), and a remote monitoring and controlling system is installed in the operator's control center to improve the efficiency of operation and maintenance.

D. Site survey

a. Problems of shading

It is necessary to confirm shading from neighboring buildings, trees, mountains, chimneys, electric or telephone poles, steel towers and signboards during the site survey. The power output from solar PV decreases when there is shadow on the PV modules. The phenomenon called the 'thermoelectric effect' is possible by partial shading. Therefore, it is an important basic requirement to install solar PV modules in a location where there is no shadow from surrounding structures. At the site survey, it is necessary to consider that there can be possible changes in the surrounding situation, which can be the growth of a tree or the construction of a new building. And also, it is necessary to consider the possibility of shading by leaves, dust and volcanic ashes, bird droppings or oily smoke.

b. Others (corrosive effects of salt, lightning, etc.)

It is necessary to investigate corrosive damages from salt in coastal areas. Data on salt concentration levels will be essential in designing the metal parts of the systems, such as the supporting structures of the solar PV system.

Lightning is categorized by either indirect and/or direct lightning strikes. If the solar PV system is in an exposed location, suitable lightning conductors must be used. Surge arresters on the DC side in the generator junction box are recommended. Over voltage protection on the AC side is also generally recommended.

It is important to study the maximum wind speed at the project site for the design of the solar PV system's support structures. It is also necessary to investigate the damage caused by hurricanes in the past. The following table shows instantaneous maximum wind speed in El Salvador. The design of support structures for solar PV systems has to consider the wind speed indicated in the table below.

Table 10.3.3.2 Instantaneous Maximum Wind Speed

Municipality	Year	Maximum Wind Speed (m/s)
OZATLAN	1938	19.4
BERLIN	1969	16.7
SAN PEDRO NONUALCO	1969	16.7
SANTIAGO DE MARIA	1969	16.7
TECAPAN	1969	16.7
JUAYUA	1970	19.4
AHUACHAPAN	1979	19.4
SANTA ANA	1979	19.4
CALIFORNIA	2002	16.7
APANECA	2006	21.1
COLON	2006	21.1
NAHUIZALCO	2006	21.1
NUEVA SAN SALVADOR	2006	21.1
SAN IGNACIO	2006	22.2
SAN SALVADOR	2006	21.1

(Source: JICA Study Team)

In case of on-ground installation, it is necessary to investigate the existing ground conditions, such as the soil bearing capacity and drainage, to avoid submergence of the site with rainwater.

c. Necessary Area for Installation

Installed capacity of a solar PV system is determined by the available area and the project budget. In general, depending on the system design, the required dimensional area is assumed at around 10 to 15 m^2 per kW. In addition, it is necessary to evaluate the required space for the installation of transformers, power conditioners and other equipment.

d. Load

Power consumption pattern on the demand side is not a relevant factor in determining the capacity of the grid-connected solar PV system. When power output from solar PV is lower than the demand from consumers, the necessary electricity will be complementally supplied from the grid. In contrast, when the power output from solar PV is larger than the demand, the surplus electricity will be supplied to the grid. In addition, it is necessary to examine the impact on and the countermeasures for the solar PV system when there are equipment or structures generating noise in the load facilities. It is necessary to understand these types and characteristics of the load facilities.

E. Equipment Plan

In El Salvador, the NEC international standard is applied for electrical equipment. However, for an international cooperation program with industrialized countries, other standards with different specified levels can generally be accepted.

a. Equipment for PV System

It is necessary to specify the technical information during tender document preparation. The following table below shows the specifications of a PV system. The specifications in parentheses are sample values for a 1.0 MW solar PV system.

Table 10.3.3.3 List of Necessary Equipment

Name	Item	Specification	No.	unit
PV system	1) PV Module	a) Type：(Silicon Crystal) b) Module capacity：(180 Wp and over) c) Maximum power：(＊180 W) d) Maximum power voltage：(＊23.7 V) e) Maximum power current：(＊7.6 A) f) Open circuit voltage：(＊30 V) g) Short circuit current：(＊8.4 A) h) Total array capacity：(1.0 MW and over)	1	set
	2) Support structure for PV module	a) Type：Support structure for PV module b) Material：(SS400 hot-dip galvanizing) c) Configuration：(Base channel, Truss)	1	set
	3) Connection Box	a) Configuration：(Outdoor, hanging type) b) Material：(SPC steel sheet) c) PV input voltage：(＊DC 800 V) d) PV input current：(＊12 A/circuit) e) Input circuit：(＊Max. 4 circuits) f) Output circuit：(1 circuit) g) Contained equipment : (cable breaker, circuit breaker, lightning surge protection)	1	set
	4) Power conditioner	a) Configuration：(Indoor, independent type) b) Main circuit type：(self-exciting voltage type) c) Switching type：(High frequency PWM) d) Insulation type：(Insulation transformer) e) Cooling：(forced air cooling) f) Rated power output : (1.2 MW and over (total)) g) Rated input voltage: (＊DC600V) h) Maximum input voltage: (＊DC900V) i) Input voltage operating range: (＊DC420V～850V) g) Maximum power point tracking range: (＊DC500V～700V) h) Type of output power: (＊3-phase 3-line, 3-phase 4-line)	*1	set

		g) Rated output voltage: (＊AC400V or 230V) h) AC output current distortion factor: (total harmonic distortion 5% and under, each harmonic distortion 3% and under) i) Power control type：(Maximum power point tracking) j) Efficiency：(＊90% and over) k) Function：(Automatic voltage adjustment, in-out current regulation, output regulation, soft start) l) Grid-connection protection function: (UVR, OVR, UFR, OFR, islanding operation prevention (passive, active detection, prevent power supply after recovery) m) Communication：(condition・accident・monitoring signal（RS485)）		
	5) Outdoor transformer	1) Rated power output：(1000 kVA and over in total) 2) Primary /secondary voltage：(13.2 kV, 23 kV, 46 kV/230V, 400V), 3 phases 4 lines,60 Hz 3) Particular specification Outdoor, Oil self-cooling type, Wiring：Δ-Y, neutral ground, Total load capacity tap ±2.5%, ±5%	1	set
	6) Load distribution board	1) Configuration：(indoor-hanging or autonomous) 2) Material：(SPHC steel sheet) 3) In-out circuit: (input : 1 circuit, output：*10circuits) Contained equipment：(Molded case circuit breaker (MCCB))	1	set
	7) Monitoring display	1) Configuration：(outdoor-hanging or self-standing) 2) Material：(SPHC steel sheet) 3) Display data：(power output/day（kWh), instantaneous power potential（kW), irradiation (kWh/m^2)) 4) Size：(＊W800×L600×H60)	1	set
	8) Data management and monitoring system	1) Pyranometer： (ISO9060, Second Class 6～8mV/(kW/m^2)) 2) Thermometer：(resistance temperature sensor Pt100Ω, 4 lines type,-50^{o}C～+100^{o}C) 3) Data logger a) Configuration：(Outdoor hanging type) b) Material：(SPHC steel sheet) c) Input signal：(irradiation (0 to 10 mV）,Thermometer（Pt100Ω）） d) Output signal：(4～20ｍA) e) Power source：(AC120V, Battery & Charger	1	set

		(DC48V)) f) Contained equipment：(Pyranometer converter T/D, thermometer T/D, power T/D, potential T/D（selling, buying electricity） 4) Monitoring equipment (indoor) a) Data monitoring： (monitoring cycle：6 seconds, collected data：irradiation, temperature, power output) b) Equipment：(PC, signal converter, UPS) c) Software：(display of instantaneous value, figure, form, condition of PC, accident, others)		
	9) Control House	1) ＊Size：(W2,400×L7,200×H2,460) 2) Accessory：(door, light, air conditioner, dial thermometer（with contact point）) 3) Contained equipments：(Power conditioner, load distribution board, Monitoring board)	1	set
Construction materials	1) Cable 2) Grounding, etc.	1) Cable ： (22 kV-CV-60sqmm-1core, 600V-CV500, 5.5, 2sqmm, 600V-CVVS-2.0sqmm) 2)Others: (Grounding terminal, PE piping materials)	1	Set

＊: reference value, applied manufacturer standards

(Source: JICA Study Team)

b. Basic Design of PV System Component

The basic design of PV system component is as shown below.

PV module (Array)

- A photovoltaic array is a linked collection of photovoltaic modules. The total capacity and type of PV module should be decided.

Mounting structure for PV module / Connection box

- The construction cost of mounting structure for the PV module and connection box with wiring works represents 20% of the total cost.
- The structure should withstand a wind speed of 30 m/s. Layout of PV array is designed for effective solar irradiation in a limited area. The area angle of PV module is around 15 degrees in El Salvador. The PV modules have to be installed at a higher vantage point to avoid shadows on the modules. The maximum height of PV modules is set at 3 meters above ground level. It is necessary to take into account 6 meters of free space between PV arrays to avoid shadows.
- The base of the support structure depends on the combination of PV modules. For six-180 Wp, which is around 1.0 kWp, the module supports a vertical load of about 160 kg. Therefore, concrete foundation is necessary to support the PV array.
- Connection box consists of breakers for the distribution line, input circuit switch, output circuit switch, backflow prevention diode and lightning protection. Connection box is used for interconnection of PV

arrays and for disconnection of circuit during maintenance and repair. It is necessary to install reverse flow diode, lightning protector and surge protection device on each direct current circuit.

Power Conditioner（protection device of grid-connected operation）

- Power conditioners convert direct current (DC) from PV array to alternating current (AC), and it consists of an inverter and other devices for grid-connected operation.
- The functions of the power conditioner are for regulation and protection of the PV system, power converter and grid connection. The main functions are as shown below. In grid-connected PV systems, reverse flow to the grid is possible but islanding operation is not affordable.

Accuracy of output voltage (isolated operation) ：AC 400V ± 10%

Accuracy of output frequency (isolated operation) ：+/- 0.2Hz

Accuracy of output frequency (grid-connected operation) ：+/-1Hz (Adjustable range)

Distortion factor of AC voltage (isolated operation) ：Total 5% and below

Distortion factor of AC current (isolated operation)

：Total current 5% and below (rated output)

：Each harmonic 3% and below (rated output)

Power factor (grid-connected operation) ： 0.85 and over

(except for emergency cases, such as to prevent voltage rises)

Total Efficiency ：90% and over

Output voltage unbalanced ratio (isolated operation) ：10% and below

Grid-connected operation and protection

: Voltage /frequency monitoring

: Maximum power point tracking function

: Islanding operation prevent function

: Automatic voltage regulate function

: DC output protection function (insulating transformer)

: DC ground detector

:UVR, OVR, UFR, OFR, islanding operation prevention (passive, active detection shall prevent power supply after recovery)

Outdoor Transformer

- Outdoor transformer converts AC power output voltage from power conditioner to high voltage for grid connection.

- The transformer shall be selected based on “SIGET standard No.65-E-2010”. The codes for transformers with 1000 kVA are shown below.

    TT021- 3phase, 1000 kVA, 23 kV

    TT022- 3phase, 1000 kVA, 13.2 kV

    TT023- 3phase, 1000 kVA, 46 kV

- Main specifications are as shown below:

    Type：Outdoor Oil-Filled Transformer

    Rated power output：1000 kVA and over

    Primary voltage/Secondary voltage：13.2 kV, 23 kV, 46 kV/230 V, 400 V, 3 phases 4 wires, 60 Hz

    Particular specification: Outdoor, Oil self-cooling type, Wiring：Δ-Y, neutral ground

Load Distribution Board

Load distribution board will receive electricity for PV system operations. The power will be utilized by air conditioner, light, data logger, monitoring display and so on. The total capacity will be about 5 to 10 kW. Load distribution board is made from steel sheets and there are indicator lights for power. Circuit breakers (MCCB) shall be equipped for each load.

Display monitor

A display monitor for solar PV has an important role as a visual aid. The display monitoring panel shall display the following information. The contractor might also suggest additional information.

- Power output/day (kWh/day)
- Instantaneous power potential (kW)
- Solar irradiation (kWh/m^2)
- CO_2 emission reduction (kg-C)

Management and monitoring system of operational data

Operational data management and monitoring system will be installed in a control room to verify PV system performance.

- Solar irradiation and outdoor ambient temperature
    - Pyranometer：ISO9060/2nd Class, input signal: irradiation (0～10 mV)
    - Ambient thermometer：Pt100Ω

c. Monitoring data

Operational data

The following data which includes data suggested by manufacturers will be logged.

- PV output voltage (V)
- PV output current (A)
- Inverter output voltage (V)
- Inverter output current (A)
- Inverter output potential (kW)
- Inverter power output (kWh)
- Inverter operational condition
- Grid connection condition

Failure information

- Grid connection failure (grid connection protection function)
- Inverter failure
- Protection function in inverter
- Trip breaker for load distribution wiring

Data logging system

Generated power, consumed power from distribution lines, and the CO_2 emission reduction will be calculated and recorded in a computer with date (day, month, year) and time.

Table 10.3.3.4 PV System Signal List

No.	Name of Signal	Type of Signal	Qty	Output/ Input
1	Power Conditioner "ON"	Digital	1	Output
2	Power Conditioner "OFF"	Digital	1	Output
3	Protection Relay "Normal"(UV, OV, UF, OF, Isolation)	Digital	1	Output
4	Protection Relay "Abnormal"(UV, OV, UF, OF, Isolation)	Digital	1	Output
5	Representative Power Conditioner "Alarm"	Digital	1	Output
6	PC Input Current (DC)	Digital	1	Output
7	PC Input Voltage (DC)	Digital	1	Output
8	PC Input Power (kW)	Digital	1	Output
9	PC Output Current (AC)	Digital	1	Output
10	PC Output Voltage (AC)	Digital	1	Output
11	PV System Temperature	Digital	1	Output
12	PV System Irradiation	Digital	1	Output
13	Temperature High Alarm in Control House	Digital	1	Output

(Note: Above-mentioned signals will be monitored for each power conditioner.)
(Source: JICA Study Team)

Control space

If indoor-type power conditioner is selected, it has to be installed in a room or a house. Others, such as load distribution board, management and monitoring system for operations will be installed in a control room in the building or house. Air conditioner, temperature alarm, lighting and spare power conditioner are equipped in the control space.

E. Operation and Maintenance

Currently, grid-connected solar PV systems are not widely used in El Salvador. To secure smooth operation, it is necessary to address issues on technical information, documents and human resources on PV systems as shown below.

- Lack of technical engineers who can work on O&M and repair.
- Lack of manuals for the training of O&M engineers.

An appropriate O&M system is necessary to secure sustainability of the project outcome. Therefore, the owner company has to confirm activities by refererring to O&M reports submitted daily and periodically by maintenance staff members. In addition, it is necessary to collect data on power generation and the amount of CO_2 emission reduction for analysis. Those data will be summarized by SIGET.

It is necessary to transfer the appropriate O&M skills for sustainable use of solar PV system. It is desirable to conduct repair or replacement of faulty parts of the PV system locally. Therefore, in addition to O&M techniques, troubleshooting techniques have to be transferred.

The following table shows items for daily inspection by the technical staff of the solar PV operating company. Basically, it is not important to conduct complicated daily O&M on PV system since it operates automatically. However, daily inspection is important to identify faulty parts early. It is also important to obtain higher power output as much as possible. In addition, the damages caused by the theft of system components and malicious mischief can be prevented through frequent inspection. In the project area, power distribution lines have to be maintained regularly by the technical staff of the system operating company. It is important to transfer the maintenance procedures of the PV system from manufacturers during installation work.

Table 10.3.3.5 Daily Inspection

	Visual Inspection
PV Array	dirt and cracks on module surfaces
	corrosion and rust on the mounting structure
	damage on outside cables
Connection Box	corrosion and rust on the box
	damage on outside cables
Power Conditioner	corrosion and rust on external surfaces
	damage on outside cables
	abnormal noise and sound during operation
	clogging of filter at ventilator exhaust
	environmental conditions in the surrounding area （humidity, temperature）
Grounding	damage on outside cables
Power Generation	check operational conditions by checking the display meters and indicators
Surrounding Condition	fence damage, growth of vegetation, bird's nest etc.

(Source: JICA Study Team)

The table below shows the list of periodic inspections which will be conducted every 2 months. The detailed items for regular inspection will be instructed by the manufacturers of the installed equipment. Regular service procedures will be transferred to technical staff.

Table 10.3.3.6 Regular Service

	Visual Inspection	Measurement
PV array	dirt and cracks on module surfaces	Insulating resistance
	corrosion and rust on the mounting structure	
	damage on outside cables	Open circuit voltage
	damage on grounding cable, tightness of grounding connection	
Connection Box	corrosion and rust on the box	Insulating resistance
	damage on outside cables	
	damage on grounding cable, tightness of grounding connection	
Power Conditioner	corrosion and rust on external surfaces	Check function
	damage on outside cables	
	abnormal noise and sound during operation	Insulating resistance
	clogging of filter at ventilator exhaust	
	environmental conditions in the surrounding area （humidity, temperature）	
	damage on grounding cable, tightness of grounding connection	
Grounding	damage on outside cables	Grounding resistance

(Source: JICA Study Team)

It is necessary to confirm the accuracy of the data which were monitored at the PV system. It is also necessary to store the data properly. When it is difficult to settle problems locally, such as repair of malfunctioning parts, operating institution will need support from the manufacturers. Except for the management procedure, monitoring of power generating conditions and the calculation of CO_2 emission reduction quantities will be transferred. The table below shows the list of main operational and data management tasks.

Table 10.3.3.7 Operational and Data Management Functions

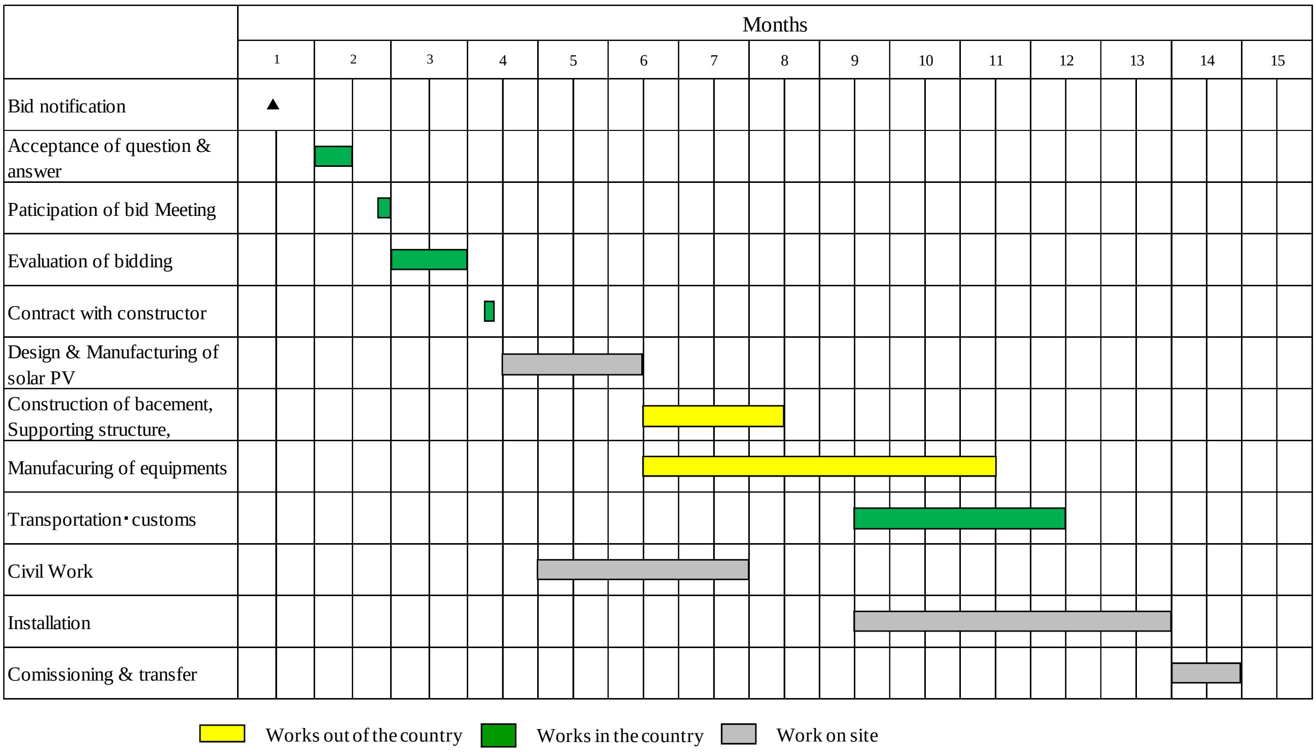
	Tasks
Operational Management	confirmation of operational condition
	educational framework for O&M technician
	coordination with manufacturers, when necessary
Data Management	monitoring of power generating condition
	compiling data on CO_2 emission reduction

(Source: JICA Study Team)

F. General Project Schedule

For the on-ground installation of solar PV, it is necessary to coordinate the land acquisition schedule in advance. Therefore, it is important to conduct site surveys to collect and confirm the information beforehand. The system's construction period varies according to the type and capacity of the solar PV system. In the case of Japan, it was necessary to consider around 6 months of construction period for the installation of a 1.0-MW solar PV. The period is from commencement of construction to commissioning of operation. This construction period is extended longer, in conformity with the increase in capacity of the solar PV system. It is desirable to avoid construction works during the rainy season as it is normally assumed that the duration of works is prolonged once stormy weather conditions start. Therefore, before construction of the solar PV system, it is necessary to examine the schedule for design and procurement of equipment, discussion with distribution companies connected to the grid, and consultation of relevant laws and regulations during the planning stage. The following table shows sample project schedule for solar PV system installation in El Salvador:

Table 10.3.3.8 Sample of Work Schedule



(Source: JICA Study Team)

G. Project Cost

In Japan, the average unit price of solar PV, with capacities greater than 100 kW, is more than US$9,100 per kW. The price varies according to installation location, type and capacity of the system. In case of on-ground installation, expenses such as land acquisition costs have to be included in the cost of the PV system. As for running cost after the installation works, O&M cost and insurance expenses will be examined.

There is a solar PV system with a 100-kW capacity at a U.S. Base in El Salvador. The project cost is shown below. The comparison of the average unit prices of Japan and El Salvador showed that the price for the El Salvador project is lower.

Price of a 100-kW solar PV system

Installation: **US$690,000 (US$6,900/kW)**

O&M: **US$1,000/year (4 visits per year)**

10.3.3.4 Master Plan

A master plan for solar PV systems for 2012 until 2026 is required in this study. However, as for the centralized solar PV system, there is only one plan by CEL. Thus, the following development plan was compiled for implementation during the period from 2012 to 2026 based on the information from CNE.

Solar PV development plan of CEL will be revised continuously. Therefore, solar PV development plans will have to be revised for several years.

Table 10.3.3.9 Master Plan of Solar PV (on-ground)

	On ground		Rooftop (Project base)	
Year	Capacity (MW)	Power Production (GWh/year)	Capacity (MW)	Power Output (GWh/year)
2012 to 2016	17	27.9	1	1.6
2017 to 2021	20	32.8	1	1.6
2022 to 2026	50	80.0	1	1.6

(Source: CNE)

10.3.4 Solar Thermal

In El Salvador, the average solar radiation is as high as 5 kWh/m^2 per day. In this chapter, the current state of solar thermal energy in El Salvador is explained. Moreover, solar radiation data obtained from LaGeo and Inversiones Energéticas S.A. de C.V. (INE) are examined. In order to realize the implementation of solar thermal projects, there are some difficulties to overcome. Therefore, measures to overcome these difficulties are considered in this chapter. Furthermore, for the introduction of the CSP system, necessary recommendations are mentioned.

10.3.4.1 Potential of Solar Thermal

Solar irradiation is an energy source for solar thermal systems. In a spatial area, solar irradiation is found to be 1353 W/m^2, and thus called as the solar constant. Before solar irradiation reaches the surface of the earth, it is attenuated by absorption, reflection, and irradiation depending on the conditions in each location and its value will always be lower than the solar constant. Solar thermal technology is based on the fact that solar light is energy in the form of electromagnetic radiation emitted in different wavelengths which range from ultraviolet, visible and/or infrared wave lengths. For low temperatures (up to 95 °C), flat plate or vacuum tube collectors are used mainly for water heating. For intermediate temperatures (up to 350 °C), CSP system is used. There are different configurations of CSP, such as parabolic trough, solar tower, parabolic dish, and Fresnel. The aim of the CSP is to concentrate high density of energy to the receiver from the focal point of the concentrator. The concentrator is made up of a reflectance surface of high efficiency. In general, reflectance factor is 95% or higher for new and clean conditions. The receiver surface exhibits the following characteristics at operating temperature: high absorptance in visible wavelengths and low emittance in infrared wavelengths. Insolation levels in El Salvador is high. In terms of energy, the average number of peak-sunshine hours is 5 hr/day. For systems without solar concentrators, such as flat plate collectors, all the energies are taken into account. For solar concentrator systems, only direct radiation is used. In this case, the potential energy available is around 70%, or 3.5 peak-sunshine hrs/m^2. Thus, it is possible to say that the national average of direct normal irradiation (DNI) is at ~3.5 kWh/m^2 per day. However, it is necessary to monitor solar irradiation at particular places where construction of CSP system is planned. According to the data monitored by LaGeo, the average DNI in Berlin is as high as 5.0 kWh/m^2 per day. In addition, based on the data monitored by INE, the average daily DNI in Miravalle (Acajutla) is 5.4 kWh/m^2 and in San Fernando (San Vicente) is 5.3 kWh/m^2.

For example, the capacity of a collector aperture is calculated below.

- Reflection efficiency: 80%
- Total efficiency of receiver and heat transfer: 80%
- DNI (Berlin): 5.0 kWh/m^2

Energy per m^2=5.0×0.8×0.8 = 3.2 kWh$_{-th}$/m^2 per day. (kWh-$_{th}$: Unit of thermal output in kWh)

As for a solar collector with 48 m^2 of effective aperture, the estimated potential thermal energy it can receive is shown below.

$3.2\ kWh_{\text{-th}}/m^2/day \times 48\ m^2 = 153.6\ kWh_{\text{-th}}/day$

Average power output can be calculated based on the effective aperture of solar collector and the number of peak-sunshine hours. Power output from the above-mentioned collector with 6 peak-sunshine hours is calculated as shown below.

$153.6\ kWh_{\text{-th}}/day \div 6\ hrs = 25.6\ kW_{th}$

Power output from unit area is computed as follows:

$25.6\ kWh \div 48\ m^2 = 0.533\ kW_{th}/m^2$

This figure must be adjusted according to the technical specifications of a collector system and the environmental conditions in a given location.

For example, in case of two sets of generators, which have similar performance capabilities to the Ahuachapán geothermal power plant, the resulting operational conditions are as follows.

- Input steam flow: 144 kg/s
- Inlet pressure: 4.6 Bar (a)
- Inlet temperature: 154 °C
- Input power, thermal: 396.5 MW_{th} (MW_{th}: Unit of thermal power in MW)
- Output power, electrical: 60 MW_e (MW_e: Unit of electrical power in MW)
- Efficiency, thermal to electrical: 15 %
- Power to mass rate: 2.4 (kg/s)/MW_e

Considering 15% efficiency and 60 MW of power output, the computed total area of the collector system's effective aperture is as follows:

$396.5\ MW_{th}/(0.533\ kW_{th}/m^2/1{,}000) = 743{,}902\ m^2$

In general, the area of land occupied by the aperture is estimated between 50 to 70% of the total plant area. Considering the area for construction and operation of the CSP system, the necessary land area is roughly 1.0 km^2 as calculated below.

$743{,}902 \div 70\% = 1{,}062{,}717\ m^2$

The thermal power obtained from a solar collector field can be converted into electric power by means of a thermodynamic cycle. The solar energy converted into heat must be transported by a transport fluid, such as heat transfer fluid or molten sodium. The heat transfer, through heat exchangers, to the working fluid, usually water, produces steam that drives a turbo generator to generate power. For some types of CSP, water is used as the working fluid which is directly converted into steam at the focal point of the concentrator. In this case, special treatment is required for energy storage. In general, storage of thermal energy is necessary to extend operational hours of CSP. It is important to consider that solar irradiation only occurs during the day, and some kind of storage must be considered in order to offer certain degree of continuity in the power output.

From a technical point of view, it is possible to construct a CSP system completely by using solar concentrators which are supplied by several international companies. Taking into account the abundant solar irradiation in El Salvador, and the developed solar thermal technology in the international market, the project has great potential for implementation. On the other hand, it is also important to consider the possibility of local manufacture of solar collectors to reduce cost. Therefore, to fully realize local manufacture of solar collectors, technical transfer of the solar thermal power plant technology is important.

10.3.4.2 Current Status and Future Prospects

A. Existing Plan in El Salvador

At present, there are three institutions working on solar thermal technology that utilizes different approaches, LaGeo, INE, and Universidad Don Bosco.

a. LaGeo

LaGeo started in 2007 a development program for the local solar thermal technology. Four modules of parabolic trough solar concentrators is designed and constructed by LaGeo. Polished stainless steel reflectors with reflective efficiency of 60%, was used in the program. As for the concentrator, a carbon steel pipe with selective coating was used. The total aperture area of the parabolic concentrators is 160 m^2 (four modules having 4-m width and 10-m length). The system heats the thermal oil and recirculates it at a rate of 1.5 kg/s until the temperature in the storage tank increases to 225°C. The capacity of the storage tank is 1.132 m^3. Heat is transferred to the separated hot water from the first flasher. This process is part of the function of a heat exchanger to generate steam by solar energy. The obtained power in this process is around 183.8 kW_{th}. Unit capacity of this system is calculated as follows:

$$183\ kW_{th} / 160\ m^2 = 1.144\ kW_{th} / m^2$$

Currently, the new prototype collectors with cavity-type receiver are being designed and will be constructed for research and development objectives. A plastic metalized film with a reflectance factor of 95% will be used as the prototype. All the systems will be installed in the northern geothermal field of Berlin. Installed capacity is planned as 30 MWe. There are five alternatives for the installation of solar thermal plant as shown in the table below.

Table 10.3.4.1 Options of Installation for Solar Thermal Plant Project (LaGeo)

Options	1	2	3	4	5
Description	Geo-solar thermal hybrid	Solar thermal	Solar thermal	Solar thermal	Solar thermal
Location	Northern geothermal field Berlin	Northern geothermal field Berlin	San Miguel	San Miguel	San Miguel
DNI (kWh/m^2 per year)	1800	1800	1860	1860	1860
MW_e	30	30	30	30	30
Plant type	Direct steam generation	Direct steam generation	Direct steam generation	HTF technology, Therminol VP1	HTF technology, Therminol VP1
Energy storage	No	No	No	No	Yes
Water input	Geothermal	De-mineralized water	De-mineralized water	N/A	N/A
Turbine operating pressure and temperature	35 Bar (a), 130 °C	28 Bar (a), 230 °C	28 Bar (a), 230 °C	100 Bar (a), 370 °C	100 Bar (a), 370 °C
Solar field aperture (m^2)	171,070	171,070	171,070	171,070	342,140
Concentrator type	Eurotrough - 100	Eurotrough - 100	Eurotrough - 100	Eurotrough - 100	Eurotrough - 100
Concentrator quantity	312	312	312	312	624
Concentrator origin	Spain	Spain	Spain	Spain	Spain
Receiver type	Schott - Germany	Schott - Germany	Schott - Germany	Schott - Germany	Schott - Germany
Total area (ha)	61	61	61	61	114
Solar field area (ha)	53	53	53	53	106
Capacity factor (%)	20.4	17.9	18.8	16.1	30.9
Total yearly energy production (GWh)	53.7	47.1	49.5	42.2	81.1
Yearly energy per unit area of solar field (GWh/ha per year)	1.01	0.89	0.93	0.8	0.77
Initial investment (Million US $)	111	111	111	115	185

(Source: LaGeo)

Mainly, there are two objectives on the Research and Development Program.

- Confirm possibility of local construction of solar collectors to reduce construction cost of solar thermal power plant.
- One of the purposes of LaGeo is that engineers understand the solar thermal technology. Obtain technical knowledge for business.

b. INE

In the case of INE, the pre-feasibility, technical, financial and legal studies for the installation of a solar thermal plant have already been carried out. The collected data from INE is as shown below..

- Western Zone: Sonsonate, Cantón Miravalle.
- Central Zone: San Vicente, Tecoluca, Cantón San Fernando.
- Eastern Zone: (No data).Selected site had poor solar irradiation.

The monitoring data was collected from September 2010 to August 2011. The average daily direct normal irradiation (DNI) data are as shown in the table below.

Table 10.3.4.2 Monitored DNI (INE)

	Miravalle (kWh/m^2 per day)	San Fernando (kWh/m^2 per day)
September 2010	3	2.9
October	5.1	5.4
November	6.6	6.4
December	7.7	7.5
January 2011	7	7
February	7.3	7.3
March	6.9	6.5
April	4	3.1
May	4.7	4
June	3.4	3.1
July	3.8	n/a
August	n/a	n/a
Average DNI	**5.41**	**5.32**

(Source: INE)

Currently, INE is waiting for the final report of the pre-feasibility study from Solar Millenium AG (Spanish Company) to establish the size and characteristics of the plant to be installed. However, INE is considering installation of solar thermal plants with 50 MW_e including storage of thermal energy by molten salt battery. The capability of the thermal storage has to be around 8 hours. Parabolic trough type of CPS system is considered for application on a plant having dimensions of 5.11 m width and 75/100/150 m length collectors, with the usage of heat transfer fluid. The operating temperature will be between 293 °C and 393 °C.

Implementation schedule is estimated at around three and a half years, i.e., one year for the feasibility study and bid process, and 2.5 years for the installation of the plant.

c. Universidad Don Bosco

El Salvador is a country with an abundance of natural energy resources such as hydro, geothermal and solar. In addition, there are no fossil fuel resources in the country. Based on the reasons above, the School of Electrical Engineering presented to the President of Universidad Don Bosco a proposal for research and development of solar thermal technology and its installation by year 2000. The Fondo para la Iniciativa de las Américas, El Salvador (FIAES) provided the financial support for the research and development. The general objectives of the project were to develop solar thermal technology and to locally accumulate knowledge and expertise on the said technology. The specific objectives were to design and construct a prototype CSP which is capable of generating electricity for the lighting of 14 rural households, and driving a corn mill, a water pump and an oven for bakery.

To be able to accomplish the established objectives, it was decided to design a circular concentrator collector and a steam generator or boiler placed at the focal point of the concentrator. The fluid chosen as the thermal transport media and as driver of thermodynamic cycle was water. Based on the demand thermal and electrical loads from users, the system should have a capacity of 30 kW_{th}.

The main parts of the system for construction are as follows:

Collector concentrator

The concentrator has 1,824 mirrors mounted on a flat circular structure and each is calibrated to assure reflection to the focal point of the receiver. Diameter of the collector is 10 m.

Boiler

During normal operation, the boiler temperature reached 250 °C, and the steam output at 193 °C with pressure of 8.379 kPa.

Solar tracking system

Two-axis system: One axis is adjusted with azimuth and the other for height over the horizon.

Steam reservoir

Typical conditions of steam are 175 psi (g) and 193°C as indicated by the instruments mounted on the reservoir. Steam trap and safety valve was adjusted at 8.379 kPa.

Pumping system

The condensate is pumped to the boiler at a rate of around 60 L/hr.

Steam engine

The steam drives a two-cylinder engine of 3 HP nominal power at 600 rpm. It is coupled to a belt speed multiplier to drive the alternator and rectifier.

Alternator

The capacity of the power generator is 1.0 kW with DC 12 V. Generated electricity is charged in the battery bank.

Thermodynamic control system

The thermodynamic cycle is controlled by a microcontroller. It operates the inlet valve of the steam engine, the current level of field circuit of alternator, and the lubricating system.

Inverter

The capacity of the inverter is 1.0 kW, and can convert DC 12 V to AC 120 V, 60 Hz.

Application loads

This system supplies both the electrical and thermal outputs. The expected electrical load was for the lighting of 14 rural households, a total of 300 W for 4 hours a day, from 5:00 to 9:00 p.m. There was also a direct thermal load that can supply an oven for bakery during sunny days. The maximum temperature in the oven was 150 °C. It was also expected to operate a small water pump.

B. Barriers to overcome.

There are several hindrances in the further dissemination of solar thermal technology as explained in this section.

a. Knowledge on solar thermal technology

Initiatives to raise awareness are important for the future development of solar thermal technology. It is important for people to understand the potential and benefits of CSP technology and its other applications. It is important to be informed of the functions of other CSP systems, such as its operations in the USA, Spain, etc. Furthermore, it is necessary to extensively introduce information about solar thermal technology due to the high solar potential in El Salvador.

b. High initial investment costs

Initial investment cost on solar thermal plant is high due to the following two reasons: 1) high initial installation cost, especially of the solar collector; and, 2) the technology is still under development and commercially, not so widely used yet.

There have been efforts to develop cost-effective solar collectors in El Salvador. For example, Universidad Don Bosco has conducted research and development works to accumulate technical knowledge and experience in the design and construction of solar collectors in the country. In addition, LaGeo has carried out two kinds of research and development works, which are as follows: 1) local manufacturing of the solar thermal collectors; and, 2) possible methodologies to lower the installation cost in case there is a need to procurement components from overseas suppliers. A sample of a specification details and the cost of the solar thermal power plant is as shown in the table below.

Table 10.3.4.3 Specification of solar collector (Eurotrough-100)

Collector width (m)	5.76
Total length of each collector (m)	98.7
Quantity of modules per collector	8
External diameter of receiver pipes (m)	0.07
Internal diameter of receiver pipes (m)	0.065
Net aperture area per collector (m^2)	548.3
Internal roughness of receiver:	20 μm
Nominal reflectivity of mirrors, *r*	0.93
Transmissivity of glass envelope of receiver, τ	0.95
Absorptance of selective surface of receiver, α	0.95
Interception factor for optical and installation errors, γ_1	0.90
Peak optical rendering: $r \times \tau \times \alpha \times \gamma_1 \times \gamma_2$	0.755
Net cost for a Euro trough-100, (Cost at factory)	US$183,000.00

(Source: Universidad Don Bosco)

General cost information is shown as follows.

Unit cost: US$334/$m^2$

(Effective area of collector, at the factory in Europe)

Operational conditions:

- Operating temperature: 300 ^oC
- Solar direct irradiation: 900 W/m^2

Output:

- Solar thermal efficiency: 66.7%
- Cost per unit thermal power: US$555/$kW_{th}$
- Thermal power per m^2: 0.601 kW_{th}/m^2

If it is possible to manufacture the collectors in El Salvador, the cost is lower than those bought from Europe. Moreover, it is not necessary to estimate transportation cost from distant countries.

In Mexico, a project of booster configuration solar thermal plant is being prepared. The details are shown below.

Project title: Solar Thermal Project Agua Prieta II

- Collector field thermal power: 31 MW_{th}

- Collector field size: 120,000 m^2
- Collector field cost: US$43,518,000.00
- Unit cost: US$362.65/$m^2$
- Cost per kW_{th} : US$1,403.81/$kW_{th}$

c. Lack of trained engineers

There is limited number of engineers or researchers who are working on solar thermal technology. Educational institutions should carry out human resource development training for the design, implementation, operation and maintenance of solar thermal plants. It is necessary to establish proper educational policies for the training activities. Currently, there is a master's degree in renewable energy management and solar thermal pilot plant design in Universidad Don Bosco.

d. Intermittent power output

Solar irradiation is available only during daytime. However, there are countermeasures to compensate the intermittent of power output, such as the following:

- Include storage system of thermal energy with capacity consistent with the project objectives and the costs involved.
- There is a complementary relation between seasonal power outputs of solar thermal and hydro power plants.

e. Minimum warranted power for wholesale contract

Minimum power output from solar thermal plants is unpredictable due to the varying weather condition. Solar irradiation is an intermittent source of energy, which as expected, translates to power output of solar thermal plant that is also intermittent. For this reason, at present, the power output from these plants is fed into a distribution grid. Power producers who are interested in trading at the wholesale market have to guarantee a minimum power output. However, this is difficult in the case of solar thermal power stations. In order to address this problem, it is necessary to involve the technical and legal sectors of El Salvador for this kind of plant to be eligible for the wholesale market.

B. Recommendations

Recommendations for the introduction of solar thermal power plant are as follows:

- Pre-feasibility and feasibility studies for the inclusion of solar thermal plants.
- Coordination with universities to develop training programs on solar thermal technologies for engineers and technicians, with international technical assistance must be included.
- Revision of legal and technical regulations and standards.

- Provide incentives for the creation of solar thermal enterprises in particular, and renewable energy in general.
- Development of local technologies that enable production of solar thermal collectors.
- Create favorable conditions for the export of some components used in solar thermal production.
- Promote international cooperation between the government and manufacturers of solar thermal technologies.
- To study the possibility of solar thermal-geothermal, hybrid generation system introduction.

10.3.4.3 Examination of Technical Aspects

A. General

Currently, solar thermal technology is not yet commercially or industrially available in El Salvador, but there is an incipient and growing interest in the universities, professional organizations, governmental institutions, and all those involved with energy, to explore new alternative sources of energy. Solar thermal technology is available from international suppliers, especially manufacturers from Spain, Germany and the USA.

Solar thermal technology has been in development for several decades, starting significantly in 1969 with the construction of a high temperature furnace in Odeillo, France. In 1986, one of the largest solar thermal plants was built in Kramer Junction, Mojave Desert. In decades of 80s and 90s, continued developments in the USA led to “solar one” and “solar two” central receiver thermal power plants. In the first decade of the 21st century, the USA, Spain and Germany have achieved great advances in the technology. At present, the technology for the installation of large solar thermal plants for generating electricity is already available.

It is possible to import many collector types such as the following: parabolic and Fresnel for linear, and heliostats for central receiver plants. Even if the initial cost is high, this can still be reduced by developing local technology for the manufacture of collectors, opening the possibility of its commercial competitiveness in the future. Aside from the collector and energy storage, the rest of the technologies are basically similar to the traditional thermal technology. However, a complete system must be considered to ensure compatibility among all its parts when implementing the project. Manufacturers usually conduct business under this concept.

B. Cost Information

In general, the initial investment cost of solar thermal is still high. LaGeo has estimated the gross cost for a project without thermal storage at **US$3,700/kW$_e$** and **US$6,167/kW$_e$** for those with thermal storage. In Mexico, the cost, only for the solar field is **US$1,404/kW$_e$.** This is based on the proposal to the GEF for “Hybrid Solar Thermal Powerplant Project Agua Prieta II”. According to INE, unit cost for a 50 MWe plant is US$5,000 to 6,000 /kWe and the unit cost for solar thermal with storage is US$ 6,000/kWe.”

Thus, the cost of the entire solar thermal plant is estimated to be around **US$300 Million**. As for Universidad Don Bosco, the total cost for “Research and Development of Solar Thermal Technology” program, which included research, development, design, materials, labor and administration was **US$207,930**. The implementation of this project took three years. It is not necessary to compare the cost per kW$_e$ to other systems as it was not developed as prototype for commercial use. It was intended to accumulate necessary technical information and expertise for the design of solar concentrator collectors.

10.3.3.4 Master Plan

A master plan for solar thermal power generation from 2012 to 2026 is required in this Study. However, as for solar thermal systems, there is only the plan by LaGeo and INE. Thus, the following development plan will be compiled from 2012 to 2026 based on the information from both organizations.

Solar thermal development plans of LaGeo and INE will be revised continuously. Therefore, solar thermal development plans will be revised in the succeeding years.

Table 10.3.4.4 Solar Thermal Master Plan

Year	Capacity (MW_e)	Power Production (GWh/yr)
2012 to 2016	60	158*
2017 to 2021	80	210*
2022 to 2026	60	158*

* : System with thermal energy storage. (Plant Factor: 30 %).
(Source: JICA Study Team, According to information given by INE and LaGeo in meeting with CNE, JST, INE and LaGeo).

10.3.5 Geothermal

Based on collected basic information described in Chapter 4, and based on method of examination described in Chapter 8, examination was made for introduction of geothermal energy sources.

Estimate of introducible amount of geothermal was presented through review of the existing plans. Possibilities of development after 2017 were estimated from the existing potential information. Further, a standard development schedule and development costs were described based on the interview results from LaGeo.

A. Development Plan up to 2017

Currently, LaGeo is the only entity engaged in geothermal power development in El Salvador. Their development plan for increasing their geothermal power generation is described in section 4.6.3. Table 10.3.5.1 is a list of their new development plan which have specific development schedule.

Table 10.3.5.1 Plan of New Development, Expansion and Modification by LaGeo

Location	Plan	Addition (MW)	Feasibility	Timing (year)	Possible Delay
Ahuachapán	Modification of Unit-2	5-9	A	2015	No
Berlín	Expansion by Unit-5	25-30	A	2017	No
Chinameca	New Development	30-50	B	2017	Up to 2 years
-	Total (by 2017)	60-89	-	-	-

(Feasibility) A: Proven (Definite), B: Probable
(Source: LaGeo)

As seen in this table, LaGeo has a plan of increasing their geothermal power generation by 60 to 89 MW by 2017 or later.

B. Development Plan after 2017

Currently, LaGeo does not have any certain plan of new power development after 2017. Thus, possibility of further geothermal power development in future is estimated in 4.6.4. Based on the result, the maximum level of total geothermal power generation in El Salvador is estimated to be 300 MW to 400 MW at the moment. This value must be revised periodically as studies in other existing zones of the country progress.

Like other underground natural resources, understanding of the geothermal resources advances in line with the advance of geothermal exploration and development. Then, possibility of the power development level changes along with the improvement of the understanding. Therefore, all the plans and estimates related to geothermal power development should be revised in line with the advance of geothermal exploration and development in El Salvador.

C. A Generalized Development Schedule and Cost

A generalized development schedule and cost estimate of a new 30 MW-class geothermal power development by LaGeo is shown in Table 10.3.5.2. As seen in this table, this project requires approximately eight years including permission procedures, with a total cost of US$150 to 200 million.

Table 10.3.5.2 Generalized Development Schedule and Cost of a 30 MW-Class Geothermal Power Development by LaGeo in El Salvador

Item	Specification	year 1	year 2	year 3	year 4	year 5	year 6	year 7	year 8	number	unit	range of price ($1,000)(*)	remarks
1. Permission/Concession													
Concession acquisition													
										Sum of 1.			
2. Surface Exploration													
Geology/Geochemistry													
Geophysics													
Conceptual model for drilling target consideration													
										Sum of 2.		1,000	
3. Well Drilling													
Civil engineering	Drilling pads												
	Roads												
Exploration wells	2- 4 X 2000m (6-1/4")											10,000-14,000	
Feasibility Wells	4 X 2000m (8-1/2")											28,000-34,000	
Production wells	5 X 2000m (8-1/2")											35,000-40,000	
Reinjection wells	3 X 1500m (8-1/2")											20,000-25,000	
										Sum of 3.		93,000-113,000	
4. Discharge test													
Single-well discharge	Short term											0	by LaGeo
Multi-well discharge	Long term (more than 6 months)											0	by LaGeo
										Sum of 4.		0	
5. Resource Assessment													
Reservoir assessment													by LaGeo
Economic assessment													by LaGeo
										Sum of 5.		0	
6. Environmental Impact Assessment													
Background monitoring													
Exploration well MARN Permission													
EIA for feasibility													
EIA for development										Sum of 6.		200	
										Sum of 1. ~ 6.		94,200-114,200	
7. Power plant construction													
Planning and basic design													
Steam facilities										30000	kW	10,000-14,000	
Power plant										30000	kW	45,000-60,000	
Transmission line												3,000-5,000	
Commissioning													
(*) Costs reference: Paul Quinlivan, S.K.M., Auckland, N.Z., WGC2010, Practical Finnancing of Geothermal Projects. Developments & operating Costs.											Total	152,200-193,200	
(Information Source/Date) LaGeo/Oct. 10, 2011													

(Source: LaGeo)

In case of new geothermal development in the future, the development will possibly be executed referring to the aforementioned schedules and costs.

10.3.6 Biomass

The necessity of introducing small-scale biomass power generation system is determined from the results of the study on biomass resources in El Salvador. In this Chapter, as small-scale biomass generation systems, biomass gasification systems and micro-binary generators which operate by utilizing biomass resources and solar heat are explained.

10.3.6.1 Biomass Gasification

A. General

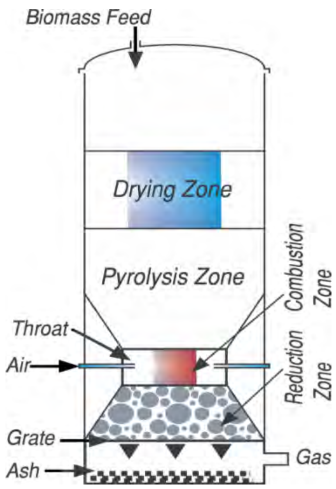
Gasification is a thermo-chemical process that converts solid biomass to combustible producer gas. Gasification technology has a long history. Research on the production of gas from wood was conducted in the 18th century. In 1881, an engine was tested to run using producer gas. This technology was most widely used during World War II. The war caused severe shortage of oil products. About a million gasifiers were used in running cars, trains and ships and in generating electricity in Europe. About 100,000 gasification vehicles were used in Japan and Russia. After the war, oil products became cheap and readily available and thus, gasification was forgotten. The technology was reconsidered during the oil shock in 1973. For the last couple of decades, biomass energy utilization has been recognized as one of the most important countermeasures against global warning. Development and utilization of biomass gasification technology has been progressing rapidly.

Biomass is recognized as one of the major potential sources for energy production. Biomass resources include forestry residues, energy crops, food manufacturing waste, coconut shell, bagasse from sugarcane processes and food processing residues have all been used for energy generation. Biomass gasification is the incomplete combustion of biomass resulting in the production of combustible gases consisting of Carbon monoxide (CO), Hydrogen (H_2) and traces of Methane (CH_4). This combustible gas is called producer gas. There are two major methods (direct combustion and gasification) to generate electricity from solid biomass. Direct combustion is the most common way of converting biomass to energy. For generating electricity, a biomass-fired boiler converts the heat of combustion into steam, this steam then drives the turbine-generator to produce electricity. This system is a proven technology and has been introduced to many agricultural processing factories around the world. The system is suitable for relatively large-scale use (e.g. > 1.0 MW), such as those using bagasse for power generation in a sugarcane factory in El Salvador. However, it is not appropriate for small-scale industries, such as the coffee and rice industries in El Salvador.

Gasification is a thermo-chemical process that converts biomass into a combustible gas called producer gas which contains about 80% of the energy originally present in the biomass. The producer gas is sent through a cooling and purifying unit before feeding into the engine to generate electricity. The system is commercially available from 4 kW to several MW. They are commonly used for rural electrification and thermal application in some countries and small-scale biomass gasification is thought of as a proven technology. This small system can be a more suitable technology for coffee and rice processing factories.

B. Biomass Gasification Technology

There are two major types of gasifiers, fixed-bed gasifiers and fluidized-bed gasifiers. Fixed-bed gasifiers are divided to updraft-type where heating occurs at the bottom and its producer gas moves to the upper part, and downdraft-type where oxidation occurs at the middle of the reactor and the gas is left at the bottom. The major advantages of updraft-type are its simple features and acceptability of high moisture content biomass (<60%). But the producer gas created by the updraft-type contains the highest amount of tar. This is not very critical in the case of thermal application but extensive gas cleaning is required for power application. On the other hand, producer gas created by downdraft-type contains the smallest amount of tar (<100 mg/Nm^3) and therefore, more appropriate for power application. But biomass fuel for downdraft-type gasifier has to be dried (<20%) and its size has to be relatively uniform (4-10 cm). Downdraft-type is not suitable for upsizing. The maximum capacity is thought to be around 500 kW. Fluidized-bed gasifiers were invented to solve the problems of the fixed-bed type. Fluidized-bed gasifier is a vertical reactor vessel filled with sand and has a porous bottom. Tar content of the gas is smaller than updraft and biomass with high moisture content can be used. It is suitable for up-scaling as well. Most of the small-scale gasifier electricity generation systems are downdraft-type.

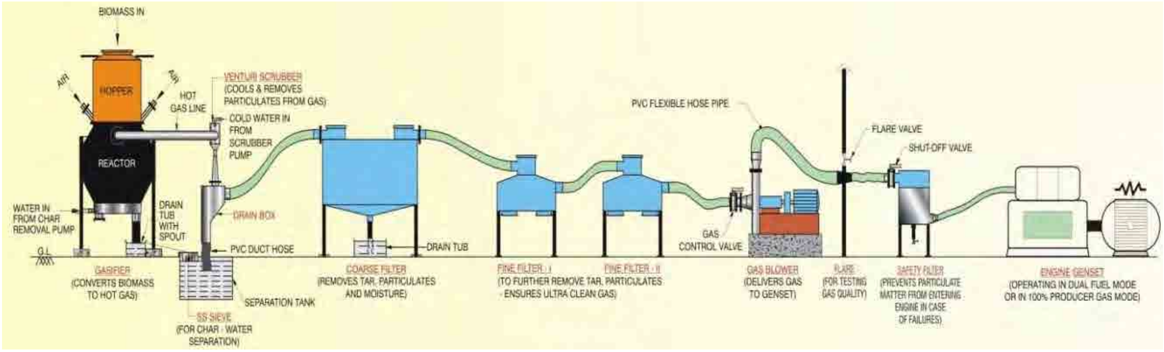


(Source：Ankur Pvt. Ltd.)

Figure 10.3.6.1 Downdraft biomass gasification reactor

The gas produced by downdraft gasifiers generally consist of combustible gases about 10 to 20% of H_2, 20 to 30% of CO and a few percent of CH_4, and non-combustible gases such as CO_2 and N_2. The producer gas contains 70% or more of the energy of biomass in the case of power application.

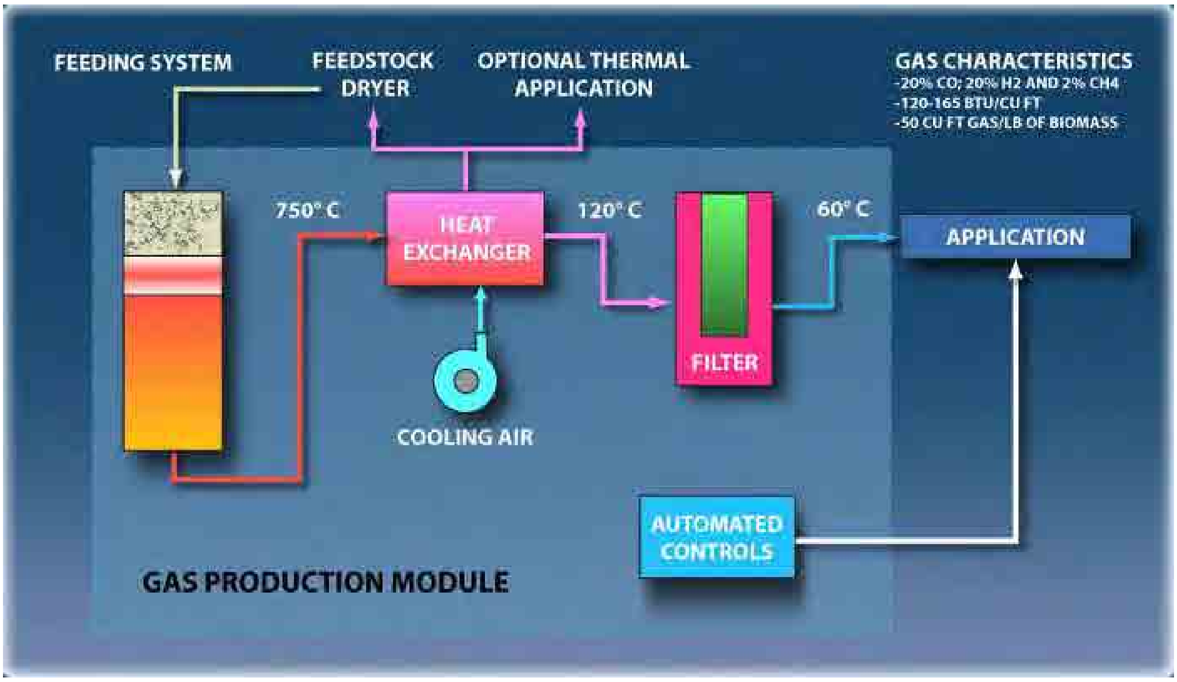
The gas produced by the gasifier is cooled and purified by passing through several filters to remove tar and other particles. The producer gas is then sent to the engine to generate power. Diesel engines can be run by dual-fuel mode (70% producer gas and 30% diesel) or by 100% producer gas with minor modifications. The gas duct needs to be connected to the engine for dual-fuel operation and an ignition spark plug needs to be installed for 100% producer gas operation.



(Source: Ankur Pvt. Ltd)

Figure 10.3.6.2 Schematic flow of biomass gasification electricity generation system

The following flowchart shows the operation of a gasification system for power generation. At first, dried biomass resources are fed into the gasifier where high temperature gas is produced. The produced gas at high temperature is then supplied into the heat exchanger to decrease gas temperature and remove moisture. After that, particles and tar are removed at the filtering system and supplied to application equipment such as internal combustion engine or diesel engine to generate electricity.



(Source: Community Power Cooperation)

Figure 10.3.6.3 Flowchart of biomass gasification

C. Sample Project

a. Bangladesh (Rice Husk)

In December 2007, a pilot test was conducted for biomass-gasified power generation of 2 sets of 130 kW generators with total capacity of 260 kW. The system supplies electricity to 8 villages around the power station through a mini-grid in the region. The system supplies electricity to 400 households including telecom facility, shops and so on. Rice husks are being used as the biomass fuel for gasification. Dream Power Ltd was established as a private power supply company for the project. There are 15 employees including 3 technicians who trained in an Indian company which manufactures gasification systems. Electricity is being supplied for 5 hours and 30 minutes every day, from 18:00 H to 23:30 H. Except during operational hours, power demand is too small to supply electricity as a private business. The total capacity of the power plant is 260 kW. However, only one set of gasification system is being operated as the power demand is too small at 60 kW compared with the estimated demand. Power meters are installed at contacted households and power tariffs are collected at metered rates. The connection fee to the mini-grid is US$1.3 and the unit price of power is US$0.065/kWh. In the financial aspect, it is not easy to manage the power supply company because the average total power tariff from users is only around US$780 per month. With this income, the company still has to pay for fuel and maintenance cost. The power demand was overestimated and is one of the reasons for the current difficulties in management. In addition, users are also trying to reduce power consumption by using effective compact fluorescent light.

1.	Operational power output	: 40 kWe
2.	Rice husk consumption	: 3 bags /hour, 50kg/hour
3.	Price of rice husk	: US$0.26-0.52/bag (seasonal change)
4.	Fuel consumption rate	: 1.25 kg/kWh
5.	Unit price of biomass fuel	: US$0.02/kWh (US$0.26/bag) US$0.026/kWh (US$0.52/bag)

(1 BDT=0.013US$)

Figure 10.3.6.4 Biomass gasified generation plant

b. Sample Project: USA (Woody Biomass, etc.)

Community Power Cooperation (CPC) was established in 1995. The company was initially involved in providing modern energy services to off-grid communities in developing countries. In 1999, CPC was selected by DOE as part of the Phase I Project to develop a 12.5-kW prototype system called the “BioMax” to provide power to a remote community in the Philippines using coconut shells as the feedstock. CPC was then given the Phase II contract in 2000 to incorporate numerous technological advances, increase the capacity to 15 kW, and deploy several systems as part of a Product Validation program. The company has since expanded its product lineup to include 25, 50 and 75 kW systems; combined heat and power systems; thermal systems; containerized systems; mobile systems; and systems that can make synthetic diesel fuel. The summarized technical information of the “BioMax” is shown below.

Table 10.3.6.1 Summarized information of BioMax series

Performance Category	63 Nm^3/hr	125 Nm^3/hr	175 Nm^3/hr
Maximum electrical output (kWe) - 100% electrical	25	50	75
Maximum thermal output (MJ/hr) - 100% heat	317	633	950
Biomass conversion rate (dry kg/hr)	22	44	66
Gasifier Type	Downdraft	Downdraft	Downdraft
Maximum Temperature (C°)	900 to 1000	1650 - 1830	1650 - 1830
Gas Temperature Out of Gasifier (C°)	650 - 700	650 - 700	650 - 700
Engine Types	Spark ignition or Compression ignition	Spark ignition or Compression ignition	Spark ignition or Compression ignition

(Source: CPC)

(Source: CPC)

Figure 10.3.6.5 BioMax 25

D. System Cost

Biomass gasification systems are already widely distributed in India, therefore system cost is lower compared to that of other countries. The following shows the typical system cost of a biomass gasification system in India.

India (ANKUR)

Typical prices are between **US$900 to 2000/kWe**

4 kW	US$
Basic	3,400
Add: transport, taxes, duties	600
Site specific civil works	800
Misc. & Contingencies	600
Total	5,400

40 kW	US$
Basic	30,640
Add: transport, taxes, duties	1,000
Site specific civil works	3,000
Misc. & Contingencies	4,000
Total	38,640

USA (CPC)

Typical prices are between **$4,500 and $7,000/kWe.**

10.3.6.2 Microbinary Generation System

In a binary-cycle power generation system, binary fluid with a low boiling point such as butane or pentane hydrocarbon is pumped at high pressure through the heat exchanger. After that, the fluid is vaporized at the heat exchanger and then directed through a turbine for electricity generation. “Microbinary” is developed as small-scale binary power generation system by KOBELCO. Microbinary is commercialized as the world's first half-sealed screw turbine. It can be operated using hot water with low temperatures between 70^0C to 95^0C. Therefore, the binary generation system can be applied to many types of renewable energy sources, such as geothermal, biomass and solar thermal. In addition, it can also use waste heat from industries.

A. Main Characteristic

High-performance power generation is available because of the adjustability of the technologies, such as screw turbine and synchronous generator, to the temperature fluctuations of the heat source.

B. Simple and small-binary power generation systems

Installation of multiple modules of 70 kW is possible. It is possible to design based on surrounding circumstances. In a microbinary generation set, the inverter, converter and controller are assembled.

Therefore, it is easy to install on-site.

C. Specifications

The following table shows the technical specifications of the microbinary generation system. The binary generation system can be operated using hot water at low temperatures between 70^{0}C to 95^{0}C. Other necessary equipment, such as inverters and converters, are packaged with the generation system.

Table 10.3.6.2 Microbinary Generation Systems Specifications

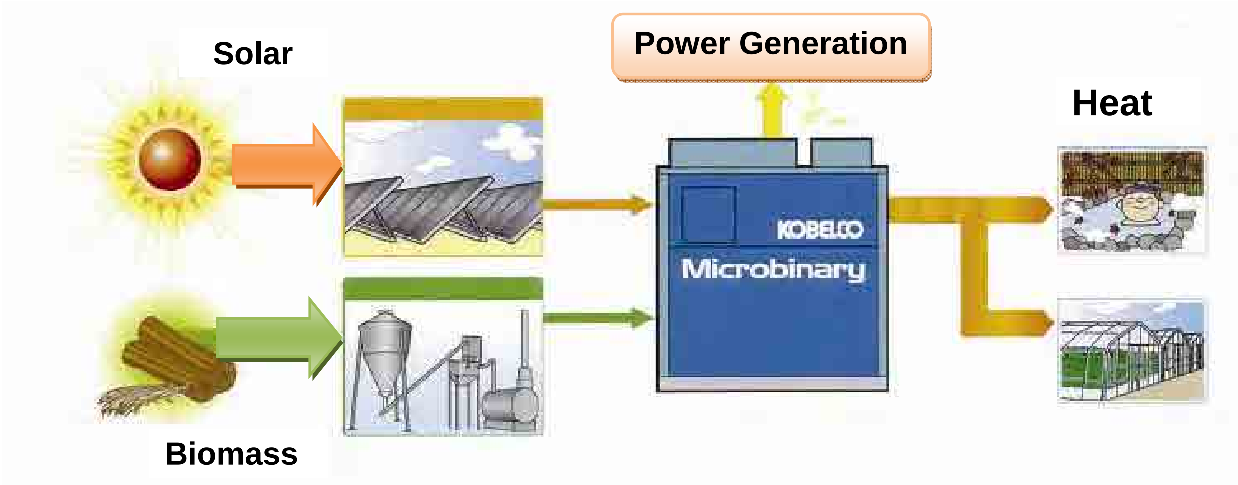
Type	MB-70H
Maximum Power Output at Generator	70 kW
Maximum Power Output at Generator	60 kW
Generator	Synchronized Generator
Rated rotational speed	5500 rpm
Binary gas	HFC245fa
Designed Pressure	0.97 MPa
Temperature of heating source	70 to 95 ^{0}C
Turbine	Screw Turbine
Inverter, Converter	in the unit
Controller	in the unit
Size	2250 mm x 2600 mm x 2250 mm
Weight	6500 kg

(Source: KOBELCO)

The following figure shows KOBELCO (MB-70H). The system can be operated using geothermal, solar and biomass sources of energy.

(Source: KOBELCO)

Figure 10.3.6.6 KOBELCO Microbinary (MB-70H)



(Source: KOBELCO)

Figure 10.3.6.7 Microbinary using Solar and Biomass

D. System Cost

The following shows only the cost of the microbinary equipment and its installation. The installation cost may vary depending on the usage purpose.

Microbinary (MB-70H): **US$312,500 (Equipment only)**

US$500,000（Including installation）

10.3.6.3 Consideration for the introduction of biomass technology

Biomass potential in El Salvador has been studied and the results are summarized below.

A. Summary of the study

a. Sugar cane: There are 3 factories with 4 bagasse power plants in the country. The total capacity is 109.5 MW by the end of December 2011. There are development plans for a generation system with additional 45 MW total capacity.

b. Coffee: Currently, coffee husks are being used as fuel for the boiler in some factories. Estimated capacity for power generation using coffee husks is small at 0.6 MW for the country. At present coffee husks is not available for generating electricity because it is totally used in generating steam in the coffee factory.

c. Rice: Estimated capacity for power generation using rice husks is small at 0.95 MW for the country.

d. Introduction of the technology

Small-scale power generation systems are introduced because biomass resources are limited and widely distributed in the country.

B. Consideration for future development

a. Updating of biomass data

It is necessary to update the information on biomass resources in the country. The information has to be made available to interested people or institutions.

b. Cooperative framework

Since biomass resources, such as coffee or rice husks, are limited for processing at a factory, regional cooperative framework consisting of several factories has to be considered.

c. Human resource development

There is a possibility to introduce the use of small-scale biomass power generation systems in small biomass potential sites. Some small-scale biomass power generation systems, such as biomass gasification can be manufactured in the country. As such, it is important to transfer those kinds of technologies locally.

10.3.7 Biogas

The necessity of introduction of small-scale biogas power generation system is found in the results of a study on biogas resources in El Salvador. In this chapter, a successful biogas project by Grameen Shakti, an NGO in Bangladesh, is discussed. As for data on costs, this is based on the result of a study by UCA on biogas. Information on wastewater treatment plants are collected from Administración Nacional de Acueductos y Alcantarillados (ANDA). The Biogas Project, which is conducted in Chile by GIZ, is explained in this chapter. The required technologies for future development are explained as recommendation. Information on waste power generation system is discussed.

10.3.7.1 Animal Waste

A. General

Biogas is the gaseous product of anaerobic digestion of organic matter. It is typically made up of 60-70% methane (CH_4), 30-40% carbon dioxide (CO_2), 1-5% hydrogen (H_2), up to 0.2% nitrogen (N_2) and a few impurities including hydrogen sulfide (H_2S). Under ideal conditions, concentration of CH_4 can increase up to 80%. However, this is more commonly around 60% with approximately 40% of CO_2. When CO_2 concentration in the biogas exceeds 40%, deterioration of combustion rate and misfires occur and the engine could not run normally.

The typical components of biogas, landfill gas and natural gas are indicated in Table 10.3.7.1. The main difference in the composition between biogas and natural gas is on the carbon dioxide content. Carbon dioxide is one of the main components of biogas, while natural gas contains very low amounts of CO_2. In addition, natural gas also contains higher levels of hydrocarbons other than methane. These differences result to lower energy content of biogas per unit volume compared to natural gas. Typical lower heating value of biogas is as low as 6.5 kWh/Nm^3 compared to that of natural gas (Danish) which is 11.0 kWh/N-m^3.

Table 10.3.7.1 Typical Components of Biogas

	Biogas	Landfill gas	Natural gas (Danish)*	Natural gas (Dutch)
Methane (CH_4) (vol-%)	60–70	35–65	89	81
Other hydrocarbons (vol-%)	0	0	9.4	35
Hydrogen (H_2) (vol-%)	0	0-3	0	–
Carbon dioxide (CO_2) (vol-%)	30–40	15–50	0.67	1
Nitrogen (N_2) (vol-%)	~0.2	5–40	0.28	14
Oxygen (O_2) (vol-%)	0	0-5	0	0
Hydrogen sulfide (H_2S) (ppm)	0–4000	0–100	2.9	–
Ammonia (NH_3) (ppm)	~100	~5	0	–
Lower heating value (kWh/Nm^3)	6.5	4.4	11.0	8.8

(Source: Biogas Upgrading Technologies – Developments and Innovations, IEA)

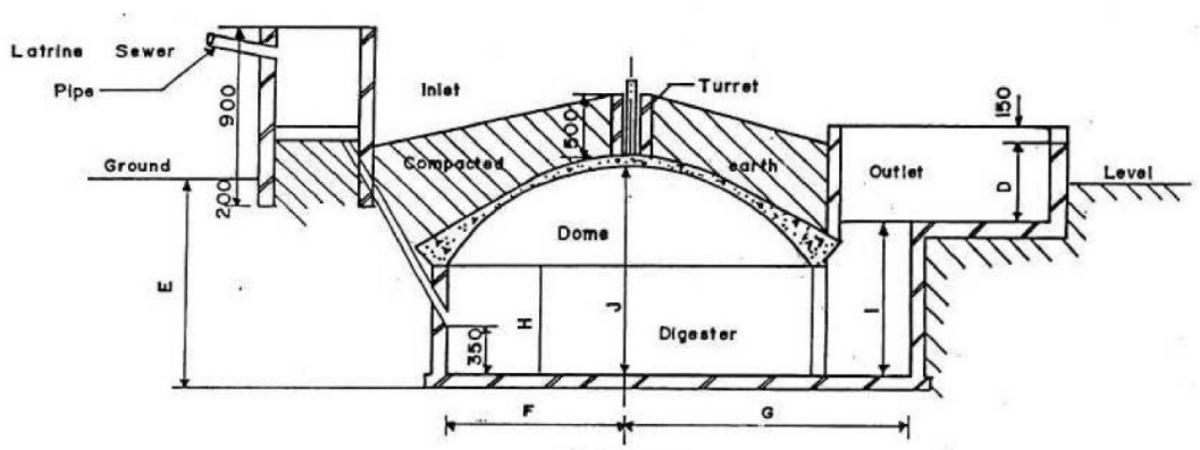
B. Biogas Technology

a. Bio- digester

The bio-digester is a physical structure that is more commonly known as the biogas plant. Since various chemical and microbiological reactions take place in the bio-digester, it is also known as bio-reactor or anaerobic reactor. The main function of this structure is to provide anaerobic conditions inside its chamber, which should be air/water-tight. This can be made using various construction materials and in different shapes and sizes. Construction of this structure comprises major part of the investment cost. Some of the commonly used designs of small-scale bio-digesters are discussed below.

Fixed-Dome Digester

Fixed-dome Chinese model biogas plant consists of an underground brick masonry compartment with a dome on the top for gas storage. In this design, the fermentation chamber and the gas holder are combined as one unit. The lifespan of fixed-dome type plant extends from 20 to 50 years. Figure 10.3.7.1 below shows typical construction of fixed-dome digester.

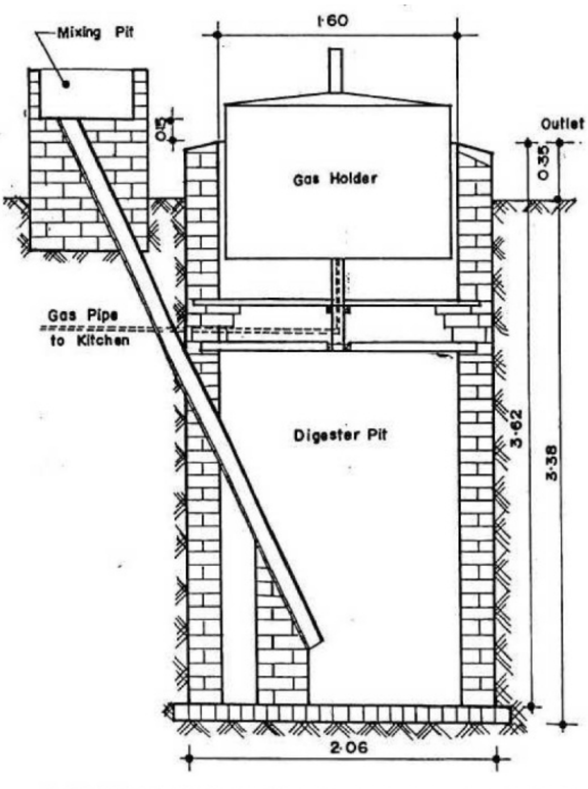


(Source: Consolidated Management Services, Nepal)

Figure 10.3.7.1 Fixed-Dome Digester

Floating Drum Digester

In this design, the digester chamber is made of brick masonry in cement mortar. A mild steel drum is placed on top of the digester to collect the biogas produced from the digester. Thus, there are two separate structures for gas production and collection. With the introduction of the fixed-dome Chinese model plant, the floating drum plants became obsolete because of its comparatively high investment and maintenance cost along with other design weaknesses. The figure below shows the typical construction layout of a fixed-dome digester.



(Source: Consolidated Management Services, Nepal)

Figure 10.3.7.2 Floating Drum Digester

b. Biogas Generator

The utilization of biogas in internal combustion engines (gas engines) is a long-established and extremely reliable technology. Thousands of engines are operated on sewage works, landfill sites and biogas installations. The engine sizes range from several kW on small farms up to several MW on large-scale landfill sites. A diesel engine can be rebuilt into a spark-ignited gas engine or a dual-fuel engine where approximately 8-10% diesel is injected for ignition. Both types of engines are often used. Latest designs show electricity conversion efficiencies of up to 41%.

c. Operation

For the operation of biogas plant, pH and temperature are useful indicators.

pH value :

The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7. The pH in a biogas digester is also a function of the retention time. In the initial period of fermentation, as large amounts of organic acids are produced by acid-forming bacteria, the pH inside the digester can decrease to below 5. This inhibits or even stops the digestion or fermentation process. When the methane production level is stabilized, the pH range remains buffered between 7.2 and 8.2.

Temperature:

The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35 °C. When the ambient temperature goes down to 10 ^{o}C, gas production virtually stops. Satisfactory gas production takes place in the mesophilic range, between 25 to 30 °C. Proper insulation of the digester helps in increasing gas production during cold season.

C. Sample Project

a. Grameen Shakti Project in Bangladesh

Biogas for cooking

In Bangladesh, around 7,000 biogas facilities are introduced in the rural area by Grameen Shakti, a world-famous NGO. Actual operational situations of 12 biogas systems were studied in the JICA study. Out of 12, there are 7 users of 2.4-m^3 biogas facilities, 3 users of 2.0-m^3 digesters and one user each of 3.2-m^3 and 4.8-m^3 digesters. Slurry discharged from biogas digesters is being used in agriculture as organic fertilizer. In addition, dried slurry with moisture content of ~15% is prepared by users and the solid form of the slurry is being sold at US¢4 per kg. In the study, 11 out of 12 households responded that they use the slurry for agricultural purposes which reduced their expenditures on fertilizers. Table 8-10 shows price list of biogas in the project. The subsidy from the government of around US$130/unit is not included in the price.

Table 10.3.7.2 Price List of Biogas: Grameen Shakti

	Capacity (m^3)	No. of Users	Construction Cost*	Minimum down Payment	Monthly Repayment
1	2.0	5-6	US$207	US$52	US$7.5
2	3.0	7-8	US$254	US$64	US$9.3
3	4.0	10-12	US$313	US$78	US$11.4
4	5.0	15-16	US$365	US$ 91	US$13.4
5	6.0	18-20	US$417	US$104	US$15.1

(Source: JICA Study Team)

Biogas for power generation

Power generation systems are being introduced slowly by private institutions. Grameen Shakti has introduced 20 biogas systems for power generation.

There are two biogas power generation facilities with 5-kW capacity each at the dairy farm in the local community. The source of biogas is the cow dung produced from the dairy farm. There are two biogas digesters in the farm. The following shows the amount of biogas production and the input to the digesters. Demand of electricity is mainly for lighting, fan and water pump in the dairy farm.

Digester No. 1
Output : 850 ft^3/day
Input : 600 kg cow dung/day + 600 L water/day

Digester No. 2
Output : 2100 ft^3/day
Input : 1500 kg cow dung/day + 1500 L water/day

In this plant, gas engine made in China is being used for power generation and the price is ~US$765. Before using the gas engine, Chinese-made small diesel generator was used and operated by dual-fuel, biogas and diesel. Instead of a diesel generator, the gas engine is being used for the new project because of the possibility to operate using 100% of produced gas. Venturi tube for air and gas mixers and filters to remove sulfur-hydrogen and moisture are manufactured in the country. Small enterprises are selling these equipment with biogas digesters.

D. System Cost

Universidad Centro Americana (UCA) has conducted research on the economic analysis of biogas systems in El Salvador. The bio-digester was installed at Miravalle, in El Porvenir Municipality, Santa Ana Department. The following assumptions are taken into account in the analysis:

- The initial investment was made in early 2010 (January 2010).
- Project life cycle is 20 years. No replacement of equipment.
- Discount rate is 7.3%.
- Loans for the initial investment have 0% interest.
- Projected income and expenses are in constant prices.
- Straight-line depreciation.

The construction and equipment costs of the bio-digester and power generation system are shown in Table 10.3.7.3. These construction costs have been provided by the actual bio-digester manufacturer.

Table 10.3.7.3 Initial Construction Cost at Miravalle

CIVIL WORKS: CONSTRUCTION

Design	--
Mixed pool perimeter fence	--
Channels	--
Machine room	--
Improvement (plaster, hermetically sealed)	--
Labor	--
Others	--
SUB-TOTAL	**US$26,668.33**

MACHINE ROOM: EQUIPMENT

Purchase of generator (15 kW)	US$10,000.00
Expenditure on imports	US$1,500.00
Others	US$1,490.33
SUB-TOTAL	**US$12,990.33**

Accessories

Gas meters	US$57.00
Piping network	US$20.00
Pumps and filters (2 units)	US$1,200.00
Metering equipment	US$30.00
Installation of other accessories	US$10.00
SUB-TOTAL	**US$1,317.00**

O&M TOOLS

Operation tools	US$10.00
Maintenance tools	US$10.00
SUB TOTAL	**US$20.00**
Lower administrative expenses	US$5.00
SUB-TOTAL	**US$5.00**
TOTAL	**US$41,000.66**

(Source: Aprovechamiento Energético del Biogás En El Salvador, UCA)

The estimated cost of monthly operation of biogas digester is shown in Table 10.3.7.4. Staff salaries are not included because the operators-in-charge are also employees of the Miravalle Farm who are already paid for their work at the farm. Water consumption is also excluded in the estimate as water from the tap will not be used for the operation of the bio-digester, instead, recycled water will be used.

Table 10.3.7.4 Monthly Operational Cost

Operation staff	Not included
Water consumption/month	Not included
Purchase of miscellaneous supplies (gloves, masks)	US$15.00
Monthly analysis	US$25.00
Lower administrative expenses	US$5.00
TOTAL	US$45.00

(Source: Aprovechamiento Energético del Biogás En El Salvador, UCA)

The estimated maintenance costs are presented in the following table.

Table 10.3.7.5 Monthly Maintenance Cost

Operation staff	Not included
Purchase of spare parts (for the plant)	US$5.00
Maintenance of measurement equipment (preventive)	US$5.00
Maintenance of generator (preventive)	US$10.00
Maintenance of pump (preventive)	US$10.00
General maintenance of the plant (preventive and corrective)	US$5.00
Maintenance of other facilities and equipment	US$5.00
Emergency fund for corrective maintenance	US$10.00
Lower administrative expenses	US$5.00
TOTAL	US$55.00

(Source: Aprovechamiento Energético del Biogás En El Salvador, UCA)

10.3.7.2 Wastewater

A. General

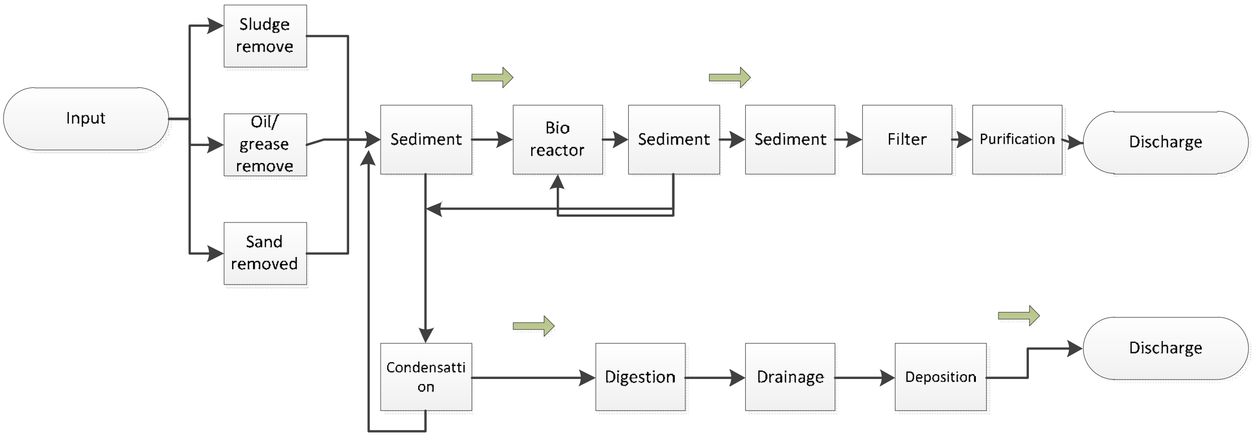
According to ANDA, there are 66 water treatment facilities which are managed by governmental organization and other external organizations. Currently, the available information on water treatment plants is only for the estimation of biogas production. In this chapter, the typical workflow on a water treatment facility is explained. And the project, “Potential de Biogas: Identification and Classification Type of Available Biomass for Biogas Generation” which was carried out by GIZ in Chile in 2007 is explained as a sample. The required technologies for future development are explained as recommendation.

B. Biogas Production by Water Treatment Plant

a. Water Treatment Plant Technology

The objective of the wastewater treatment plant is to remove solids, reduce organic matter and pollutants, and restore oxygen. Mainly, there are two methods of wastewater treatment, namely, aerobic and anaerobic treatment. The first type of wastewater treatment is with oxygen, and the other treatment is without oxygen (anaerobic reactors).

A pre-treatment must be done to remove all the solids such as plastic, metals and inorganic matter. Reducing the organic matter is a natural process where bacteria and microorganisms consume organic matter from the wastewater. In the final process, more oxygen is introduced and this supports aquatic life in the water resource. The following figure shows the work processes in a wastewater treatment plant.



(Source: JICA Study Team)

Figure 10.3.7.3 Conventional Wastewater Treatment Plant

b. Operation

Wastewater treatment process of conventional facility is described below.

Physical treatment

After wastewater is introduced into the wastewater treatment plant, sludge, grease and sand are removed before the preliminary treatment. All the solid particles are removed in this process.

Sediment tank

In sediment tanks, solid particles settle at the bottom of the tank. These solid particles, which are called sludge, can be used after anaerobic treatment.

Biofilters

The solid particles in wastewater can be removed by passing the water through filters. Bacteria and micro-organisms are used in the filter to reduce the amount of organic materials. Also, activated sludge can be used for the aerobic treatment.

Anaerobic reactors

Wastewater treatment plants can use anaerobic reactors to produce biogas. However, this is not a common technology on all wastewater treatment plants. The most common technology for producing biogas is the anaerobic reactor or the UASB reactor.

Purification

Basically, if water after treatment process is for consumption by humans, the water has to include purification in the process.

Discharge

Water will be discharged after the treatment process. Treated water can be used for other purposes such as irrigation, human consumption and discharge to water resources.

C. Sample Project

a. Potential of Biogas in Chile

Engines used

Internal combustion engines were used in the project. In general, capacities of engines using biogas range from few kW to around 20 MW. The efficiency of these engines can be between 70 to 80%. The efficiency of power generation varies between 30 and 40%. The recovery of exhaust heat is dependent on the performance of the heat exchanger installed at the engine cooling system. Two cooling systems are attached to these engines. The range of operational temperature for first cooling system is ~85 to 99°C and that of the other cooling system is around 40 to 70 °C. The cooling system lowers the temperature of engine, oil, and compressed air at the entrance of the system. In this project, around 30% of the engine's energy consumption is supplied by produced biogas. Heat recovery from exhaust pipe is an additional process. The temperature reaches ~350 to 550 °C at the exhaust pipe. The exhaust heat represents roughly 23 to 35% of energy produced by the biogas engine. The table below shows performance of an internal combustion engine which is operated using biogas.

Table 10.3.7.6 Regular Performance of a CAT 352 Engine

Performance	Efficiency (%)
Electric	30.0
Thermic (gases)	20.7
Thermic (cooler)	19.3

(Source: Identificacion y clasificacion de biomasa, en Chile, GTZ)

Biomass analyses for electricity

The project, "Potential de Biogas: Identification and Classification of Types of Available Biomass for Biogas Generation in Chile" was carried out by GIZ in 2007.

In the study, identification and classification of different types of biomass for power generation which are available in Chile were carried out. The following table shows the variations between different types of biomass available in Chile. The amount of each waste is indicative of the potential biogas production for each biomass type evaluated.

Table 10.3.7.7 Amount of Biogas Production

Biomass	Waste	Unit	Biogas Production
Anaerobic treatment	169.370	Ton DBO/year	480 m^3/ton DQO
Sludge*	249.762	Ton Organic M/year	550 m^3/ton Organic M.
Beer factory*	12.546	Ton Organic M/year	700 m^3/ton Organic M.

*dry waste
Organic M: Organic Material /
DQO: Demanda Quimica de Oxígeno (Chemical Oxygen Demand)
DBO: Demanda Biológica de Oxígeno (Biological Oxygen Demand)
(Source: Identificacion y clasificacion de biomasa, en Chile, GIZ)

The table below shows available power output and capacity based on the available amount of biogas production.

Table 10.3.7.8 Available Power Output and Capacity

Biomass	Total electric power		Electric power capacity installed	
	Min. available (MWh/year)	Max. available (MWh/year)	Min. available MW	Max. available MW
Anaerobic treatment	19.396	38.793	20	33
Sludge*	161.271	258.033	20	33
Beer factory*	16.762	19.905	2	3

*dry waste
(Source: Identificacion y clasificacion de biomasa, en Chile, GTZ)

D. System Cost

GIZ has conducted research on economic analysis of biogas systems in Chile. The study was conducted at beer breweries which produce biogas from solid waste. The biogas production system used in the beer brewery was anaerobic digestion. The following table shows the amount of solid waste, volume of produced biogas, capacity and number of generators.

Table 10.3.7.9 Summarized Information of Biogas System in Beer Breweries in Chile

Beer brewery	Amount of solid waste (ton/year)	Volume of biogas production (km^3/year)	Size of the generator MW	Number of generators
1	50,000	122,880	4	2
2	20,000	45,056	2	1

(Source: Identificacion y clasificacion de biomasa, en Chile, GIZ)

The result of the study shows that the power plant has capability to generate 122,880 cubic kilometers of biogas in a year.

The following table shows the total cost of the project for a cogeneration of 4 MW for solid waste generated by the beer breweries. All the solid waste (sludge) underwent anaerobic treatment after its discharge from the wastewater treatment facility.

Table 10.3.7.10 Investments Costs of Cogeneration Plant (4 MW) in Beer Breweries

Cost	Unit	Value
Specific investments cost		
- Grid connection	US$	10,000
Engine cost	US$	1,379.048
Digester cost and plant	US$	5,464.161
Others (buildings)	US$	342,160
Heat grid (connection cost)	US$	20,000
Investment cost	US$	7,215.369
Planning cost/permits: 10% of the investment costs	US$	721.537
Total	US$	7,936.907

(Source: Identificacion y clasificacion de biomasa, en Chile, GIZ)

E. Future Requirements

The production of biogas from water treatment plants can be estimated based on accumulated data and information. The following shows the list of processes essential in the analysis of the biogas production potential from wastewater.

Information update: The data of water treatment facility has to be updated. And the data has to be made available to engineers who estimate output production of biogas resources.

Water treatment plant input: The volume of organic materials in water has to be measured at each plant. It is necessary to calculate the expected biogas production based on the analysis of the anaerobically treated-water at each wastewater treatment plant. Also, BOD level has to be examined for estimation purposes as the BOD levels provide an indicative value of the amount of organic matter in water.

Sludge production measurement: The produced agglomerated residue after water treatment process is called sludge. This sludge can undergo treatment using anaerobic reactors to produce biogas. The sludge productions have to be studied to find out the potential for biogas production. Also, analysis of the different sludge types can be conducted to establish estimation procedures of biogas production rates.

Capacity of the plant: The total number of water treatment plants managed by ANDA is 66. However, the capacities of most facilities are as low as $<1.0\ m^3$. In most water treatment facilities, there are no anaerobic reactors or UASB reactors that can be used to produce biogas.

10.3.7.3 Waste Power Generation

A. General

Waste power generation system produces steam by elevating temperature and pressure with the heat from incinerated solid waste. Then, electricity is generated from the steam turbine. The exhaust heat of the generator can be used effectively as energy source for air-conditioner and water heater in the neighboring areas of the plant. The waste power generation requires large amount of solid waste. However, it is possible to introduce waste power generation systems in small communities if some communities work together. Also, cooperation from residents is important in the introduction of waste power generation facilities into their community. Some features of waste generation are as follows:

- Waste power generation contributes solution to both problems of garbage disposal and energy.
- Discharge of dioxin is controlled by incineration at high temperature.
- Potential to supply heat in the neighboring areas.

Classification of waste is important in effectively using waste as an energy source. For example, classification of plastic, paper and wood is necessary. However, in El Salvador, laws that promote utilization of recycled resources based on the 3R concept (Reuse, Recycle, Reduce) are not yet in place. Recently, discharge of dioxins caused by the combustion of waste and the lack of ash disposal facilities contribute to the problem. However, technology development to control discharge of dioxins by incineration at high temperatures has been carried out recently.

B. Sample Project

Joint study for power generation projects and efficient utilization of industrial wastes in Vietnam was carried out by NEDO and IEA in 2009. In the study, conceptual design of an industrial waste power generation project was prepared. The following shows the summary of the results of the study:

a. Specifications

Incineration capacity:	75 tons/day (ave. calorie content: 16,000 kJ/kg)
Type of incinerator:	Rotary kiln stoker (fluidized-bed furnace is also possible)
Generation capacity:	1.2 MW (transmission end base)
Operation:	24 hrs/day × 330 days/yr = 7,920 hrs/yr
Power production rate:	1.2 MW × 0.90 × 24 hrs/day ÷ 75 ton/day = 345.6 kWh/ton

b. Estimated Project Cost and Energy Efficiency

Total project cost:	approximately US$21 million
Energy efficiency:	8.7%
Power generation cost:	approximately US$0.26/kWh
O &M costs:	approximately US$416,000/yr

c. Preliminary Schedule

The following preliminary schedule was suggested by the NEDO study team for the project in Vietnam.

Table 10.7.3.11 Preliminary Schedule

No.	Item	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
	Commencement of Project Work	▼																																			
A	Design	━	━	━	━	━	━	━	━																												
B	Equipment Procurement				━	━	━	━	━	━	━	━	━	━	━	━	━																				
C	Constrution Work														←	─	─	─	─	─	─	─	─	─	─	─	─	─	→								
	Civil & Archtectual														━	━	━	━	━	━	━	━	━	━	━	━	━	━	━								
	Mechanical Installation																	━	━	━	━	━	━	━	━	━											
	Refractory																					━	━	━	━												
	Piping																						━	━	━	━											
	Electrical & Instrument																						━	━	━	━	━										
	Insulation & Painting																							━	━	━	━										
D	Commissioning																											←	─	─	─	→					
	Cold Commissioning																											━	━								
	Hot Commissioning																													━	━	━					
	Performance Test																																━				
E	Trial Operation																																	━			
F	Commercial Operation																																		▼		

(Source: Joint Study for a Power Generation Project and Efficient Utilization in Vietnam Hanoi Area, NEDO)

The following figure shows the concept of waste power generation system:

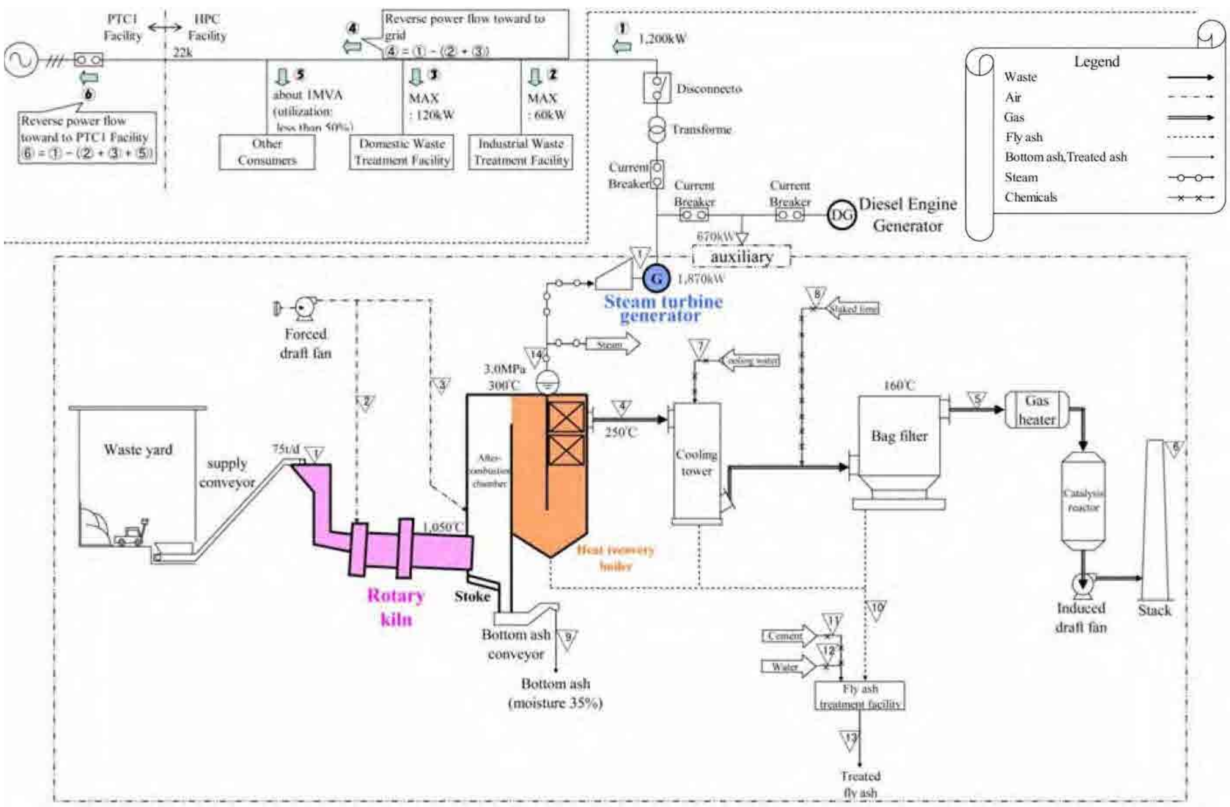


Figure 10.3.7.4 Waste Power Plant

(Source: Joint Study for a Power Generation Project and Efficient Utilization in Vietnam Hanoi Area, NEDO)

10.3.7.4 Consideration for Introduction of Biogas Technology

Biogas potentials in El Salvador have been studied and the results are summarized below.

A. Summary of the Study

a. Landfill: There is a landfill biogas power generation system in Nejapa with an installed capacity of 6.3 MW. There is potential to increase capacity to 10 MW at present, and 25 MW in the future. Total capacity for development is around 7.9 MW excluding Nejapa.

b. Animal Waste: Estimated capacity for power generation using cattle waste is around 84 MW in total. Estimated power generation capacity from pig waste is roughly 2.4 MW, and from poultry is estimated at around 96 MW.

c. Industrial Waste: There are some industries using industrial waste for biogas production such as coffee factory and beer factory. Current condition of using biogas from these industrial waste sources was studied.

d. Wastewater: There are 66 water treatment plants managed by ANDA. The possibility of biogas production from wastewater treatment is examined.

e. Introduction of technology

Small-scale power generation systems are introduced because biogas resources are limited and distributed throughout the country. In the report, small-scale biogas digester, biogas from wastewater and waste power generation are explained.

B. Consideration for Future Development

a. Updating of biogas data

It is necessary to update the information on biogas resources in the country. The information has to be made available to interested individuals or institutions.

b. Cooperative framework

It is necessary to cooperate with institutions, such as ANDA, for biogas production from wastewater. Also, it is necessary to provide available technical information to private institutions.

c. Human resource development

There is possibility to introduce small-scale biogas power generation system in places such as cattle, pig and poultry farms. Small-scale biogas digesters are already introduced in El Salvador. The configuration of the biogas system is simple; therefore, it can be manufactured in the country. It is important to transfer the technology for design, construction and operation of biogas power generation system.

Appendix - A

Evaluation of Distributed Generation Capacity

Appendix A – Evaluation of Distributed Generation Capacity

In the case of El Salvador, the interconnection of distributed generators in the primary distribution networks will be performed at the voltage levels of 23 kV (urban and rural) and 13.2 kV (rural area). The following table shows the maximum capacities of distribution facilities. The maximum capacity of feeders in 23 kV is higher than 13.2 kV due to the higher voltage level has greater carrying capacity. Usually the urban area has a higher load density compared to rural areas (greater number of users per area), that is, urban feeders are smaller in length and can serve a greater number of users, and thus they have a greater feeder capacity.

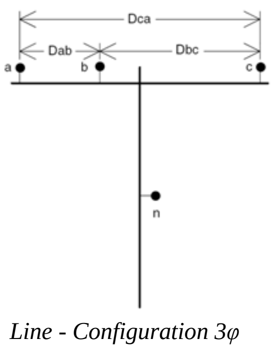
Table A.1 Maximum capacity of distribution facilities in El Salvador

#	Voltage Level	Area	Number Feeders per Substation	Trunk Feeder Length (km)	Maximum Capacity per Feeder (MVA)	Total Capacity per Substation (MVA)
1	23 kV	Urban	5	8	12	60
2	23 kV	Rural	4	15	8	32
3	13.2 kV	Rural	4	15	5	20

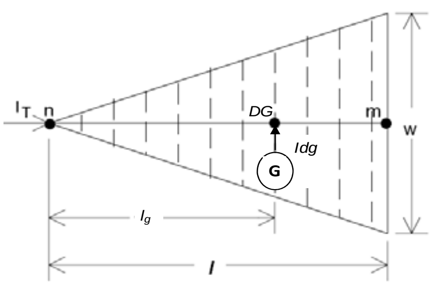
(Source: Information of several distribution companies in El Salvador in December 2011)

An approximate evaluation can be performed to check the feeder and maximum capacities for each voltage level. This evaluation can be performed using the connection of distributed generation unit in a typical feeder using the specifications obtained in El Salvador. The following figure shows the considerations for the approximate evaluation of distribution feeders.

#	Description	Value
1	Trunk feeder conductor	336,4 MCM 26/7 ACSR
2	Geometric configuration of the conductors	Dab = 0.7 m Dbc = 1.2 m Dac = 1.9 m
3	Characteristics of demand for the triangular area of uniform density	Power factor = 0.95 % minimum = 25% % peak = 80%
4	Characteristics of distributed generation	Power factor = 0.90 Connection at 75% of the total length



Line - Configuration 3φ



Model of feeder and distributed generator connection

(Source: JICA Study Team)

Figure A.1 Considerations for approximate evaluation of distribution feeders

The criteria for determining the maximum capacity of distributed generation that can be connected to the feeder in the worst condition of demand (in this case of minimum demand) was defined according to their performance in terms of: i) maintaining low voltage drop at node “m” and ii) prevent the increase in total electrical losses feeder.

Table A.2 Maximum capacity of distributed generation in El Salvador

#	Voltage Level	Area	Total Capacity per Substation (MVA)	Maximum Capacity per Feeder (MVA)	Maximum Capacity of Distributed Generation (MVA)
1	23 kV	Urban	60	12	4.8
2	23 kV	Rural	32	8	3.0
3	13.2 kV	Rural	20	5	2.1

(Source: JICA Study Team)

The above results show the dependence of the maximum capacity of a distributed generator connected in a typical feeder respect to the voltage level and type of area (urban or rural). For the typical feeder in El Salvador, it can be defined a general maximum capacity of approximately 5 MVA. This value is recommended considering that it might be used the IEEE technical standard 1547-2003 (IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems), which covers the connection of distributed generators with a capacity less than 10 MVA.

Appendix - B

Procedure of Electrical Loss Calculation for Distributed Generators

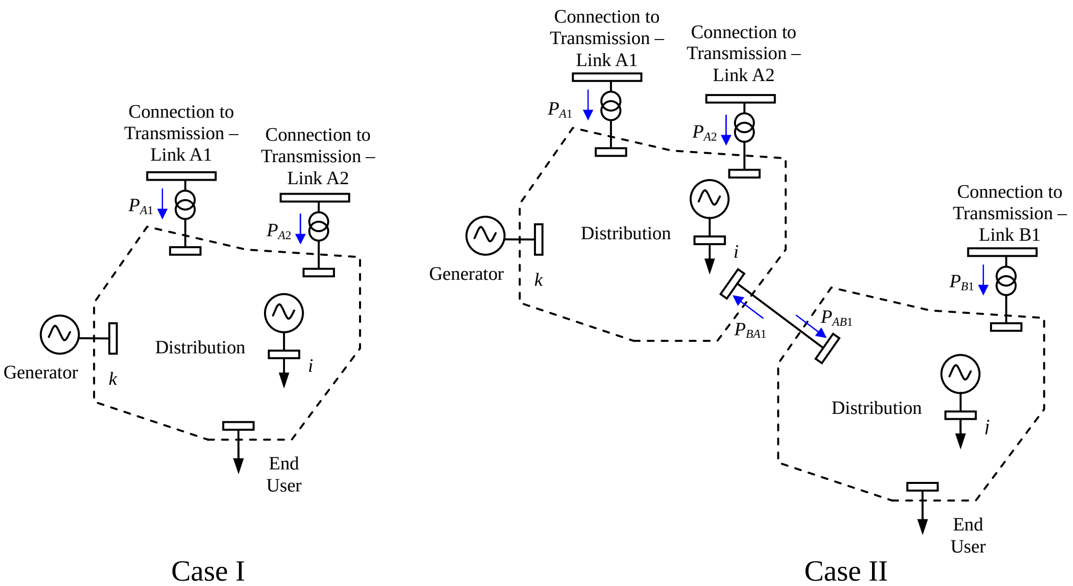
Appendix-B Procedure of Electrical Loss Calculation for Distributed Generators

To establish the technical benefits that can bring a small generator connected to distribution networks, a general procedure is proposed. This procedure may be performed for two cases:

Case I: Generator connected to the same distribution system of the end-user.
Case II: Generator connected to a different distribution of the end user.

The general procedure for calculating electrical losses follows the next steps:

(1) Demarcate the areas of power loss analysis for distribution systems where the generator and the end user areas are connected.



For case I, it is demarcated only the distribution system A. For the case II, it is demarcated the distribution systems A and B related to the nodes of the generator and end user, respectively.

(2) Perform a power flow simulation using the electrical network consisting of all distribution systems without the generator connected to node *k*. All nodes connected to the transmission are considered with control bus voltage. The electrical losses are calculated as follows:

a. Case I:

$$P_{lossA(0)} = P_{A1(0)} + P_{A2(0)} + \sum_{\substack{i\in\Omega_A \\ i\neq k}} P_{g,i} - \sum_{i\in\Omega_A} P_{c,i}$$

where:

$P_{lossA(0)}$	Electrical loss of distribution system A without generator connected to node *k* (MW)
$P_{A1(0)}$	Injected power from transmission network to distribution system A, through to link A1, without generator connected to node *k* (MW)
$P_{A2(0)}$	Injected power from transmission network to distribution system A, through to link A2, without generator connected to node *k* (MW)
Ω_A	Set of nodes relative to the distribution system A

$P_{g,i}$ Power of generator connected to node i (MW), where node i is any node that belongs to the distribution system A

$P_{c,i}$ Power of load connected to node i (MW)

b. Case II:
$$P_{lossA(0)} = P_{A1(0)} + P_{A2(0)} + \sum_{\substack{i \in \Omega_A \\ i \neq k}} P_{g,i} - \sum_{i \in \Omega_A} P_{c,i} + P_{BA1(0)}$$

$$P_{lossB(0)} = P_{B1(0)} + \sum_{j \in \Omega_B} P_{g,j} - \sum_{j \in \Omega_B} P_{c,j} + P_{AB1(0)}$$

where:

$P_{lossB(0)}$ Electrical loss of distribution system B without generator connected to node k (MW)

$P_{B1(0)}$ Injected power from transmission network to distribution system B, through to link B1, without generator connected to node k (MW)

$P_{BA1(0)}$ Injected power from distribution system B to distribution system A, through to link BA1, without generator connected to node k (MW)

$P_{AB1(0)}$ Injected power from distribution system A to distribution system B, through to link AB1, without generator connected to node k (MW)

Ω_B Set of nodes relative to the distribution system B

$P_{g,j}$ Power of generator connected to node j (MW), where node j is any node that belongs to the distribution system B

$P_{c,j}$ Power of load connected to node j (MW)

(3) Perform a power flow simulation using the electrical network consisting of distribution systems with the generator connected to node k. All nodes connected to the transmission are considered with control bus voltage. The electrical losses are calculated as follows:

a. Case I:
$$P_{lossA(1)} = P_{A1(1)} + P_{A2(1)} + \sum_{i \in \Omega_A} P_{g,i} - \sum_{i \in \Omega_A} P_{c,i}$$

where:

$P_{lossA(1)}$ Electrical loss of distribution system A with generator connected to node k (MW)

$P_{A1(1)}$ Injected power from transmission network to distribution system A, through to link A1, with generator connected to node k (MW)

$P_{A2(1)}$ Injected power from transmission network to distribution system A, through to link A2, with generator connected to node k (MW)

b. Case II:
$$P_{lossA(1)} = P_{A1(1)} + P_{A2(1)} + \sum_{i \in \Omega_A} P_{g,i} - \sum_{i \in \Omega_A} P_{c,i} + P_{BA1(1)}$$

$$P_{lossB(1)} = P_{B1(1)} + \sum_{j \in \Omega_B} P_{g,j} - \sum_{j \in \Omega_B} P_{c,j} + P_{AB1(1)}$$

where:

$P_{lossB(1)}$ Electrical loss of distribution system B with generator connected to node k (MW)

$P_{B1(1)}$ Injected power from transmission network to distribution system B, through to link B1, with generator connected to node k (MW)

$P_{BA1(1)}$ Injected power from distribution system B to distribution system A, through to link BA1, with generator connected to node k (MW)

$P_{AB1(1)}$ Injected power from distribution system A to distribution system B, through to link AB1, with generator connected to node k (MW)

(4) The variation of the electrical losses can be calculated as follows:

a. Case I: $\Delta P_{lossA} = P_{lossA(0)} - P_{lossA(1)}$

b. Case II: $\Delta P_{lossA} = P_{lossA(0)} - P_{lossA(1)}$, $\Delta P_{lossB} = P_{lossB(0)} - P_{lossB(1)}$

The results of the variation of the electrical losses can be interpreted as follows:

$\Delta P_{lossA} > 0$ $\Rightarrow$ Electrical losses decrease in the distribution system A due to the connection to the generator at node k.

$\Delta P_{lossA} < 0$ $\Rightarrow$ Electrical losses increase in the distribution system A due to the connection to the generator at node k.

In case it is required only the variation of the electrical losses, it can be simplified the steps (2) through (4) as follows:

(2) Perform a power flow simulation as seen in step (2) above, without generator connected at node k. Save the following information:

a. Case I: $P_{A1(0)}$, $P_{A2(0)}$.

b. Case II: $P_{A1(0)}$, $P_{A2(0)}$, $P_{B1(0)}$, $P_{AB1(0)}$, $P_{BA1(0)}$.

(3) Perform a power flow simulation as seen in step (3) above, with generator connected at node k. Save the following information:

a. Case I: $P_{A1(1)}$, $P_{A2(1)}$.

b. Case II: $P_{A1(1)}$, $P_{A2(1)}$, $P_{B1(1)}$, $P_{AB1(1)}$, $P_{BA1(1)}$.

(4) The variation of the electrical losses can be calculated as follows:

a. Case I: $\Delta P_{lossA} = P_{A1(0)} + P_{A2(0)} - P_{A1(1)} - P_{A2(1)} - P_{g,k}$

b. Case II: $\Delta P_{lossA} = P_{A1(0)} + P_{A2(0)} + P_{BA1(0)} - P_{A1(1)} - P_{A2(1)} - P_{BA1(1)} - P_{g,k}$

$$\Delta P_{lossB} = P_{B1(0)} + P_{AB1(0)} - P_{B1(1)} - P_{AB1(1)} - P_{g,k}$$

where:

$P_{g,k}$ Injected power of generator connected to node k (MW)

Appendix - E

Economic & Financial Analysis

Case-H0(5MW)

Cash Flow for Small Hydropower -5 MW (Case-H0)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
5	50%	4%	12,500	150	5%	70%	8,855	10	8%	10	25%

NPV ($000)	16,024
FIRR	37.7%
B/C	2.05

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	1,875			1,875			1,875	-1,875	0	-1,875	-1,875	
0			0	1,875	45		1,920		354	2,274	-2,274	0	-2,274	-4,149	
1	140	21,900	3,066			153	153	886	708	1,747	1,319	0	1,319	-2,830	633
2	145.6	21,900	3,189			159	159	886	638	1,682	1,506	0	1,506	-1,324	633
3	151.4	21,900	3,316			166	166	886	567	1,618	1,698	0	1,698	374	633
4	157.5	21,900	3,449			172	172	886	496	1,554	1,895	0	1,895	2,269	633
5	163.8	21,900	3,587			179	179	886	425	1,490	2,097	0	2,097	4,366	633
6	170.3	21,900	3,730			187	187	886	354	1,426	2,304	0	2,304	6,670	633
7	177.1	21,900	3,879			194	194	886	283	1,363	2,517	0	2,517	9,187	633
8	184.2	21,900	4,035			202	202	886	213	1,300	2,735	0	2,735	11,921	633
9	191.6	21,900	4,196			210	210	886	142	1,237	2,959	0	2,959	14,880	633
10	199.3	21,900	4,364			218	218	886	71	1,175	3,189	0	3,189	18,070	633
11	207.2	21,900	4,538			227	227			227	4,312	920	3,392	21,462	633
12	215.5	21,900	4,720			236	236			236	4,484	963	3,521	24,983	633
13	224.1	21,900	4,909			245	245			245	4,663	1,008	3,656	28,638	633
14	233.1	21,900	5,105			255	255			255	4,850	1,054	3,796	32,434	633
15	242.4	21,900	5,309			265	265			265	5,044	1,103	3,941	36,375	633
16	252.1	21,900	5,522			276	276			276	5,246	1,153	4,092	40,467	633
17	262.2	21,900	5,743			287	287			287	5,455	1,206	4,250	44,717	633
18	272.7	21,900	5,972			299	299			299	5,674	1,260	4,413	49,130	633
19	283.6	21,900	6,211			311	311			311	5,901	1,317	4,584	53,714	633
20	295.0	21,900	6,460			323	323			323	6,137	1,376	4,761	58,474	633
Total		438,000	91,300	3,750	45	4,565	8,360	8,855	4,250	21,465	69,834	11,360	58,474	58,474	
Source: JICA Study Team			31,324							15,301		NPV=	16,024		

Case-H2(3MW)

Cash Flow for Small Hydropower -3 MW (Case-H2)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
3	50%	4%	7,500	150	5%	70%	5,355	10	8%	10	25%

NPV ($000)	9,563
FIRR	37.3%
B/C	2.04

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	1,125			1,125			1,125	-1,125	0	-1,125	-1,125	
0			0	1,125	45		1,170		214	1,384	-1,384	0	-1,384	-2,509	
1	140	13,140	1,840			92	92	536	428	1,056	784	0	784	-1,725	383
2	145.6	13,140	1,913			96	96	536	386	1,017	896	0	896	-829	383
3	151.4	13,140	1,990			99	99	536	343	978	1,012	0	1,012	183	383
4	157.5	13,140	2,069			103	103	536	300	939	1,130	0	1,130	1,313	383
5	163.8	13,140	2,152			108	108	536	257	900	1,252	0	1,252	2,565	383
6	170.3	13,140	2,238			112	112	536	214	862	1,377	0	1,377	3,942	383
7	177.1	13,140	2,328			116	116	536	171	823	1,504	0	1,504	5,446	383
8	184.2	13,140	2,421			121	121	536	129	785	1,636	0	1,636	7,082	383
9	191.6	13,140	2,518			126	126	536	86	747	1,771	0	1,771	8,853	383
10	199.3	13,140	2,618			131	131	536	43	709	1,909	0	1,909	10,762	383
11	207.2	13,140	2,723			136	136			136	2,587	551	2,036	12,798	383
12	215.5	13,140	2,832			142	142			142	2,690	577	2,113	14,911	383
13	224.1	13,140	2,945			147	147			147	2,798	604	2,194	17,105	383
14	233.1	13,140	3,063			153	153			153	2,910	632	2,278	19,383	383
15	242.4	13,140	3,186			159	159			159	3,026	661	2,365	21,748	383
16	252.1	13,140	3,313			166	166			166	3,147	691	2,456	24,205	383
17	262.2	13,140	3,446			172	172			172	3,273	723	2,551	26,755	383
18	272.7	13,140	3,583			179	179			179	3,404	755	2,649	29,404	383
19	283.6	13,140	3,727			186	186			186	3,540	789	2,751	32,155	383
20	295.0	13,140	3,876			194	194			194	3,682	825	2,857	35,012	383
Total		262,800	54,780	2,250	45	2,739	5,034	5,355	2,570	12,959	41,820	6,808	35,012	35,012	
Source: JICA Study Team			18,795							9,232		NPV=	9,563		

Case-H1(4MW)

Cash Flow for Small Hydropower -4 MW (Case-H1)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
4	50%	4%	10,000	150	5%	70%	7,105	10	8%	10	25%

NPV ($000)	12,793
FIRR	37.5%
B/C	2.04

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	1,500			1,500			1,500	-1,500	0	-1,500	-1,500	
0			0	1,500	45		1,545		284	1,829	-1,829	0	-1,829	-3,329	
1	140	17,520	2,453			123	123	711	568	1,402	1,051	0	1,051	-2,278	508
2	145.6	17,520	2,551			128	128	711	512	1,350	1,201	0	1,201	-1,077	508
3	151.4	17,520	2,653			133	133	711	455	1,298	1,355	0	1,355	278	508
4	157.5	17,520	2,759			138	138	711	398	1,246	1,513	0	1,513	1,791	508
5	163.8	17,520	2,869			143	143	711	341	1,195	1,674	0	1,674	3,466	508
6	170.3	17,520	2,984			149	149	711	284	1,144	1,840	0	1,840	5,306	508
7	177.1	17,520	3,104			155	155	711	227	1,093	2,011	0	2,011	7,316	508
8	184.2	17,520	3,228			161	161	711	171	1,042	2,185	0	2,185	9,502	508
9	191.6	17,520	3,357			168	168	711	114	992	2,365	0	2,365	11,867	508
10	199.3	17,520	3,491			175	175	711	57	942	2,549	0	2,549	14,416	508
11	207.2	17,520	3,631			182	182			182	3,449	735	2,714	17,130	508
12	215.5	17,520	3,776			189	189			189	3,587	770	2,817	19,947	508
13	224.1	17,520	3,927			196	196			196	3,731	806	2,925	22,872	508
14	233.1	17,520	4,084			204	204			204	3,880	843	3,037	25,908	508
15	242.4	17,520	4,247			212	212			212	4,035	882	3,153	29,062	508
16	252.1	17,520	4,417			221	221			221	4,196	922	3,274	32,336	508
17	262.2	17,520	4,594			230	230			230	4,364	964	3,400	35,736	508
18	272.7	17,520	4,778			239	239			239	4,539	1,008	3,531	39,267	508
19	283.6	17,520	4,969			248	248			248	4,720	1,053	3,667	42,934	508
20	295.0	17,520	5,168			258	258			258	4,909	1,100	3,809	46,743	508
Total		350,400	73,040	3,000	45	3,652	6,697	7,105	3,410	17,212	55,827	9,084	46,743	46,743	
			25,060							12,266		NPV=	12,793		

Source: JICA Study Team

Case-H3(2MW)

Cash Flow for Small Hydropower -2 MW (Case-H3)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
2	50%	4%	5,000	150	5%	70%	3,605	10	8%	10	25%

NPV ($000)	6,332
FIRR	36.9%
B/C	2.02

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	750			750			750	-750	0	-750	-750	
0			0	750	45		795		144	939	-939	0	-939	-1,689	
1	140	8,760	1,226			61	61	361	288	710	516	0	516	-1,173	258
2	145.6	8,760	1,275			64	64	361	260	684	592	0	592	-581	258
3	151.4	8,760	1,326			66	66	361	231	658	669	0	669	88	258
4	157.5	8,760	1,380			69	69	361	202	631	748	0	748	836	258
5	163.8	8,760	1,435			72	72	361	173	605	829	0	829	1,665	258
6	170.3	8,760	1,492			75	75	361	144	579	913	0	913	2,578	258
7	177.1	8,760	1,552			78	78	361	115	553	998	0	998	3,576	258
8	184.2	8,760	1,614			81	81	361	87	528	1,086	0	1,086	4,662	258
9	191.6	8,760	1,678			84	84	361	58	502	1,176	0	1,176	5,839	258
10	199.3	8,760	1,746			87	87	361	29	477	1,269	0	1,269	7,108	258
11	207.2	8,760	1,815			91	91			91	1,725	367	1,358	8,466	258
12	215.5	8,760	1,888			94	94			94	1,794	384	1,410	9,875	258
13	224.1	8,760	1,964			98	98			98	1,865	402	1,463	11,338	258
14	233.1	8,760	2,042			102	102			102	1,940	421	1,519	12,858	258
15	242.4	8,760	2,124			106	106			106	2,018	440	1,578	14,435	258
16	252.1	8,760	2,209			110	110			110	2,098	460	1,638	16,073	258
17	262.2	8,760	2,297			115	115			115	2,182	481	1,701	17,774	258
18	272.7	8,760	2,389			119	119			119	2,269	503	1,766	19,541	258
19	283.6	8,760	2,484			124	124			124	2,360	526	1,835	21,375	258
20	295.0	8,760	2,584			129	129			129	2,455	549	1,905	23,281	258
Total		175,200	36,520	1,500	45	1,826	3,371	3,605	1,730	8,706	27,813	4,533	23,281	23,281	
			12,530							6,197		NPV=	6,332		

Source: JICA Study Team

Case-H4(1MW)

Cash Flow for Small Hydropower -1MW (Case-H4)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
1	50%	4%	3,000	150	5%	70%	2,205	10	8%	10	25%

NPV ($000)	2,666
FIRR	28.5%
B/C	1.74

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	450			450			450	-450	0	-450	-450	
0			0	450	45		495		88	583	-583	0	-583	-1,033	
1	140	4,380	613			31	31	221	176	428	186	0	186	-848	158
2	145.6	4,380	638			32	32	221	159	411	227	0	227	-621	158
3	151.4	4,380	663			33	33	221	141	395	268	0	268	-353	158
4	157.5	4,380	690			34	34	221	123	378	311	0	311	-41	158
5	163.8	4,380	717			36	36	221	106	362	355	0	355	314	158
6	170.3	4,380	746			37	37	221	88	346	400	0	400	714	158
7	177.1	4,380	776			39	39	221	71	330	446	0	446	1,160	158
8	184.2	4,380	807			40	40	221	53	314	493	0	493	1,653	158
9	191.6	4,380	839			42	42	221	35	298	541	0	541	2,195	158
10	199.3	4,380	873			44	44	221	18	282	591	0	591	2,786	158
11	207.2	4,380	908			45	45			45	862	176	686	3,472	158
12	215.5	4,380	944			47	47			47	897	185	712	4,184	158
13	224.1	4,380	982			49	49			49	933	194	739	4,923	158
14	233.1	4,380	1,021			51	51			51	970	203	767	5,689	158
15	242.4	4,380	1,062			53	53			53	1,009	213	796	6,485	158
16	252.1	4,380	1,104			55	55			55	1,049	223	826	7,312	158
17	262.2	4,380	1,149			57	57			57	1,091	233	858	8,169	158
18	272.7	4,380	1,194			60	60			60	1,135	244	890	9,060	158
19	283.6	4,380	1,242			62	62			62	1,180	256	924	9,984	158
20	295.0	4,380	1,292			65	65			65	1,227	267	960	10,944	158
Total		87,600	18,260	900	45	913	1,858	2,205	1,058	5,121	13,139	2,194	10,944	10,944	
			6,265							3,599		NPV=	2,666		

Source: JICA Study Team

Case-H5(0.7MW)

Cash Flow for Small Hydropower -0.7 MW (Case-H5)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
0.7	50%	4%	2,100	150	5%	70%	1,575	10	8%	10	25%

NPV ($000)	1,827
FIRR	27.8%
B/C	1.71

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	315			315			315	-315	0	-315	-315	
0			0	315	45		360		63	423	-423	0	-423	-738	
1	140	3,066	429			21	21	158	126	305	124	0	124	-614	113
2	145.6	3,066	446			22	22	158	113	293	153	0	153	-461	113
3	151.4	3,066	464			23	23	158	101	282	183	0	183	-278	113
4	157.5	3,066	483			24	24	158	88	270	213	0	213	-65	113
5	163.8	3,066	502			25	25	158	76	258	244	0	244	179	113
6	170.3	3,066	522			26	26	158	63	247	276	0	276	455	113
7	177.1	3,066	543			27	27	158	50	235	308	0	308	763	113
8	184.2	3,066	565			28	28	158	38	224	341	0	341	1,104	113
9	191.6	3,066	587			29	29	158	25	212	375	0	375	1,480	113
10	199.3	3,066	611			31	31	158	13	201	410	0	410	1,890	113
11	207.2	3,066	635			32	32			32	604	123	481	2,371	113
12	215.5	3,066	661			33	33			33	628	129	499	2,870	113
13	224.1	3,066	687			34	34			34	653	135	518	3,387	113
14	233.1	3,066	715			36	36			36	679	142	537	3,925	113
15	242.4	3,066	743			37	37			37	706	148	558	4,482	113
16	252.1	3,066	773			39	39			39	734	155	579	5,061	113
17	262.2	3,066	804			40	40			40	764	163	601	5,662	113
18	272.7	3,066	836			42	42			42	794	170	624	6,286	113
19	283.6	3,066	870			43	43			43	826	178	648	6,934	113
20	295.0	3,066	904			45	45			45	859	187	672	7,606	113
Total		61,320	12,782	630	45	639	1,314	1,575	756	3,645	9,137	1,531	7,606	7,606	
			4,385							2,558		NPV=	1,827		

Source: JICA Study Team

Case-H6(0.5MW)

Cash Flow for Small Hydropower - 0.5 MW (Case-H6)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
0.5	50%	4%	1,500	150	5%	70%	1,155	10	8%	10	25%

NPV ($000)	1,268
FIRR	26.8%
B/C	1.68

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	225			225			225	-225	0	-225	-225	
0			0	225	45		270		46	316	-316	0	-316	-541	
1	140	2,190	307			15	15	116	92	223	83	0	83	-458	83
2	145.6	2,190	319			16	16	116	83	215	104	0	104	-354	83
3	151.4	2,190	332			17	17	116	74	206	126	0	126	-228	83
4	157.5	2,190	345			17	17	116	65	197	147	0	147	-80	83
5	163.8	2,190	359			18	18	116	55	189	170	0	170	89	83
6	170.3	2,190	373			19	19	116	46	180	193	0	193	282	83
7	177.1	2,190	388			19	19	116	37	172	216	0	216	498	83
8	184.2	2,190	403			20	20	116	28	163	240	0	240	738	83
9	191.6	2,190	420			21	21	116	18	155	265	0	265	1,003	83
10	199.3	2,190	436			22	22	116	9	147	290	0	290	1,293	83
11	207.2	2,190	454			23	23			23	431	87	344	1,637	83
12	215.5	2,190	472			24	24			24	448	91	357	1,994	83
13	224.1	2,190	491			25	25			25	466	96	370	2,364	83
14	233.1	2,190	511			26	26			26	485	101	384	2,748	83
15	242.4	2,190	531			27	27			27	504	105	399	3,147	83
16	252.1	2,190	552			28	28			28	525	111	414	3,561	83
17	262.2	2,190	574			29	29			29	546	116	430	3,991	83
18	272.7	2,190	597			30	30			30	567	121	446	4,437	83
19	283.6	2,190	621			31	31			31	590	127	463	4,900	83
20	295.0	2,190	646			32	32			32	614	133	481	5,381	83
Total		43,800	9,130	450	45	456	951	1,155	554	2,661	6,469	1,088	5,381	5,381	
Source: JICA Study Team			3,132							1,864		NPV=	1,268		

Case-H7(0.3MW)

Cash Flow for Small Hydropower -0.3 MW (Case-H7)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
0.3	50%	4%	900	150	5%	70%	735	10	8%	10	25%

NPV ($000)	710
FIRR	24.9%
B/C	1.61

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	135			135			135	-135	0	-135	-135	
0			0	135	45		180		29	209	-209	0	-209	-344	
1	140	1,314	184			9	9	74	59	141	42	0	42	-302	53
2	145.6	1,314	191			10	10	74	53	136	55	0	55	-247	53
3	151.4	1,314	199			10	10	74	47	130	68	0	68	-178	53
4	157.5	1,314	207			10	10	74	41	125	82	0	82	-96	53
5	163.8	1,314	215			11	11	74	35	120	96	0	96	-1	53
6	170.3	1,314	224			11	11	74	29	114	110	0	110	109	53
7	177.1	1,314	233			12	12	74	24	109	124	0	124	233	53
8	184.2	1,314	242			12	12	74	18	103	139	0	139	372	53
9	191.6	1,314	252			13	13	74	12	98	154	0	154	526	53
10	199.3	1,314	262			13	13	74	6	92	169	0	169	695	53
11	207.2	1,314	272			14	14			14	259	52	207	903	53
12	215.5	1,314	283			14	14			14	269	54	215	1,117	53
13	224.1	1,314	295			15	15			15	280	57	223	1,340	53
14	233.1	1,314	306			15	15			15	291	60	231	1,572	53
15	242.4	1,314	319			16	16			16	303	63	240	1,812	53
16	252.1	1,314	331			17	17			17	315	66	249	2,061	53
17	262.2	1,314	345			17	17			17	327	69	259	2,320	53
18	272.7	1,314	358			18	18			18	340	72	268	2,588	53
19	283.6	1,314	373			19	19			19	354	75	279	2,867	53
20	295.0	1,314	388			19	19			19	368	79	289	3,156	53
Total		26,280	5,478	270	45	274	589	735	353	1,677	3,801	645	3,156	3,156	
Source: JICA Study Team			1,879							1,170		NPV=	710		

Case-H8(0.2MW)

Cash Flow for Small Hydropower -0.2 MW (Case-H8)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
0.2	50%	4%	600	150	5%	70%	525	10	8%	10	25%

NPV ($000)	430
FIRR	22.6%
B/C	1.52

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	90			90			90	-90	0	-90	-90	
0			0	90	45		135		21	156	-156	0	-156	-246	
1	140	876	123			6	6	53	42	101	22	0	22	-224	38
2	145.6	876	128			6	6	53	38	97	31	0	31	-193	38
3	151.4	876	133			7	7	53	34	93	40	0	40	-153	38
4	157.5	876	138			7	7	53	29	89	49	0	49	-104	38
5	163.8	876	143			7	7	53	25	85	59	0	59	-45	38
6	170.3	876	149			7	7	53	21	81	68	0	68	23	38
7	177.1	876	155			8	8	53	17	77	78	0	78	101	38
8	184.2	876	161			8	8	53	13	73	88	0	88	189	38
9	191.6	876	168			8	8	53	8	69	99	0	99	288	38
10	199.3	876	175			9	9	53	4	65	109	0	109	397	38
11	207.2	876	182			9	9			9	172	34	139	536	38
12	215.5	876	189			9	9			9	179	35	144	679	38
13	224.1	876	196			10	10			10	187	37	149	829	38
14	233.1	876	204			10	10			10	194	39	155	984	38
15	242.4	876	212			11	11			11	202	41	161	1,144	38
16	252.1	876	221			11	11			11	210	43	167	1,311	38
17	262.2	876	230			11	11			11	218	45	173	1,484	38
18	272.7	876	239			12	12			12	227	47	180	1,664	38
19	283.6	876	248			12	12			12	236	50	186	1,850	38
20	295.0	876	258			13	13			13	245	52	193	2,043	38
Total		17,520	3,652	180	45	183	408	525	252	1,185	2,467	424	2,043	2,043	
Source: JICA Study Team			1,253							823		NPV=	430		

Case-H9(0.2MW)

Cash Flow for Small Hydropower -0.2 MW (Case-H9)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
0.2	40%	4%	600	150	5%	70%	525	10	8%	10	25%

NPV ($000)	214
FIRR	16.3%
B/C	1.27

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	90			90			90	-90	0	-90	-90	
0			0	90	45		135		21	156	-156	0	-156	-246	
1	140	701	98			5	5	53	42	99	-1	0	-1	-247	38
2	145.6	701	102			5	5	53	38	95	7	0	7	-241	38
3	151.4	701	106			5	5	53	34	91	15	0	15	-226	38
4	157.5	701	110			6	6	53	29	87	23	0	23	-203	38
5	163.8	701	115			6	6	53	25	83	31	0	31	-172	38
6	170.3	701	119			6	6	53	21	79	40	0	40	-132	38
7	177.1	701	124			6	6	53	17	76	49	0	49	-83	38
8	184.2	701	129			6	6	53	13	72	58	0	58	-26	38
9	191.6	701	134			7	7	53	8	68	67	0	67	41	38
10	199.3	701	140			7	7	53	4	64	76	0	76	117	38
11	207.2	701	145			7	7			7	138	25	113	230	38
12	215.5	701	151			8	8			8	143	26	117	347	38
13	224.1	701	157			8	8			8	149	28	121	468	38
14	233.1	701	163			8	8			8	155	29	126	594	38
15	242.4	701	170			8	8			8	161	31	130	724	38
16	252.1	701	177			9	9			9	168	33	135	860	38
17	262.2	701	184			9	9			9	175	34	140	1,000	38
18	272.7	701	191			10	10			10	182	36	146	1,145	38
19	283.6	701	199			10	10			10	189	38	151	1,296	38
20	295.0	701	207			10	10			10	196	40	157	1,453	38
Total		14,016	2,922	180	45	146	371	525	252	1,148	1,774	320	1,453	1,453	
Source: JICA Study Team			1,002							789		NPV=	214		

Case-H10(0.1MW)

Cash Flow for Small Hydropower -0.1 MW (Case-H10)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
0.1	50%	4%	300	150	5%	70%	315	10	8%	10	25%

NPV ($000)	151
FIRR	17.4%
B/C	1.32

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	45			45			45	-45	0	-45	-45	
0			0	45	45		90		13	103	-103	0	-103	-148	
1	140	438	61			3	3	32	25	60	2	0	2	-146	23
2	145.6	438	64			3	3	32	23	57	6	0	6	-140	23
3	151.4	438	66			3	3	32	20	55	11	0	11	-128	23
4	157.5	438	69			3	3	32	18	53	16	0	16	-112	23
5	163.8	438	72			4	4	32	15	50	22	0	22	-90	23
6	170.3	438	75			4	4	32	13	48	27	0	27	-64	23
7	177.1	438	78			4	4	32	10	45	32	0	32	-31	23
8	184.2	438	81			4	4	32	8	43	38	0	38	6	23
9	191.6	438	84			4	4	32	5	41	43	0	43	49	23
10	199.3	438	87			4	4	32	3	38	49	0	49	98	23
11	207.2	438	91			5	5			5	86	16	70	169	23
12	215.5	438	94			5	5			5	90	17	73	241	23
13	224.1	438	98			5	5			5	93	18	76	317	23
14	233.1	438	102			5	5			5	97	19	78	395	23
15	242.4	438	106			5	5			5	101	20	81	477	23
16	252.1	438	110			6	6			6	105	21	84	561	23
17	262.2	438	115			6	6			6	109	22	87	648	23
18	272.7	438	119			6	6			6	113	23	91	739	23
19	283.6	438	124			6	6			6	118	24	94	833	23
20	295.0	438	129			6	6			6	123	25	98	931	23
Total		8,760	1,826	90	45	91	226	315	151	692	1,133	203	931	931	
			626							476		NPV=	151		

Source: JICA Study Team

Case-H11(0.1MW)

Cash Flow for Small Hydropower -0.1 MW (Case-H11)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax	Subsidy
0.1	60%	4%	300	150	5%	70%	315	10	8%	10	25%	

NPV ($000)	259
FIRR	22.8%
B/C	1.53

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	45			45			45	-45	0	-45	-45	
0			0	45	45		90		13	103	-103	0	-103	-148	
1	140	526	74			4	4	32	25	60	13	0	13	-134	23
2	145.6	526	77			4	4	32	23	58	19	0	19	-116	23
3	151.4	526	80			4	4	32	20	56	24	0	24	-92	23
4	157.5	526	83			4	4	32	18	53	29	0	29	-62	23
5	163.8	526	86			4	4	32	15	51	35	0	35	-27	23
6	170.3	526	90			4	4	32	13	49	41	0	41	14	23
7	177.1	526	93			5	5	32	10	46	47	0	47	61	23
8	184.2	526	97			5	5	32	8	44	53	0	53	113	23
9	191.6	526	101			5	5	32	5	42	59	0	59	173	23
10	199.3	526	105			5	5	32	3	39	65	0	65	238	23
11	207.2	526	109			5	5			5	103	20	83	321	23
12	215.5	526	113			6	6			6	108	21	86	408	23
13	224.1	526	118			6	6			6	112	22	90	497	23
14	233.1	526	123			6	6			6	116	23	93	590	23
15	242.4	526	127			6	6			6	121	25	96	687	23
16	252.1	526	133			7	7			7	126	26	100	787	23
17	262.2	526	138			7	7			7	131	27	104	890	23
18	272.7	526	143			7	7			7	136	28	108	998	23
19	283.6	526	149			7	7			7	142	30	112	1,110	23
20	295.0	526	155			8	8			8	147	31	116	1,226	23
Total		10,512	2,191	90	45	110	245	315	151	711	1,480	254	1,226	1,226	
			752							493		NPV=	259		

Source: JICA Study Team

Case-W0

Cash Flow for Wind Power-20MW (Case-W0)

			1,800									
Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
20	25%	4%	36,000		22	70%	25,200	10	8%	5	25%

NPV ($000)	15,796
FIRR	19.6%
B/C	1.34

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	5,400			5,400			5,400	-5,400	0	-5,400	-5,400	
0			0	5,400	0		5,400		1,008	6,408	-6,408	0	-6,408	-11,808	
1	140	43,800	6,132			964	964	2,520	2,016	5,500	632	0	632	-11,176	2,400
2	145.6	43,800	6,377			1,002	1,002	2,520	1,814	5,337	1,041	0	1,041	-10,135	2,400
3	151.4	43,800	6,632			1,042	1,042	2,520	1,613	5,175	1,457	0	1,457	-8,678	2,400
4	157.5	43,800	6,898			1,084	1,084	2,520	1,411	5,015	1,883	0	1,883	-6,795	2,400
5	163.8	43,800	7,174			1,127	1,127	2,520	1,210	4,857	2,317	0	2,317	-4,478	2,400
6	170.3	43,800	7,461			1,172	1,172	2,520	1,008	4,700	2,760	90	2,670	-1,808	2,400
7	177.1	43,800	7,759			1,219	1,219	2,520	806	4,546	3,213	203	3,010	1,202	2,400
8	184.2	43,800	8,069			1,268	1,268	2,520	605	4,393	3,676	319	3,357	4,559	2,400
9	191.6	43,800	8,392			1,319	1,319	2,520	403	4,242	4,150	438	3,713	8,272	2,400
10	199.3	43,800	8,728			1,372	1,372	2,520	202	4,093	4,635	559	4,076	12,348	2,400
11	207.2	43,800	9,077			1,426	1,426			1,426	7,650	1,313	6,338	18,686	2,400
12	215.5	43,800	9,440			1,483	1,483			1,483	7,957	1,389	6,567	25,253	2,400
13	224.1	43,800	9,818			1,543	1,543			1,543	8,275	1,469	6,806	32,059	2,400
14	233.1	43,800	10,210			1,604	1,604			1,604	8,606	1,551	7,054	39,113	2,400
15	242.4	43,800	10,619			1,669	1,669			1,669	8,950	1,637	7,312	46,426	2,400
16	252.1	43,800	11,043			1,735	1,735			1,735	9,308	2,327	6,981	53,407	
17	262.2	43,800	11,485			1,805	1,805			1,805	9,680	2,420	7,260	60,667	
18	272.7	43,800	11,945			1,877	1,877			1,877	10,068	2,517	7,551	68,218	
19	283.6	43,800	12,422			1,952	1,952			1,952	10,470	2,618	7,853	76,070	
20	295.0	43,800	12,919			2,030	2,030			2,030	10,889	2,722	8,167	84,237	
Total		876,000	182,599	10,800	0	28,694	39,494	25,200	12,096	76,790	105,809	21,572	84,237	84,237	
			62,649							46,853		NPV=	15,796		

Source: JICA Study Team

Case-W1

Cash Flow for Wind Power-20MW (Case-W1)

			1,700									
Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
20	25%	4%	34,000		22	70%	23,800	10	8%	5	25%

NPV ($000)	17,384
FIRR	21.2%
B/C	1.38

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	5,100			5,100			5,100	-5,100	0	-5,100	-5,100	
0			0	5,100	0		5,100		952	6,052	-6,052	0	-6,052	-11,152	
1	140	43,800	6,132			964	964	2,380	1,904	5,248	884	0	884	-10,268	2,267
2	145.6	43,800	6,377			1,002	1,002	2,380	1,714	5,096	1,282	0	1,282	-8,986	2,267
3	151.4	43,800	6,632			1,042	1,042	2,380	1,523	4,945	1,687	0	1,687	-7,299	2,267
4	157.5	43,800	6,898			1,084	1,084	2,380	1,333	4,797	2,101	0	2,101	-5,198	2,267
5	163.8	43,800	7,174			1,127	1,127	2,380	1,142	4,650	2,524	0	2,524	-2,674	2,267
6	170.3	43,800	7,461			1,172	1,172	2,380	952	4,504	2,956	172	2,784	109	2,267
7	177.1	43,800	7,759			1,219	1,219	2,380	762	4,361	3,398	283	3,115	3,225	2,267
8	184.2	43,800	8,069			1,268	1,268	2,380	571	4,219	3,850	396	3,454	6,679	2,267
9	191.6	43,800	8,392			1,319	1,319	2,380	381	4,080	4,313	511	3,801	10,480	2,267
10	199.3	43,800	8,728			1,372	1,372	2,380	190	3,942	4,786	630	4,156	14,636	2,267
11	207.2	43,800	9,077			1,426	1,426			1,426	7,650	1,346	6,305	20,941	2,267
12	215.5	43,800	9,440			1,483	1,483			1,483	7,957	1,422	6,534	27,475	2,267
13	224.1	43,800	9,818			1,543	1,543			1,543	8,275	1,502	6,773	34,247	2,267
14	233.1	43,800	10,210			1,604	1,604			1,604	8,606	1,585	7,021	41,268	2,267
15	242.4	43,800	10,619			1,669	1,669			1,669	8,950	1,671	7,279	48,548	2,267
16	252.1	43,800	11,043			1,735	1,735			1,735	9,308	2,327	6,981	55,529	
17	262.2	43,800	11,485			1,805	1,805			1,805	9,680	2,420	7,260	62,789	
18	272.7	43,800	11,945			1,877	1,877			1,877	10,068	2,517	7,551	70,339	
19	283.6	43,800	12,422			1,952	1,952			1,952	10,470	2,618	7,853	78,192	
20	295.0	43,800	12,919			2,030	2,030			2,030	10,889	2,722	8,167	86,359	
Total		876,000	182,599	10,200	0	28,694	38,894	23,800	11,424	74,118	108,481	22,122	86,359	86,359	
			62,649							45,264		NPV=	17,384		

Source: JICA Study Team

Case-W2

Cash Flow for Wind Power-20MW (Case-W2)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	1,700 Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
20	34%	4%	34,000		22	70%	23,800	10	8%	5	25%

NPV ($000)	33,365
FIRR	31.9%
B/C	1.64

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	5,100			5,100			5,100	-5,100	0	-5,100	-5,100	
0			0	5,100	0		5,100		952	6,052	-6,052	0	-6,052	-11,152	
1	140	59,568	8,340			1,310	1,310	2,380	1,904	5,594	2,745	0	2,745	-8,407	2,267
2	145.6	59,568	8,673			1,363	1,363	2,380	1,714	5,457	3,217	0	3,217	-5,190	2,267
3	151.4	59,568	9,020			1,417	1,417	2,380	1,523	5,321	3,699	0	3,699	-1,491	2,267
4	157.5	59,568	9,381			1,474	1,474	2,380	1,333	5,187	4,194	0	4,194	2,703	2,267
5	163.8	59,568	9,756			1,533	1,533	2,380	1,142	5,055	4,701	0	4,701	7,403	2,267
6	170.3	59,568	10,146			1,594	1,594	2,380	952	4,926	5,220	738	4,482	11,885	2,267
7	177.1	59,568	10,552			1,658	1,658	2,380	762	4,800	5,752	871	4,881	16,766	2,267
8	184.2	59,568	10,974			1,725	1,725	2,380	571	4,676	6,299	1,008	5,291	22,057	2,267
9	191.6	59,568	11,413			1,794	1,794	2,380	381	4,554	6,859	1,148	5,711	27,767	2,267
10	199.3	59,568	11,870			1,865	1,865	2,380	190	4,436	7,434	1,292	6,142	33,910	2,267
11	207.2	59,568	12,345			1,940	1,940			1,940	10,405	2,035	8,370	42,280	2,267
12	215.5	59,568	12,838			2,017	2,017			2,017	10,821	2,139	8,682	50,962	2,267
13	224.1	59,568	13,352			2,098	2,098			2,098	11,254	2,247	9,007	59,969	2,267
14	233.1	59,568	13,886			2,182	2,182			2,182	11,704	2,359	9,345	69,314	2,267
15	242.4	59,568	14,441			2,269	2,269			2,269	12,172	2,476	9,696	79,009	2,267
16	252.1	59,568	15,019			2,360	2,360			2,360	12,659	3,165	9,494	88,503	
17	262.2	59,568	15,620			2,455	2,455			2,455	13,165	3,291	9,874	98,377	
18	272.7	59,568	16,245			2,553	2,553			2,553	13,692	3,423	10,269	108,646	
19	283.6	59,568	16,894			2,655	2,655			2,655	14,240	3,560	10,680	119,326	
20	295.0	59,568	17,570			2,761	2,761			2,761	14,809	3,702	11,107	130,433	
Total		1,191,360	248,335	10,200	0	39,024	49,224	23,800	11,424	84,448	163,887	33,454	130,433	130,433	
Source: JICA Study Team			85,203							51,837		NPV=	33,365		

Case-W3

Cash Flow for Wind Power-20MW (Case-W3)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	1,600 Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
20	34%	4%	32,000		22	70%	22,400	10	8%	5	25%

NPV ($000)	34,954
FIRR	34.5%
B/C	1.70

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	**(c) Operation Income ($000)**	d) Capital Cost ($000) Power Plant	Inter-Connection Cost	e) O/M Cost ($000)	**f) Sub Total Cost (d+e)**	(g) Loan ($000) Principal Repayment	Interest	**(h) Total Cost (f+g) ($000)**	**(i) Profit befor Tax (c-h) ($000)**	(j) Corporate Tax (25%)	**(k) Net Income (i-j) ($000)**	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	4,800			4,800			4,800	-4,800	0	-4,800	-4,800	
0			0	4,800	0		4,800		896	5,696	-5,696	0	-5,696	-10,496	
1	140	59,568	8,340			1,310	1,310	2,240	1,792	5,342	2,997	0	2,997	-7,499	2,133
2	145.6	59,568	8,673			1,363	1,363	2,240	1,613	5,216	3,457	0	3,457	-4,042	2,133
3	151.4	59,568	9,020			1,417	1,417	2,240	1,434	5,091	3,929	0	3,929	-113	2,133
4	157.5	59,568	9,381			1,474	1,474	2,240	1,254	4,969	4,412	0	4,412	4,300	2,133
5	163.8	59,568	9,756			1,533	1,533	2,240	1,075	4,848	4,908	0	4,908	9,207	2,133
6	170.3	59,568	10,146			1,594	1,594	2,240	896	4,730	5,416	821	4,595	13,803	2,133
7	177.1	59,568	10,552			1,658	1,658	2,240	717	4,615	5,937	951	4,986	18,789	2,133
8	184.2	59,568	10,974			1,725	1,725	2,240	538	4,502	6,472	1,085	5,387	24,176	2,133
9	191.6	59,568	11,413			1,794	1,794	2,240	358	4,392	7,021	1,222	5,799	29,976	2,133
10	199.3	59,568	11,870			1,865	1,865	2,240	179	4,284	7,585	1,363	6,222	36,198	2,133
11	207.2	59,568	12,345			1,940	1,940			1,940	10,405	2,068	8,337	44,535	2,133
12	215.5	59,568	12,838			2,017	2,017			2,017	10,821	2,172	8,649	53,184	2,133
13	224.1	59,568	13,352			2,098	2,098			2,098	11,254	2,280	8,974	62,157	2,133
14	233.1	59,568	13,886			2,182	2,182			2,182	11,704	2,393	9,311	71,469	2,133
15	242.4	59,568	14,441			2,269	2,269			2,269	12,172	2,510	9,662	81,131	2,133
16	252.1	59,568	15,019			2,360	2,360			2,360	12,659	3,165	9,494	90,625	
17	262.2	59,568	15,620			2,455	2,455			2,455	13,165	3,291	9,874	100,499	
18	272.7	59,568	16,245			2,553	2,553			2,553	13,692	3,423	10,269	110,768	
19	283.6	59,568	16,894			2,655	2,655			2,655	14,240	3,560	10,680	121,448	
20	295.0	59,568	17,570			2,761	2,761			2,761	14,809	3,702	11,107	132,554	
Total		1,191,360	248,335	9,600	0	39,024	48,624	22,400	10,752	81,776	166,559	34,005	132,554	132,554	
Source: JICA Study Team			85,203							50,249		NPV=	34,954		

Case-S0

Cash Flow for PV Power-20MW (Case-S0)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
			3,800								
20	18%	4%	76,000		4	70%	53,200	10	8%	5	25%

NPV ($000)	-26,811
FIRR	1.7%
B/C	0.63

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	11,400			11,400			11,400	-11,400	0	-11,400	-11,400	
0			0	11,400	0		11,400		2,128	13,528	-13,528	0	-13,528	-24,928	
1	140	31,536	4,415			126	126	5,320	4,256	9,702	-5,287	0	-5,287	-30,215	5,067
2	145.6	31,536	4,592			131	131	5,320	3,830	9,282	-4,690	0	-4,690	-34,905	5,067
3	151.4	31,536	4,775			136	136	5,320	3,405	8,861	-4,086	0	-4,086	-38,991	5,067
4	157.5	31,536	4,966			142	142	5,320	2,979	8,441	-3,475	0	-3,475	-42,466	5,067
5	163.8	31,536	5,165			148	148	5,320	2,554	8,021	-2,856	0	-2,856	-45,322	5,067
6	170.3	31,536	5,372			153	153	5,320	2,128	7,601	-2,230	0	-2,230	-47,552	5,067
7	177.1	31,536	5,586			160	160	5,320	1,702	7,182	-1,596	0	-1,596	-49,147	5,067
8	184.2	31,536	5,810			166	166	5,320	1,277	6,763	-953	0	-953	-50,100	5,067
9	191.6	31,536	6,042			173	173	5,320	851	6,344	-302	0	-302	-50,402	5,067
10	199.3	31,536	6,284			180	180	5,320	426	5,925	359	0	359	-50,043	5,067
11	207.2	31,536	6,535			187	187			187	6,349	320	6,028	-44,015	5,067
12	215.5	31,536	6,797			194	194			194	6,603	384	6,219	-37,796	5,067
13	224.1	31,536	7,069			202	202			202	6,867	450	6,417	-31,380	5,067
14	233.1	31,536	7,351			210	210			210	7,141	519	6,623	-24,757	5,067
15	242.4	31,536	7,645			218	218			218	7,427	590	6,837	-17,920	5,067
16	252.1	31,536	7,951			227	227			227	7,724	1,931	5,793	-12,127	
17	262.2	31,536	8,269			236	236			236	8,033	2,008	6,025	-6,102	
18	272.7	31,536	8,600			246	246			246	8,354	2,089	6,266	163	
19	283.6	31,536	8,944			256	256			256	8,689	2,172	6,516	6,680	
20	295.0	31,536	9,302			266	266			266	9,036	2,259	6,777	13,457	
Total		630,720	131,471	22,800	0	3,756	26,556	53,200	25,536	105,292	26,179	12,722	13,457	13,457	
Source: JICA Study Team			45,107							71,919		NPV=	-26,811		

Case-S1

Cash Flow for PV Power-20MW (Case-S1)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
			2,700								
20	18%	4%	54,000		4	70%	37,800	10	8%	5	25%

NPV ($000)	-7,518
FIRR	6.9%
B/C	0.86

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	8,100			8,100			8,100	-8,100	0	-8,100	-8,100	
0			0	8,100	0		8,100		1,512	9,612	-9,612	0	-9,612	-17,712	
1	140	31,536	4,415			126	126	3,780	3,024	6,930	-2,515	0	-2,515	-20,227	3,600
2	145.6	31,536	4,592			131	131	3,780	2,722	6,633	-2,041	0	-2,041	-22,268	3,600
3	151.4	31,536	4,775			136	136	3,780	2,419	6,336	-1,560	0	-1,560	-23,829	3,600
4	157.5	31,536	4,966			142	142	3,780	2,117	6,039	-1,072	0	-1,072	-24,901	3,600
5	163.8	31,536	5,165			148	148	3,780	1,814	5,742	-577	0	-577	-25,478	3,600
6	170.3	31,536	5,372			153	153	3,780	1,512	5,445	-74	0	-74	-25,552	3,600
7	177.1	31,536	5,586			160	160	3,780	1,210	5,149	437	0	437	-25,115	3,600
8	184.2	31,536	5,810			166	166	3,780	907	4,853	957	0	957	-24,158	3,600
9	191.6	31,536	6,042			173	173	3,780	605	4,557	1,485	0	1,485	-22,673	3,600
10	199.3	31,536	6,284			180	180	3,780	302	4,262	2,022	0	2,022	-20,651	3,600
11	207.2	31,536	6,535			187	187			187	6,349	687	5,661	-14,990	3,600
12	215.5	31,536	6,797			194	194			194	6,603	751	5,852	-9,138	3,600
13	224.1	31,536	7,069			202	202			202	6,867	817	6,050	-3,088	3,600
14	233.1	31,536	7,351			210	210			210	7,141	885	6,256	3,168	3,600
15	242.4	31,536	7,645			218	218			218	7,427	957	6,470	9,639	3,600
16	252.1	31,536	7,951			227	227			227	7,724	1,931	5,793	15,432	
17	262.2	31,536	8,269			236	236			236	8,033	2,008	6,025	21,456	
18	272.7	31,536	8,600			246	246			246	8,354	2,089	6,266	27,722	
19	283.6	31,536	8,944			256	256			256	8,689	2,172	6,516	34,239	
20	295.0	31,536	9,302			266	266			266	9,036	2,259	6,777	41,016	
Total		630,720	131,471	16,200	0	3,756	19,956	37,800	18,144	75,900	55,571	14,556	41,016	41,016	
Source: JICA Study Team			45,107							52,625		NPV=	-7,518		

Case-S2

Cash Flow for PV Power-20MW (Case-S2)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
			2,700								
20	25%	4%	54,000		4	70%	37,800	10	8%	5	25%

NPV ($000)	7,889
FIRR	13.2%
B/C	1.14

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	8,100			8,100			8,100	-8,100	0	-8,100	-8,100	
0			0	8,100	0		8,100		1,512	9,612	-9,612	0	-9,612	-17,712	
1	140	43,800	6,132			175	175	3,780	3,024	6,979	-847	0	-847	-18,559	3,600
2	145.6	43,800	6,377			182	182	3,780	2,722	6,684	-307	0	-307	-18,866	3,600
3	151.4	43,800	6,632			189	189	3,780	2,419	6,389	244	0	244	-18,622	3,600
4	157.5	43,800	6,898			197	197	3,780	2,117	6,094	804	0	804	-17,818	3,600
5	163.8	43,800	7,174			205	205	3,780	1,814	5,799	1,374	0	1,374	-16,444	3,600
6	170.3	43,800	7,461			213	213	3,780	1,512	5,505	1,955	0	1,955	-14,489	3,600
7	177.1	43,800	7,759			222	222	3,780	1,210	5,211	2,548	0	2,548	-11,941	3,600
8	184.2	43,800	8,069			231	231	3,780	907	4,918	3,152	0	3,152	-8,789	3,600
9	191.6	43,800	8,392			240	240	3,780	605	4,625	3,767	42	3,726	-5,064	3,600
10	199.3	43,800	8,728			249	249	3,780	302	4,332	4,396	199	4,197	-867	3,600
11	207.2	43,800	9,077			259	259			259	8,818	1,304	7,513	6,646	3,600
12	215.5	43,800	9,440			270	270			270	9,170	1,393	7,778	14,424	3,600
13	224.1	43,800	9,818			281	281			281	9,537	1,484	8,053	22,477	3,600
14	233.1	43,800	10,210			292	292			292	9,919	1,580	8,339	30,816	3,600
15	242.4	43,800	10,619			303	303			303	10,315	1,679	8,636	39,452	3,600
16	252.1	43,800	11,043			316	316			316	10,728	2,682	8,046	47,498	
17	262.2	43,800	11,485			328	328			328	11,157	2,789	8,368	55,866	
18	272.7	43,800	11,945			341	341			341	11,603	2,901	8,702	64,568	
19	283.6	43,800	12,422			355	355			355	12,067	3,017	9,051	73,619	
20	295.0	43,800	12,919			369	369			369	12,550	3,138	9,413	83,031	
Total		876,000	182,599	16,200	0	5,217	21,417	37,800	18,144	77,361	105,238	22,207	83,031	83,031	
Source: JICA Study Team			62,649							54,760		NPV=	7,889		

Case-S3

Cash Flow for PV Power-20MW (Case-S3)

Plant Cap (MW)	Capacity Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost ($)/MWh	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax
			1,600								
20	25%	4%	32,000		4	70%	22,400	10	8%	5	25%

NPV ($000)	25,745
FIRR	27.8%
B/C	1.70

Year	(a) Unit Price ($/MWh)	(b) Generation (MWh)	(c) Operation Income ($000)	d) Capital Cost ($000) Power Plant	d) Capital Cost ($000) Inter-Connection Cost	e) O/M Cost ($000)	f) Sub Total Cost (d+e)	(g) Loan ($000) Principal Repayment	(g) Loan ($000) Interest	(h) Total Cost (f+g) ($000)	(i) Profit befor Tax (c-h) ($000)	(j) Corporate Tax (25%)	(k) Net Income (i-j) ($000)	(l) Accumulated Income ($000)	Depreciation ($000)
0			0	4,800			4,800			4,800	-4,800	0	-4,800	-4,800	
0			0	4,800	0		4,800		896	5,696	-5,696	0	-5,696	-10,496	
1	140	43,800	6,132			175	175	2,240	1,792	4,207	1,925	0	1,925	-8,571	2,133
2	145.6	43,800	6,377			182	182	2,240	1,613	4,035	2,342	0	2,342	-6,229	2,133
3	151.4	43,800	6,632			189	189	2,240	1,434	3,863	2,769	0	2,769	-3,460	2,133
4	157.5	43,800	6,898			197	197	2,240	1,254	3,691	3,206	0	3,206	-253	2,133
5	163.8	43,800	7,174			205	205	2,240	1,075	3,520	3,653	0	3,653	3,400	2,133
6	170.3	43,800	7,461			213	213	2,240	896	3,349	4,111	495	3,617	7,017	2,133
7	177.1	43,800	7,759			222	222	2,240	717	3,178	4,580	612	3,969	10,985	2,133
8	184.2	43,800	8,069			231	231	2,240	538	3,008	5,061	732	4,329	15,315	2,133
9	191.6	43,800	8,392			240	240	2,240	358	2,838	5,554	855	4,699	20,013	2,133
10	199.3	43,800	8,728			249	249	2,240	179	2,669	6,059	981	5,078	25,091	2,133
11	207.2	43,800	9,077			259	259			259	8,818	1,671	7,146	32,238	2,133
12	215.5	43,800	9,440			270	270			270	9,170	1,759	7,411	39,649	2,133
13	224.1	43,800	9,818			281	281			281	9,537	1,851	7,686	47,335	2,133
14	233.1	43,800	10,210			292	292			292	9,919	1,946	7,972	55,307	2,133
15	242.4	43,800	10,619			303	303			303	10,315	2,045	8,270	63,577	2,133
16	252.1	43,800	11,043			316	316			316	10,728	2,682	8,046	71,623	
17	262.2	43,800	11,485			328	328			328	11,157	2,789	8,368	79,990	
18	272.7	43,800	11,945			341	341			341	11,603	2,901	8,702	88,693	
19	283.6	43,800	12,422			355	355			355	12,067	3,017	9,051	97,743	
20	295.0	43,800	12,919			369	369			369	12,550	3,138	9,413	107,156	
Total		876,000	182,599	9,600	0	5,217	14,817	22,400	10,752	47,969	134,630	27,474	107,156	107,156	
Source: JICA Study Team			62,649							36,904		NPV=	25,745		

Appendix - S

Small Hydropower

Table S.1 Condition of Cost Estimation (Example)

Catchment Area	***A***	km2	424.0	
Firm Discharge	***Qfm***	m3/s	1.20	Q90% of flow duration curve
Design Intake Discharge	***Qd***	m3/s	8.79	Parameter
Maximum plant discharge	***Qmax***	m3/s	8.79	Qd = Qmax
Intake Water Level	***IWL***	m		from Topo. Map
Tail Water Level	***TWL***	m		from Topo. Map
Gross Head	***Hg***	m	57	Hg=IWL - TWL
Length of headrace channel	***L1***	m	2,600	from Topo. Map
Length of penstock	***L2***	m	290	from Topo. Map
Length of tailrace channel	***L3***	m	10	(assumed)
Factor of head loss for headrace	***a***	-	0.0002	1/1,000 for tunnel, 1/5.000 for open channel
Factor of head loss for penstock	***b***	-	0.0050	assumed 1/200
Factor of head loss for tailrace	***c***	-	0.0002	1/1,000 for tunnel, 1/5.000 for open channel
Other head loss	***Dh***	m	0.00	(assumed)
Total head loss	***Hl***	m	1.97	Hl = a*L1 + b*L2 + c*L3 + DL
Effective Head	***He***	m	55.43	He = Hg - Hl
Combined Efficiency of Maximum Output	***η***	-	87.5%	h = ht * hg
Maximum Output	***Pmax***	kW	4,175	P=9.8*Qd*He*hr*ht
Combined Efficiency of Firm Output	***ηϕ***	-	59%	h = ht * hg
Firm Output	***Pf***	kW	385	Q90%
Number of Turbine Unit	***n***	nos	2	IF(Pmax>=1000, 2, 1)
Transmission Line		km	3.00	(assumed)
Access Road (Gravel Paved, W=4m)		km	2.00	(assumed)

(Source: JICA Study Team)

Table S.2 Cost Estimation of Civil Works (Example) (1/2)

Civil Works and Material Cost			Unit	Q'ty	Unit Price (US$)		Notes	Amount (US$)
Preliminary / General and Day work			**L.S.**	-		10.0%	**% of Civil Work Cost**	**972,000**
Intake Weir								**260,800**
	Maximum plant discharge	***Qmax***	m3/s	8.8				
	Weir/Dam Height	***Hd***	m	2.0			assumed	
*	Crest Width	***Li***	m	62.2	US$/m3		Li = Qmax * 198 / Hd^2 / 7	
	Catchment Area	***A***	km2	424.0			from Topo.Map	
	Region coefficient for Flood	***a***	-	17.0			a=17~84	
	Design Flood	***Qf***	m3/s	1,490			assumed, Qf =(a*A^(A^(-0.05)-1))*A	
	Excavation Volume (Rock)	***Ve***	m3	2,100	US$/m3	3.39	Ve=8.69*(Hd*L)^1.14	7,200
	Temp.Coffer Dam Vol.	***Vsd***	m3	400	US$/m3	16.3	Vsd= Li*Hd *3m	6,600
	Concrete Volume	***Vc***	m3	700	US$/m3	247.4	Vc=16.1*(Hd^2*L)^0.695	173,200
	(Weight of Cement)	***Wc***	ton	290			Wc=Vc * 8.3bag * 50kg/bag (Class:A)	
	(Weight of Fixation Wire)	***Ww***	ton	5.8			Ww=Wc*2%	
	(Weight of Sand)	***Ws***	ton	739			Ws=Vc* 0.48m3 *2200kg/m3 (Class:A)	
	(Weight of Gravel/Stones)	***Wa***	ton	1,232			Wa=Vc* 0.8m3 *2200kg/m3 (Class:A)	
	Weight of Reinforcement Bar	***Wr***	ton	6.0	US$/ton	2,260	Wr=0.0274*Vc^0.830	13,600
	Others		L.S.	-			30% of above costs	60,200
Intake								**179,300**
	Design Intake Discharge	***Qd***	m3/s	8.79				
	Design Intake Velocity	***V***	m/s	1.40			assumed	
	Diameter of Intake	***Di***	m	2.39			***Di=SQRT(4*Ac / (pi *V))***	
	Excavation Volume	***Ve***	m3	820	US$/m3	3.93	Ve=171*(R*Q)^0.666, R=D/2	3,300
	Concrete Volume	***Vc***	m3	440	US$/m3	236.4	Vc=147*(R*Q)^0.470	104,100
	(Weight of Cement)	***Wc***	ton	150.0			Wc=Vc * 6.8bag * 50kg/bag (Class:B)	
	(Weight of Fixation Wire)	***Ww***	ton	3.00			Ww=Wc*2%	
	(Weight of Sand)	***Ws***	ton	523			Ws=Vc* 0.54m3 *2200kg/m3 (Class:B)	
	(Weight of Gravel/Stones)	***Wa***	ton	794			Wa=Vc* 0.82m3 *2200kg/m3 (Class:B)	
	Weight of Reinforcement Bar	***Wr***	ton	15.9	US$/ton	2,260	Wr=0.0145*Vc^1.15	36,000
	Others		L.S.	-			25% of above costs	35,900
Settling Basin (Sandtrap)								**535,400**
	Maximum plant discharge	***Qmax***	m3/s	8.79				
	Excavation Volume	***Ve***	m3	5,300	US$/m3	3.93	Ve=515*Qmax^1.07	20,900
*	Concrete Volume	***Vc***	m3	1,300	US$/m3	236.40	Vc=169*(Qd)^0.936	307,400
	(Weight of Cement)	***Wc***	ton	215.0			Wc=Vc * 3.3bag * 50kg/bag (stone masonry 1:4)	
	(Weight of Fixation Wire)	***Ww***	ton	4.30			Ww=Wc*2%	
	(Weight of Sand)	***Ws***	ton	1,420			Ws=Vc* 0.496m3 *2200kg/m3 (stone masonry 1:4)	
	(Weight of Gravel/Stones)	***Wa***	ton	3,430			Wa=Vc* 1.2m3 *2200kg/m3 (stone masonry 1:4)	
	Weight of Reinforcement Bar	***Wr***	ton	52.1	US$/ton	2,260	Wr=0.120*Vc^0.847	117,800
	Others		L.S.	-			20% of above costs	89,300
Headrace Channel								**1,339,200**
	Length of Headrace Canal	***Lc***	m	2,600			from Topo.Map	
	Headrace Flow Velocity	***vc***	m/s	2.5			(Open Channel or Pipe Channel =2 ~ 3 m/s)	
	Water Area (Cross Section)	***Ac***	m2	3.52			***Qmax / vc***	
	Thickness of concrete wall	***tc***	m	0.00			assumed	
	* Pipe Diameter (if Piped channel	***Dc***	mm	1,338			*(if piped canal) Dc=SQRT(4*Ac / (pi *vc))*	
	* Pipe Wight (if Pipe channel)	***Wp***	ton	80.00	-	-	Wp [kg]=(0.0227x + 0.022) * L	
	Excavation Volume	***Ve***	m3	59,790	US$/m3	3.93	Ve=6.22*(Ac)^1.04*Lc	235,000
	Concrete Volume	***Vc***	m3	0	US$/m3	236.40	Vc={H*tc*2+(B+2*tc)*tc}*Lc	0
	(Weight of Cement)	***Wc***	ton	0			Wc=Vc * 3.3bag * 50kg/bag (stone masonry 1:4)	
	(Weight of Fixation Wire)	***Ww***	ton	0.00			Ww=Wc*2%	
	(Weight of Sand)	***Ws***	ton	0			Ws=Vc* 0.496m3 *2200kg/m3 (stone masonry 1:4)	
	(Weight of Gravel/Stones)	***Wa***	ton	0			Wa=Vc* 1.2m3 *2200kg/m3 (stone masonry 1:4)	
	Weight of Reinforcement Bar	***Wr***	ton	0	US$/ton	2,260	Wr=0.577* (Vc/L)^0.888*Lc	0
	* Pipe Material Cost		m	2,600	US$/m	338.85	[US$/m]=0.0916*Dp + 0.0233	881,000
	Others		L.S.	-			20% of above costs	223,200

(Source: JICA Study Team)

Table S.2 Cost Estimation of Civil Works (Example) (2/2)

Item	Symbol	Unit	Q'ty	Unit Price (US$)		Notes	Amount (US$)
Head Tank							**477,000**
Excavation Volume	*Ve*	m3	3,680	US$/m3	3.93	Ve=808*Qmax^0.697	14,500
* Concrete Volume	*Vcf*	m3	930	US$/m3	236.40	Vc=197*Qmax^0.716	219,900
(Weight of Cement)	*Wc*	ton	317			Wc=Vc * 6.8bag * 50kg/bag (Class:B)	
(Weight of Fixation Wire)	*Ww*	ton	6.34			Ww=Wc*2%	
(Weight of Sand)	*Ws*	ton	1,105			Ws=Vc* 0.54m3 *2200kg/m3 (Class:B)	
(Weight of Gravel/Stones)	*Wa*	ton	1,680			Wa=Vc* 0.82m3 *2200kg/m3 (Class:B)	
Weight of Reinforcement Bar	*Wr*	ton	47.0	US$/ton	2,260	Wr=0.051*Vc	106,300
Others		L.S.	-			40% of above costs	136,300
Penstock							**644,000**
Penstock Design Flow Velocity	*Vp*	m	3.0	-	-	(ave. Vp=2 ~ 4 m/s)	
Inner Diameter of Pestock Pipe	*Dp*	m	1.90	-	-	Dp=(4*Qd/ (pi*Vt))^(1/2)	
Penstock Roughness	*np*	mm	0.01			assumed	
Effective Head	*He*	m	55.43			from waterway profile	
Thickness of Steel Pipe	*Tp*	mm	6	-	-	***Tp=0.0362*Hg*Dp+2***	
Length of Penstock Pipe	*Lp*	m	290.0	-	-	from Topo.Map	
Excavation Volume	*Ve*	m3	7,500	US$/m3	3.93	Ve=10.9*Dp^1.33*Lp	29,500
Concrete Volume	*Vc*	m3	1,830	US$/m3	236.40	Vc=2.14*Dp^1.68*Lp	432,600
(Weight of Cement)	*Wc*	ton	620			Wc=Vc * 6.8bag * 50kg/bag (Class:B)	
(Weight of Fixation Wire)	*Ww*	ton	12.40			Ww=Wc*2%	
(Weight of Sand)	*Ws*	ton	1,860			Ws=Vc* 0.46m3 *2200kg/m3 (Class:B)	
(Weight of Gravel/Stones)	*Wa*	ton	3,300			Wa=Vc* 0.82m3 *2200kg/m3 (Class:B)	
Weight of Reinforcement Bar	*Wr*	ton	33.0	US$/ton	2,260	Wr=0.018*Vc	74,600
Others		L.S.	-			20% of above costs	107,300
Spillway							**231,500**
Inner Diameter of Spillway Pipe	*Ds*	m	0.85		-	Ds=Dp * 50%	
Length of Spillway	*Ls*	m	290.0		-	(assumed Installed parallel with penstock)	
Excavation Volume	*Ve*	m3	2,160	US$/m3	3.93	Ve=9.87 * Ds^1.69 * Ls	8,500
Concrete Volume	*Vc*	m3	610	US$/m3	236.40	Vc=2.78 * Ds^1.70 * Ls	144,300
(Weight of Cement)	*Wc*	ton	101.0			Wc=Vc * 3.3bag * 50kg/bag (stone masonry 1:4)	
(Weight of Fixation Wire)	*Ww*	ton	2.02			Ww=Wc*2%	
(Weight of Sand)	*Ws*	ton	666			Ws=Vc* 0.496m3 *2200kg/m3 (stone masonry 1:4)	
(Weight of Gravel/Stones)	*Wa*	ton	1,611			Wa=Vc* 1.2m3 *2200kg/m3 (stone masonry 1:4)	
Weight of Reinforcement Bar	*Wr*	ton	17.7	US$/ton	2,260	Wr=0.029* Vc	40,100
Others		L.S.	-			20% of above costs	38,600
Power House							**913,300**
Number of unit	*n*	nos	2	unit	-		
Excavation Volume	*Ve*	m3	4,300	US$/m3	3.93	Ve=97.8*{Q*He^(2/3)*n^(1/2)}^0.727	16,900
Concrete Volume	*Vc*	m3	1,700	US$/m3	236.40	Vc=28.1*{Q*He^(2/3)*n^(1/2)}^0.795	401,900
(Weight of Cement)	*Wc*	ton	281			Wc=Vc * 3.3bag * 50kg/bag (stone masonry 1:4)	
(Weight of Fixation Wire)	*Ww*	ton	5.62			Ww=Wc*2%	
(Weight of Sand)	*Ws*	ton	1,860			Ws=Vc* 0.496m3 *2200kg/m3 (stone masonry 1:4)	
(Weight of Gravel/Stones)	*Wa*	ton	4,490			Wa=Vc* 1.2m3 *2200kg/m3 (stone masonry 1:4)	
Weight of Reinforcement Bar	*Wr*	ton	114	US$/ton	2,260	Wr=0.046*Vc^1.05	257,700
Others		L.S.	-			35% of above costs	236,800
Tailrace							**78,500**
Waterway radius	*R*	m	1.10			assumed	
Excavation Volume	*Ve*	m3	1,200	US$/m3	3.93	Ve=395 * (R*Q)^0.479	4,700
Concrete Volume	*Vc*	m3	191	US$/m3	236.4	Vc=40.4 * (R*Q)^0.684	45,200
(Weight of Cement)	*Wc*	ton	31.5			Wc=Vc * 3.3bag * 50kg/bag (stone masonry 1:4)	
(Weight of Fixation Wire)	*Ww*	ton	0.63			Ww=Wc*2%	
(Weight of Sand)	*Ws*	ton	208			Ws=Vc* 0.496m3 *2200kg/m3 (stone masonry 1:4)	
(Weight of Gravel/Stones)	*Wa*	ton	504			Wa=Vc* 1.2m3 *2200kg/m3 (stone masonry 1:4)	
Weight of Reinforcement Bar	*Wr*	ton	6.8	US$/ton	2,260	Wr=0.278* Vc^0.61	15,500
Others		L.S.	-			20% of above costs	13,100
Access Pass/ Road Construction							**400,000**
Access Road (Gravel Paved, W=4m)		km	2.0	US$/km	200,000	from Topo.Map	400,000
						Sub Total	**6,031,000**

(Source: JICA Study Team)

Table S.3 Cost Estimation of Hydraulic and Electro-Mechanical Equipments (Example)

Hydraulic Equipment & Material Cost		Unit	Q'ty	Unit Price (US$)		Notes	Amount (US$)
Intake Weir							**50,600**
Weight of Gate	*Wg*	ton	23.0	US$/ton	2,200	Wg=0.145*Qf^0.692	50,600
Intake							**107,400**
Weight of Gate	*Wg*	ton	44.5	US$/ton	2,200	Wg=12.7*(R*Q)^0.533, R=Di/2	97,900
Weight of Screen	*Ws*	ton	2.8	US$/ton	3,390	Ws=0.701*(R*Q)^0.582, R=Di/2	9,500
Settling Basin (Sandtrap)							**24,400**
Weight of Gate	*Wg*	ton	3.5	US$/ton	2,200	Wg=0.910*Qmax^0.613	7,700
Weight of Screen	*Ws*	ton	4.9	US$/ton	3,390	Ws=0.879*Qmax^0.785	16,700
Penstock							**318,700**
Wight of Pipe	*Wp*	ton	94.0	US$/ton	3,390	Wp [ton]=7.85*pi*Dp*Tp/1000*1.15*L	318,700
Outlet Gate							**0**
Weight of Gate	*Wo*	ton	-	US$/ton	2,200	Wg=0.910*Qmax^0.613	-
Others							**100,000**
		L.S.	-			20%	100,000
Sub Total							**601,100**

Electro-Mechanical Equipment	Unit	Q'ty	Unit Price (US$)		Notes	Amount (US$)
Electro-Mechanical Equipment (Turbine & Ger	kW	4,175	US$/kW	600	Cost [mil.US$] = 0.7452 * P []mW] ^0.8546	2,505,000
Mechanical Transmission	kW	4,175	US$/kW	-	included in Turbine & Generator Cost	0
Generator	kW	4,175	US$/kW	-	included in Turbine & Generator Cost	0
Controller	nos.	2	US$/set	24,000	Cost = 23867 * (Turbine nos.)	48,000
Switch Board Cubicle	kW	4,175	US$/kW	39.28	included in Turbin Cost	164,000
Mandatory Spare Parts	kW	4,175	US$/kW	39.28	Cost = 15.484*P + 3589	164,000
Miscellanies	kW	4,175	US$/kW	16.29	Cost = 4.3077*P + 1355.1	68,000
Erection, Test, Commissioning and Training	kW	4,175	US$/kW	55.81	Cost = 51.824*P + 16269	233,000
					Sub Total	**3,182,000**

Transmission Line	Unit	Q'ty	Unit Price (US$)		Notes	Amount (US$)
Transmission Line	km	3.00	US$/km	50,000	13.2 kV or 46 kV of distribution line (less 5 MW)	150,000
					Sub Total	**150,000**

(Source: JICA Study Team)

Table S.4 Estimated Total Construction Cost (Example)

Description	Estimated Cost US$	Note
I. Preparatory work		
(1) Access Road	400,000	
(2) Camp & Facilities	291,200	5.0% * (3 Civil work)
Sub total	**691,200**	
2. Environmental Mitigation Cost	**58,200**	1.0% * (3 Civil work)
3. Civil Works		
(1) Intake Weir	260,800	
(2) Intake	179,300	
(3) Settling Basin	535,400	
(4) Headrace	1,339,200	
(5) Head tank	477,000	
(6) Penstock	644,000	
(7) Spillway	231,500	
(8) Powerhouse	913,300	
(9) Tailrace channel	-	
(10) Tailrace	78,500	
(11) Miscellaneous Works	1,164,800	25.0% * ((1)~(10))
Sub total	**5,824,000**	
4. Hydraulic Equipment		
(1) Gate & Screen	282,400	
(2) Penstock	318,700	
Sub total	**601,000**	
5. Electro-mechanical Equipment	**3,182,000**	
6. Transmission Line	**150,000**	
Direct Cost	**10,506,400**	1+2+3+4+5+6
7. Administration & Engineering fee	**315,000**	3.0% *** Direct Cost**
8. Contingency	**105,000**	1.0% *** Direct Cost**
Total	**10,926,400**	

(Source: JICA Study Team)

Table S.5 Example of Financial Analysis (Without Bank Loan)

Plant Cap (MW)	Energy (MWh/yr)	Operation Factor (%)	Escalation Rate	Plant Cost ($000)	O/M Cost	Insualance	Discount Rate
4.175	17,688	48%	4%	10,926	5%	1.50	10%
				-			

Salaries of operators	Person(s)	Unit Cost (US$/month)
Engineer	1	$1,800/month
Operator	2	$500/month
Security guar	2	$400/month
Resident man	1	$500/month

Year	Unit Price	Generation	Benefit Operation Income	Capital Cost ($000)	O/M Cost ($000)	Insuarance Seguros ($000)	Depreciation	Sub Total Cost (d~g) ($000)	Gross Profit	Salaries of operators, engineers, securities, ect.	Tax of Alcaldia	SIGET Annuity	Commercial Registration (CNR)
	($/MWh)	(MWh/year)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)
	a (4%)	b	c=a*b	d	e=c*5%+b*0.35	f=Plant Cost*1.5/1000 (98% per year)	g=Plant Cost/50	h=sum(d~e)	i=c-h	j=(1800+2*500+2*400+500)*12*(105%)	k=0.00216*plant cost	l=b*0.51	m=Plant Cost/100,000*11.43
0			0.0	-5,463									
0			0.0	-5,463									
1	140.00	17,688.0	2,476.3		130.0	16.4	218.5	364.9	2,111.4	49.2	23.6	9.0	1.249
2	145.60	17,688.0	2,575.4		135.0	16.1	218.5	369.5	2,205.8	51.2	23.6	9.0	1.249
3	151.42	17,688.0	2,678.4		140.1	15.7	218.5	374.4	2,304.0	53.2	23.6	9.0	1.249
4	157.48	17,688.0	2,785.5		145.5	15.4	218.5	379.4	2,406.1	55.3	23.6	9.0	1.249
5	163.78	17,688.0	2,896.9		151.0	15.1	218.5	384.7	2,512.3	57.6	23.6	9.0	1.249
6	170.33	17,688.0	3,012.8		156.8	14.8	218.5	390.2	2,622.6	59.9	23.6	9.0	1.249
7	177.14	17,688.0	3,133.3		162.9	14.5	218.5	395.9	2,737.4	62.3	23.6	9.0	1.249
8	184.23	17,688.0	3,258.7		169.1	14.2	218.5	401.9	2,856.8	64.7	23.6	9.0	1.249
9	191.60	17,688.0	3,389.0		175.6	13.9	218.5	408.1	2,980.9	67.3	23.6	9.0	1.249
10	199.26	17,688.0	3,524.6		182.4	13.7	218.5	414.6	3,110.0	70.0	23.6	9.0	1.249
11	207.23	17,688.0	3,665.6		189.5	13.4	218.5	421.4	3,244.2	72.8	23.6	9.0	1.249
12	215.52	17,688.0	3,812.2		196.8	13.1	218.5	428.5	3,383.7	75.7	23.6	9.0	1.249
13	224.14	17,688.0	3,964.7		204.4	12.9	218.5	435.8	3,528.8	78.8	23.6	9.0	1.249
14	233.11	17,688.0	4,123.2		212.4	12.6	218.5	443.5	3,679.8	81.9	23.6	9.0	1.249
15	242.43	17,688.0	4,288.2		220.6	12.4	218.5	451.5	3,836.7	85.2	23.6	9.0	1.249
16	252.13	17,688.0	4,459.7		229.2	12.1	218.5	459.8	3,999.9	88.6	23.6	9.0	1.249
17	262.22	17,688.0	4,638.1		238.1	11.9	218.5	468.5	4,169.6	92.2	23.6	9.0	1.249
18	272.71	17,688.0	4,823.6		247.4	11.6	218.5	477.5	4,346.1	95.8	23.6	9.0	1.249
19	283.61	17,688.0	5,016.6		257.0	11.4	218.5	486.9	4,529.6	99.7	23.6	9.0	1.249
20	294.96	17,688.0	5,217.2		267.1	11.2	218.5	496.7	4,720.5	103.7	23.6	9.0	1.249
Total		353,759.5	73,739.9	-10,926.4	3,810.8	272.4		8,453.8					24.978

NPV ($000)	11,575
FIRR (TIR)	21.3%
B/C	1.79
B - C ($000)	11,575

Year	Total Operation cost	Total Cost	Operation Benefit	Interest	Benefit before taxes	Income Taxes	Net income without depresiation	Cash Flow	residual value	Principal Repayment	Net Income	Accumulated Income ($000)	Total Benefit	Total Cost
	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)
	n=j+k+l+m	o=h+n	p=i - n	q=0 (no loan case)	r=p - q	s=r*25% (after 12 year)	t=p-s	u=g+t	v=Plant Cost/50*30	w=0 (no loan case)	x=u+v-w	y		
0											-5,463.2	-5,463	0.0	5,463.2
0											-5,463.2	-10,926	0.0	5,463.2
1	83.1	448.0	2,028.3	0	2,028.3	0.0	2,028.3	2,246.8		0.0	2,246.8	-8,680	2,476.3	229.5
2	85.0	454.6	2,120.8	0	2,120.8	0.0	2,120.8	2,339.3		0.0	2,339.3	-6,340	2,575.4	236.1
3	87.1	461.5	2,216.9	0	2,216.9	0.0	2,216.9	2,435.4		0.0	2,435.4	-3,905	2,678.4	242.9
4	89.2	468.6	2,316.9	0	2,316.9	0.0	2,316.9	2,535.4		0.0	2,535.4	-1,369	2,785.5	250.1
5	91.4	476.1	2,420.8	0	2,420.8	0.0	2,420.8	2,639.4		0.0	2,639.4	1,270	2,896.9	257.6
6	93.7	483.9	2,528.9	0	2,528.9	0.0	2,528.9	2,747.4		0.0	2,747.4	4,017	3,012.8	265.4
7	96.1	492.0	2,641.3	0	2,641.3	0.0	2,641.3	2,859.8		0.0	2,859.8	6,877	3,133.3	273.5
8	98.6	500.5	2,758.2	0	2,758.2	0.0	2,758.2	2,976.7		0.0	2,976.7	9,854	3,258.7	282.0
9	101.2	509.3	2,879.7	0	2,879.7	0.0	2,879.7	3,098.2		0.0	3,098.2	12,952	3,389.0	290.8
10	103.9	518.5	3,006.1	0	3,006.1	0.0	3,006.1	3,224.6		0.0	3,224.6	16,177	3,524.6	300.0
11	106.7	528.1	3,137.5	0	3,137.5	784.4	2,353.1	2,571.6		0.0	2,571.6	18,748	3,665.6	1,093.9
12	109.6	538.1	3,274.1		3,274.1	818.5	2,455.6	2,674.1		0.0	2,674.1	21,422	3,812.2	1,138.1
13	112.6	548.5	3,416.2		3,416.2	854.1	2,562.2	2,780.7		0.0	2,780.7	24,203	3,964.7	1,184.0
14	115.8	559.3	3,564.0		3,564.0	891.0	2,673.0	2,891.5		0.0	2,891.5	27,095	4,123.2	1,231.7
15	119.1	570.5	3,717.6		3,717.6	929.4	2,788.2	3,006.8		0.0	3,006.8	30,101	4,288.2	1,281.4
16	122.5	582.3	3,877.4		3,877.4	969.4	2,908.1	3,126.6		0.0	3,126.6	33,228	4,459.7	1,333.1
17	126.0	594.5	4,043.6		4,043.6	1,010.9	3,032.7	3,251.2		0.0	3,251.2	36,479	4,638.1	1,386.9
18	129.7	607.2	4,216.4		4,216.4	1,054.1	3,162.3	3,380.8		0.0	3,380.8	39,860	4,823.6	1,442.8
19	133.5	620.5	4,396.1		4,396.1	1,099.0	3,297.1	3,515.6		0.0	3,515.6	43,376	5,016.6	1,501.0
20	137.5	634.3	4,583.0		4,583.0	1,145.7	3,437.2	3,655.7	6,555.8	0.0	10,211.6	53,587	11,773.1	1,561.5
Total	2,142.5	10,596.3								0.0	10,522.5	49,918	PV (Benefit)	PV (Cost)
Source: JICA Study Team										NPV=	11,574.8		26,185.7	14,610.9

(Source: JICA Study Team)

Table S.6 Example of Financial Analysis (With Bank Loan)

Plant Cap (MW)	Energy (MWh/yr)	Operation Factor (%)	Escalation Rate	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost	% of Loan	Bank Loan ($000)	Repayment Period (year)	Loan Interest Rate p.a	Tax Exemption (year)	Corporate Tax	Discount Rate
4.18	17,688	48%	4%	10,926	0	5%	70%	7,648	10	8%	10	25%	10%
					Included Plant Cost								

Salaries of operators	Person(s)	Unit Cost (US$/month)
Engineer	1	$1,800/month
Operator	2	$500/month
Security gu	2	$400/month
Resident ma	1	$500/month

Year	Unit Price	Generation	Benefit: Operation Income	Capital Cost ($000)	O/M Cost ($000)	Insuarance Seguros ($000)	Depreciation	Sub Total Cost (d~g) ($000)	Gross Profit	Salaries of operators, engineers, securitys, ect.	Tax of Alcaldia	SIGET Annuity	Commercial Registration (CNR)
	($/MWh)	(MWh/year)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)
	a (4%)	b	c=a*b	d	e=c*5%+b*0.35	f=Plant Cost*1.05/1000 (98% per year)	g=Plant Cost/50	h=sum(d~e)	i=c-h	j=(1800+2*500+2*400+500)*12* (105%)	k=0.00216*d	l=b*0.51	m=Plant Cost/100,000*11.43
0			0.0	-1,639									
0			0.0	-1,639									
1	140.00	17,688.0	2,476.3		130.0	0.5	218.5	349.1	2,127.2	49.2	23.6	9.0	1.249
2	145.60	17,688.0	2,575.4		135.0	0.5	218.5	354.0	2,221.3	51.2	23.6	9.0	1.249
3	151.42	17,688.0	2,678.4		140.1	0.5	218.5	359.2	2,319.2	53.2	23.6	9.0	1.249
4	157.48	17,688.0	2,785.5		145.5	0.5	218.5	364.5	2,421.0	55.3	23.6	9.0	1.249
5	163.78	17,688.0	2,896.9		151.0	0.5	218.5	370.1	2,526.9	57.6	23.6	9.0	1.249
6	170.33	17,688.0	3,012.8		156.8	0.5	218.5	375.9	2,637.0	59.9	23.6	9.0	1.249
7	177.14	17,688.0	3,133.3		162.9	0.5	218.5	381.9	2,751.5	62.3	23.6	9.0	1.249
8	184.23	17,688.0	3,258.7		169.1	0.5	218.5	388.1	2,870.5	64.7	23.6	9.0	1.249
9	191.60	17,688.0	3,389.0		175.6	0.5	218.5	394.6	2,994.4	67.3	23.6	9.0	1.249
10	199.26	17,688.0	3,524.6		182.4	0.5	218.5	401.4	3,123.2	70.0	23.6	9.0	1.249
11	207.23	17,688.0	3,665.6		189.5	0.4	218.5	408.4	3,257.1	72.8	23.6	9.0	1.249
12	215.52	17,688.0	3,812.2		196.8	0.4	218.5	415.8	3,396.4	75.7	23.6	9.0	1.249
13	224.14	17,688.0	3,964.7		204.4	0.4	218.5	423.4	3,541.3	78.8	23.6	9.0	1.249
14	233.11	17,688.0	4,123.2		212.4	0.4	218.5	431.3	3,691.9	81.9	23.6	9.0	1.249
15	242.43	17,688.0	4,288.2		220.6	0.4	218.5	439.5	3,848.6	85.2	23.6	9.0	1.249
16	252.13	17,688.0	4,459.7		229.2	0.4	218.5	448.1	4,011.6	88.6	23.6	9.0	1.249
17	262.22	17,688.0	4,638.1		238.1	0.4	218.5	457.0	4,181.1	92.2	23.6	9.0	1.249
18	272.71	17,688.0	4,823.6		247.4	0.4	218.5	466.3	4,357.3	95.8	23.6	9.0	1.249
19	283.61	17,688.0	5,016.6		257.0	0.4	218.5	475.9	4,540.6	99.7	23.6	9.0	1.249
20	294.96	17,688.0	5,217.2		267.1	0.4	218.5	486.0	4,731.3	103.7	23.6	9.0	1.249
Total		353,759.5	73,739.9	-3,277.9	3,810.8	9.1		8,190.5					24.978

NPV ($000)	12,282
FIRR	33.0%
B/C	1.88
B - C ($000)	12,282

Year	Total Operation cost	Total Cost	Operation Benefit	Interest	Benefit before taxes	Income Taxes	Net income without depresiation	Cash Flow	residual value	Principal Repayment	Net Income	Accumulated Income ($000)	Total Benefit	Total Cost
	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)	(x1000 US$)
	n=j+k+l+m	o=h+n	p=i - n	q	r=p - q	s=r*25% (after 12 year)	t=p-s	u=g+t	v=Plant Cost/50*30	w=0 (no loan case)	x=u+v-w	y		
0											-1,639.0	-1,639	0.0	1,639.0
0				306	-305.9	0.0	-305.9	-305.9			-1,944.9	-3,584	0.0	1,944.9
1	83.1	432.2	2,044.2	612	1,432.3	0.0	1,432.3	1,650.8		764.8	886.0	-2,698	2,476.3	1,590.4
2	85.0	439.1	2,136.3	551	1,585.6	0.0	1,585.6	1,804.1		764.8	1,039.3	-1,659	2,575.4	1,536.1
3	87.1	446.2	2,232.1	490	1,742.6	0.0	1,742.6	1,961.2		764.8	1,196.3	-462	2,678.4	1,482.1
4	89.2	453.7	2,331.8	428	1,903.5	0.0	1,903.5	2,122.0		764.8	1,357.2	895	2,785.5	1,428.4
5	91.4	461.5	2,435.4	367	2,068.3	0.0	2,068.3	2,286.8		764.8	1,522.0	2,417	2,896.9	1,374.9
6	93.7	469.6	2,543.2	306	2,237.3	0.0	2,237.3	2,455.8		764.8	1,691.0	4,108	3,012.8	1,321.8
7	96.1	478.0	2,655.3	245	2,410.6	0.0	2,410.6	2,629.1		764.8	1,864.3	5,972	3,133.3	1,269.1
8	98.6	486.7	2,771.9	184	2,588.4	0.0	2,588.4	2,806.9		764.8	2,042.0	8,014	3,258.7	1,216.6
9	101.2	495.8	2,893.2	122	2,770.8	0.0	2,770.8	2,989.3		764.8	2,224.5	10,239	3,389.0	1,164.5
10	103.9	505.3	3,019.3	61	2,958.1	0.0	2,958.1	3,176.6		764.8	2,411.8	12,650	3,524.6	1,112.8
11	106.7	515.1	3,150.4	0	3,150.4	787.6	2,362.8	2,581.3		0.0	2,581.3	15,232	3,665.6	1,084.2
12	109.6	525.4	3,286.8		3,286.8	821.7	2,465.1	2,683.6		0.0	2,683.6	17,915	3,812.2	1,128.5
13	112.6	536.0	3,428.6		3,428.6	857.2	2,571.5	2,790.0		0.0	2,790.0	20,705	3,964.7	1,174.7
14	115.8	547.1	3,576.2		3,576.2	894.0	2,682.1	2,900.6		0.0	2,900.6	23,606	4,123.2	1,222.6
15	119.1	558.6	3,729.6		3,729.6	932.4	2,797.2	3,015.7		0.0	3,015.7	26,622	4,288.2	1,272.5
16	122.5	570.6	3,889.1		3,889.1	972.3	2,916.8	3,135.4		0.0	3,135.4	29,757	4,459.7	1,324.3
17	126.0	583.0	4,055.1		4,055.1	1,013.8	3,041.3	3,259.8		0.0	3,259.8	33,017	4,638.1	1,378.3
18	129.7	596.0	4,227.6		4,227.6	1,056.9	3,170.7	3,389.2		0.0	3,389.2	36,406	4,823.6	1,434.4
19	133.5	609.5	4,407.1		4,407.1	1,101.8	3,305.3	3,523.8		0.0	3,523.8	39,930	5,016.6	1,492.7
20	137.5	623.5	4,593.7		4,593.7	1,148.4	3,445.3	3,663.8	6,555.8	0.0	10,219.7	50,150	11,773.1	1,553.4
Total	2,142.5	10,332.9								7,648.5	-1,087.3	-2,641	PV (Benefit)	PV (Cost)
Source: JICA Study Team										NPV=	12,282.1		26,185.7	13,903.6

(Source: JICA Study Team)

Table S.7 List of Small Hydropower Potential Sites (1/4)

No.	Nombre de Proyecto	Río	Departamento	Latitud	Longitud	Etapa del Proyecto	Fuente Original	Actualizado por	Área de Drenaje	Caudal Diseño	Caida bruta	Longitud de la Canal	Longitud de tubería de presión	Area Natural Protegida	Potencia	Energía
	Project Name	River	Department	Latitude	Longitude	Project Stage	Original Source	Updated by	Catchment Area	Design Discharge	Gross Head	Length of Canal	Length of Pestock	Natural Protect Area	Potential	Energy
				(N)	(W)				(km²)	(m³/s)	(m)	(m)	(m)	(SANP)	(MW)	(MWh/Año)
1	El Calambre	Río El Calambre	Morazán	13.9928	88.0804	Construcción	AEA	ONG SABES	6.41	0.422	72.3	n.d.	n.d.		0.058	311
2	Mirazalco	Río Gran.d.e de Sonsonate	Sonsonate	13.8414	89.7456	Construcción	GIZ 2011	Hydro West	219.00	1.706	238.0	n.d.	n.d.		3.370	? 14,762
3	Gualpuca	Río Gualpuca	Morazán	13.8333	88.2333	Financiamiento	AEA	ONG SABES	3.39	0.392	423.0	n.d.	n.d.		1.000	6,155
4	Ilopango Aguacayo	lago de Ilopanago	La Paz	13.6311	89.0334	Financiamiento	INGENDEHSA	INGENDEHSA	n.d.	9.000	n.d.	n.d.	n.d.		17.000	? 74,460
5	San Luis IV	Rio Suquiapa	La Libertad	13.9942	89.4828	Bid Process	CECSA	INGENDEHSA	n.d.	n.d.	n.d.	n.d.	n.d.		1.500	? 6,570
6	Sumpul	Río Sumpul	Chalatenango	13.8300	89.7300	De Registro SIGET	INGENDEHSA	INGENDEHSA	966.43	64.720	62.0	3,000	1,000		16.200	64,043
7	Sucio, Los Tetuntes	Río Sucio	La Libertad	13.8822	89.2594	De Registro SIGET			n.d.	n.d.	n.d.	n.d.	n.d.		6.600	? 28,908
8	La Joya	Río Acahuapa	San Vicente	13.6248	88.7383	De Registro SIGET	AEA	ONG SABES	n.d.	n.d.	n.d.	n.d.	n.d.		3.000	? 13,140
9	San Francisco	Rio Tapuchina	Sonsonate	13.8482	89.7285	De Registro SIGET			n.d.	n.d.	n.d.	n.d.	n.d.		1.000	? 4,380
10	La Colmena (El Volcán)	Río El Volcán/Rio Sn Juan	San Miguel	13.7339	88.2375	De Registro SIGET	ONG SABES	ONG SABES	2.05	0.238	59.1	n.d.	n.d.		0.097	450
11	Quebrada la Cueva / San Jose	Quebrada la cueva / San Jose	Morazán	13.7855	88.2146	De Registro SIGET	GIZ 2011	De Registro SIGET	n.d.	n.d.	n.d.	n.d.	n.d.		0.065	455
12	Santa Rosa (El Riachuelo)	Río Riachuelo	San Miguel	13.8518	88.2707	De Registro SIGET	AEA	ONG SABES	24.60	1.854	12.4	n.d.	n.d.		0.038	260
13	Atehuecillas (Rehabilitation)		Ahuachapán	13.9228	89.8811	Rehabilitación	AEA	CECSA	n.d.	n.d.	n.d.	n.d.	n.d.		0.630	? 2,759
14	San Esteban	Río San Esteban	San Miguel	13.5196	88.1829	Rehabilitación	CEL-UCA 1989	CECSA	44.90	1.222	74.0	n.d.	n.d.		0.751	3,287
15	Cucumacayan (Reconversion)	Río Grande de Sonsonate	Sonsonate	13.7500	89.7167	Reconversion	AEA	CECSA	n.d.	n.d.	n.d.	n.d.	n.d.		2.300	17,895
16	Acahuapa (Rehabilitation)		San Vicente	13.6583	88.8157	Rehabilitación		CECSA	n.d.	n.d.	n.d.	n.d.	n.d.		0.120	? 526
17	Sapuyo (Rehabilitation)		La Paz	13.4941	88.8667	Rehabilitación		CECSA	n.d.	n.d.	n.d.	n.d.	n.d.		0.060	? 263
18	Chorreron Jiboa	n.d.	La Paz			Factibilidad	CECSA	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.		2.000	? 8,760
19	La Montañita		Morazan	13.8167	88.2167	Factibilidad		ONG SABES,2008	n.d.	n.d.	n.d.	n.d.	n.d.		0.900	? 3,942
20	El Sapo	Río Sapo	Morazán	13.9216	88.1056	Factibilidad	Ing.Alfaro	INGENDEHSA	53.54	4.046	95.3	n.d.	n.d.		0.060	? 263
21	San Luis III	Río Suquiapa	Santa Ana	13.9942	89.4828	Factibilidad	CECSA	INGENDEHSA	n.d.	n.d.	n.d.	n.d.	n.d.		0.600	? 2,628
22	Sonzacate (Nahuizalco II)	Río Sensunapán	Sonsonate	13.7567	89.7153	Factibilidad	GIZ 2011	Sensunapán S.A. de C	76.23	4.205	110.0	n.d.	n.d.		3.839	16,816
23	Potrerillos	Quebrada Las Lajas	Morazán	13.8084	88.2417	Factibilidad	AEA	ONG SABES	5.31		310.9	n.d.	n.d.		0.320	2,600
24	Guanijiquil - Poza Hon.d.a	Río Sapo	Morazán	13.8500	88.1500	Factibilidad	AEA	ONG SABES	137.58	9.836	2.7	n.d.	n.d.		0.131	510
25	La Cabaña	Río Gran.d.e de San Miguel	Usulután	13.3019	88.2885	Factibilidad	AEA	ONG SABES	1,900.00	53.492	3.7	n.d.	n.d.		0.980	4,300
26	La Loma	Río Osicala	Morazán	13.8167	88.1333	Factibilidad	AEA	ONG SABES	11.36	0.790	84.4	n.d.	n.d.		0.055	398
27	El Progreso	Río Aruate	Morazán	13.8797	88.2216	Factibilidad	AEA	ONG SABES	63.89	5.046	8.3	n.d.	n.d.		0.033	280
28	Araute	Río Araute	Morazán	13.8751	88.2245	Factibilidad	INGENDHESA	INGENDHESA, 2005	n.d.	n.d.	n.d.	n.d.	n.d.		0.033	284
29	Cumaro	Río Cumaro	n.d.	13.9167	88.1333	Factibilidad		ONG SABES, 2008	n.d.	n.d.	n.d.	n.d.	n.d.		0.040	? 175
30	El Naranjito	Río El Naranjito	Ahuachapán	13.7050	89.9333	Factibilidad	AEA	ONG SABES	1.40	0.112	38.5	n.d.	n.d.		0.031	146
31	Quezalapa	Río Quezalapa	Cuscatlán/Cabañas	13.8833	88.9667	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		1.050	2,628
32	Tihuapa 1	Río Tihuapa	San Salvador/La Paz	13.5883	89.1383	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		1.315	3,870
33	Tihuapa 2	Río Tihuapa	San Salvador/La Paz	13.5500	89.1333	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		0.900	2,580
34	San Simón 1	Río San Simón	Usulután	13.5619	88.5176	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		0.900	2,040
35	San Simón 2	Río San Simón	Usulután	13.5699	88.5362	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		0.915	2,484
36	San Simón 3	Río San Simón	Usulután	13.5833	88.5667	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		0.870	2,570
37	Titihuapa 3	Río Titihuapa	Cabañas/San Vicente	13.6067	88.6500	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		2.100	6,802
38	Titihuapa 5	Río Titihuapa	Cabañas/San Vicente	13.7667	88.6000	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		1.410	5,673
39	Cuyuapa	Río Cuyuapa	Sonsonate	13.7500	88.8000	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		1.020	2,840
40	Suquiapa	Río Suquiapa	Santa Ana	13.9833	89.4333	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		3.530	13,630
41	Gr. Chalatenango	Río Gr. Chalatenango	Chalatenango	14.7167	89.0833	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		1.630	3,680
42	Sucio 3	Río Sucio	La Libertad/San Salvad	13.9833	89.2833	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		2.025	11,149
43	Polorós		La Unión	13.8050	89.8083	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		2.025	5,250
44	Huiza 2	Río Huiza	La Libertad/San Salvad	13.5500	89.2333	Diseños Básicos	CEL-ACCIONA	CEL-ACCIONA, 2011	n.d.	n.d.	n.d.	n.d.	n.d.		2.100	6,009
45	Santo Domingo (Presa 1 & 2 &3)	Río Tepechapa/ Río Cacahuata/	Sonsonate	13.7497	89.7838	Pre Factibilidad	CEL-UCA 1989	INGENDEHSA	29.12	1.280	145.0	3,230	1,090		1.540	7,885
46	Chacala Los Apantes (Presa 1 & 2)	Río Chacala / Río Los Apantes	Ahuachapán	13.8037	89.8484	Pre Factibilidad	INGENDEHSA	INGENDEHSA	19.04	0.838	207.0	3,660	1,140		1.500	8,126
47	Santa Rita	Río Jiboa	La Páz	13.6143	88.9630	Pre Factibilidad	CEL-UCA 1989	INGENDEHSA	374.97	7.403	136.0	4,000	770		8.357	36,603
48	Milingo (Reconversion)	Río Acelhuate	San Salvador	13.7443	89.1619	Pre Factibilidad	AEA	CECSA	n.d.	n.d.	n.d.	n.d.	n.d.		0.800	? 3,504
49	Copinula I	Río Copinula	Ahuachapán	13.7864	89.8444	Pre Factibilidad	INGENDEHSA	INGENDEHSA	27.89	1.211	60.0	2,265	270		0.603	2,641
50	San José Loma	Río Jiboa	La Páz	13.5411	88.9845	Pre Factibilidad	CEL-UCA 1989	INGENDEHSA	429.69	8.483	27.0	2,076	145		1.901	8,327
51	Cara Sucia (Presa 1 & 2)	Río Mistepe / Río Maishtapula	Ahuachapán	13.8286	89.9814	Pre Factibilidad	INGENDEHSA	INGENDEHSA	16.21	0.704	100.0	4,328	860	SANP	0.584	2,559
52	San Pedro II	Río San Pedro	Ahuachapán	13.7603	89.8080	Pre Factibilidad	INGENDEHSA	INGENDEHSA	13.77	0.598	80.0	2,048	450		0.397	1,739
53	Copinula II	Río Copinula	Ahuachapán	13.7482	89.8388	Pre Factibilidad	INGENDEHSA	INGENDEHSA	33.75	1.466	40.0	n.d.	n.d.		0.487	2,132
54	Qbda El Naranjito al Naranjo		Ahuachapán	13.7050	89.9333	Pre Factibilidad		ONG SABES	n.d.	n.d.	n.d.	n.d.	n.d.		0.080	? 350
55	Qbda El Singual, al Cuyapo		Morazan	13.8333	88.2333	Pre Factibilidad		ONG SABES	n.d.	n.d.	n.d.	n.d.	n.d.		0.058	? 254
56	Venecia Prusia	n.d.	n.d.			Pre Factibilidad	AEA	Compania Electrica Me	n.d.	n.d.	n.d.	n.d.	n.d.		1.200	? 5,256
57	Las Pilonas	Río Huiza	San Salvador	13.5762	89.2177	Pre Factibilidad	INGENDEHSA	INGENDEHSA	34.63	1.031	79.0	n.d.	n.d.		1.100	2,961

(Source: JICA Study Team)

Table S.7 List of Small Hydropower Potential Sites (2/4)

No.	Nombre de Proyecto / Project Name	Río / River	Departamento / Department	Latitud / Latitude (N)	Longitud / Longitude (W)	Etapa del Proyecto / Project Stage	Fuente Original / Original Source	Actualizado por / Updated by	Área de Drenaje / Catchment Area (km²)	Caudal Diseño / Design Discharge (m³/s)	Caida bruta / Gross Head (m)	Longitud de la Canal / Length of Canal (m)	Longitud de tubería de presión / Length of Pestock (m)	Area Natural Protegida / Natural Protect Area (SANP)	Potencia / Potential (MW)	Energía / Energy (MWh/Año)
58	Copinula	Río Copinula	Ahuachapán	13.7862	89.8445	Pre Factibilidad	INGENDEHSA	INGENDEHSA	28.18	0.509	57.0	n.d.	n.d.		0.241	1,055
59	Santa Emilia I	n.d.	n.d.			Pre Factibilidad	AEA	http://appext.sica.int/	n.d.	n.d.	n.d.	n.d.	n.d.		0.500	? 2,190
60	Santa Emilia II	n.d.	n.d.			Pre Factibilidad	AEA	http://appext.sica.int/	n.d.	n.d.	n.d.	n.d.	n.d.		0.500	? 2,190
61	Torola	Río Torola	San Miguel	13.8501	88.4663	Inventory	CEL-UCA 1990	CEL-UCA, 1990.Pag.4	n.d.	n.d.	n.d.	n.d.	n.d.		4.321	18,667
62	Copinula III	Río Copinula	Ahuachapán	13.7721	89.8431	Inventory	INGENDEHSA	JICA Study Team	29.27	0.692	80.0	1,100	270		0.463	3,187
63	La Calzadora I	Quebrada La Calzadora	Usulután	13.5667	88.5000	Inventory	CEL-UCA 1989	JICA Study Team	6.97	0.136	378.1	3,000	1,000		0.432	2,300
64	Los Hervideros I	Río Los Hervideros	Ahuachapán	13.9550	89.9534	Inventory	CEL-UCA 1989	JICA Study Team	95.94	1.475	80.0	2,280	130		0.993	5,457
65	Los Hervideros II (Presa 1 & 2)	Río El Molino / Río Nejapa	Ahuachapán	13.9484	89.9264	Inventory	INGENDEHSA	JICA Study Team	84.48	0.868	60.0	3,824	145		0.435	3,136
66	Malancola	Río Jiboa	La Páz	13.5695	88.9850	Inventory	CEL-UCA 1989	JICA Study Team	423.98	8.789	57.4	2,600	290		4.175	17,688
67	Gran.d.e de San Miguel, Sn Juan	Rio Gran.d.e de San Miguel	Usulután	13.2947	88.3068	Inventory	CEL-UCA 1989	Transénergia, PNUD/G	n.d.	n.d.	n.d.	n.d.	n.d.		4.500	19,710
68	Gn.d.e de San Miguel, San José	Rio Gran.d.e de San Miguel	Usulután	13.2947	88.3068	Inventory	CEL-UCA 1989	Transénergia, PNUD/G	n.d.	n.d.	n.d.	n.d.	n.d.		3.200	14,016
69	Chilama I (Presa 1 & 2)	Río Chilama / Río Siguapate	La Libertad	13.6212	89.3309	Inventory	CEL-UCA 1989	JICA Study Team	37.62	1.730	180.0	2,464	360		2.623	7,840
70	Guayapa II	Río Guayapa	Ahuachapán	13.8221	89.9345	Inventory	INGENDEHSA	JICA Study Team	12.58	0.495	120.0	3,015	325	SANP	0.497	2,599
71	La Calzadora II	Quebrada La Calzadora	Usulután	13.5347	88.5294	Inventory	CEL-UCA 1989	JICA Study Team	12.90	0.252	218.7	3,000	1,000		0.457	2,434
72	EL Jabio	Rio Gran.d.e de Sonsonate	Sonsonate	13.7532	88.2887	Inventory	CECSA	CECSA	n.d.	n.d.	n.d.	n.d.	n.d.		2.000	8,760
73	El Rosario II	Río El Rosario	Ahuachapán	13.7754	89.8729	Inventory	CEL-UCA 1989	JICA Study Team	19.02	0.747	80.0	2,265	270		0.498	2,606
74	San Sebastián	Río Tihuapa	La Páz	13.5544	89.1366	Inventory	INGENDEHSA	JICA Study Team	37.42	0.715	80.0	1,000	210		0.480	2,317
75	Chilama II	Río Chilama	La Libertad	13.5929	89.3300	Inventory	CEL-UCA 1989	JICA Study Team	42.13	0.682	80.0	2,604	175		0.457	2,343
76	El Molino I	Río El Molino	Ahuachapán	13.9325	89.8960	Inventory	INGENDEHSA	JICA Study Team	50.38	0.517	60.0	2,272	150		0.260	1,876
77	Guayapa I	Río Guayapa	Ahuachapán	13.7955	89.9466	Inventory	INGENDEHSA	JICA Study Team	17.13	0.673	80.0	2,630	230	SANP	0.450	2,353
78	El Refugio	Río Las Lajas	La Libertad	13.5569	89.2385	Inventory	INGENDEHSA	JICA Study Team	29.06	0.555	100.0	1,364	320		0.465	2,243
79	Los Toles	Río Los Toles	Ahuachapán	13.9715	89.9386	Inventory	INGENDEHSA	JICA Study Team	22.80	0.424	120.0	1,713	275		0.428	2,035
80	El Peñon	Río Gran.d.e de San Vicente	La Libertad	13.5855	89.3947	Inventory	INGENDEHSA	JICA Study Team	21.91	0.482	120.0	1,366	300		0.486	2,212
81	Guayapa V	Río Guayapa	Ahuachapán	13.9476	89.9636	Inventory	INGENDEHSA	JICA Study Team	31.26	0.581	100.0	2,518	280		0.486	2,310
82	Río Frío / Agua Caliente	Río Frío / Río Agua Caliente	Ahuachapán	14.0387	89.8397	Inventory	INGENDEHSA	JICA Study Team	205.44	2.109	60.0	1,850	1,330	SANP	0.958	6,906
83	El Charrerón	El Chorrerón	La Libertad	13.6178	89.3460	Inventory	CEL-UCA 1989	JICA Study Team	12.60	0.277	180.0	2,057	515		0.418	1,903
84	Santa Lucía	Río Tamanique	La Libertad	13.5962	89.4202	Inventory	INGENDEHSA	JICA Study Team	12.58	0.411	280.0	957	885		0.966	3,609
85	El Rosario I	Río El Rosario	Ahuachapán	13.7531	89.8731	Inventory	CEL-UCA 1989	JICA Study Team	21.56	0.847	60.0	2,484	230		0.423	2,155
86	Maishtapula	Río Maishtapula	Ahuachapán	13.8444	89.9520	Inventory	INGENDEHSA	JICA Study Team	5.29	0.239	160.0	1,754	500	SANP	0.320	1,528
87	Asesesco (Presa 1 & 2)	Río Asesesco / Río Viejo	Cabañas	13.8793	88.9226	Inventory	INGENDEHSA	JICA Study Team	14.86	0.864	60.0	2,715	145		0.435	2,105
88	Miramundo	Qda. Miramun.d.o	Chalatenango	14.3268	89.1353	Inventory	INGENDEHSA	JICA Study Team	4.53	0.287	200.0	631	735		0.480	1,877
89	Tilapa II	Río Gran.d.e de Chalatenango	Chalatenango	14.2237	89.0976	Inventory	CEL-UCA 1989	JICA Study Team	31.71	2.867	80.0	2,486	230		1.925	6,402
90	El Faro (Presa 1 & 2)	Río Los Leones / Río La Máquina	La Libertad	13.5990	89.3561	Inventory	INGENDEHSA	JICA Study Team	8.44	0.231	220.0	2,632	620		0.426	1,750
91	Santa María	Río Tihuapa	La Páz	13.5893	89.1307	Inventory	INGENDEHSA	JICA Study Team	19.85	0.649	160.0	3,049	290		0.874	3,264
92	El Molino II	Río El Molino	Ahuachapán	13.9060	89.8345	Inventory	INGENDEHSA	JICA Study Team	24.58	0.272	100.0	2,221	820		0.221	1,523
93	San Pedro I	Río San Pedro	Ahuachapán	13.7386	89.8057	Inventory	INGENDEHSA	JICA Study Team	20.83	0.697	60.0	1,520	410		0.344	1,944
94	Ashuquema I	Río Ashuquema	Ahuachapán	13.9420	89.9720	Inventory	INGENDEHSA	JICA Study Team	28.05	0.288	80.0	2,431	505		0.189	1,361
95	El Caoba	Río El Naranjo	Ahuachapán	13.7948	89.9263	Inventory	INGENDEHSA	JICA Study Team	12.16	0.548	100.0	2,352	610		0.451	2,156
96	El Rosario IV	Río El Rosario	Ahuachapán	13.8103	89.8788	Inventory	CEL-UCA 1989	JICA Study Team	8.24	0.372	100.0	1,849	195		0.313	1,496
97	Sunzacuapa III	Río Sunzacuapa	Ahuachapán	13.7681	89.8283	Inventory	INGENDEHSA	JICA Study Team	8.13	0.272	80.0	356	150		0.184	1,060
98	Tizapa II	Río Tempisque	Cuscatlán	13.7917	88.9461	Inventory	INGENDEHSA	JICA Study Team	12.86	0.833	60.0	1,812	220		0.418	1,907
99	San Isidro	Río Sensipa	La Libertad	13.6160	89.4840	Inventory	INGENDEHSA	JICA Study Team	9.64	0.315	180.0	2,205	390		0.477	1,782
100	Cauta	Río Cauta	Ahuachapán	13.8035	89.8641	Inventory	INGENDEHSA	JICA Study Team	8.93	0.141	160.0	1,406	245		0.191	971
101	Loma de San Juan	Río Huiza	San Salvador	13.5449	89.2304	Inventory	CEL-UCA 1989	JICA Study Team	69.44	1.900	60.0	1,628	215		0.954	3,837
102	San Juan Buenavista	Río Aquiquisquillo	La Libertad	13.5382	89.2479	Inventory	INGENDEHSA	JICA Study Team	17.34	0.683	160.0	1,768	390	SANP	0.918	3,063
103	Los Pozos	Río Los Pozos	Chalatenango	14.3289	89.1455	Inventory	INGENDEHSA	JICA Study Team	7.75	0.700	140.0	1,085	260		0.827	2,791
104	Los Pueblos II	Río de Los Pueblos	Cabañas	13.8643	88.6869	Inventory	INGENDEHSA	JICA Study Team	24.10	1.881	80.0	2,848	345		1.247	4,627
105	El Jícaro (Presa 1 & 2)	Río Chuluma/Grand. de San Vicente	La Libertad	13.5933	89.4021	Inventory	INGENDEHSA	JICA Study Team	18.06	0.591	100.0	2,726	225		0.496	1,851
106	Guarumo	Río Guarumo	Cabañas	13.7670	88.8046	Inventory	INGENDEHSA	JICA Study Team	19.81	2.661	40.0	1,122	90		0.897	3,647
107	Guascoran	Rio el Sauce	La Unión	13.6446	87.7524	Inventory	CEL-UCA 1989	Transénergia, PNUD/G	n.d.	n.d.	n.d.	n.d.	n.d.		12.500	38,000
108	El Diamante II	Río El Diamante	Ahuachapán	13.7672	89.9006	Inventory	INGENDEHSA	JICA Study Team	8.83	0.267	100.0	2,076	725		0.218	1,333
109	Río Nejapa I	Río Nejapa	Ahuachapán	13.9336	89.9175	Inventory	CEL-UCA 1989	JICA Study Team	27.79	0.263	60.0	1,781	185		0.132	1,000
110	Asuchío	Río Asuchío	La Libertad	13.5618	89.3135	Inventory	INGENDEHSA	JICA Study Team	13.50	0.369	140.0	1,985	730	SANP	0.428	1,756
111	Agua Fría	Río Agua Fría	Cabañas	13.8100	88.8215	Inventory	CEL-UCA 1989	JICA Study Team	14.79	1.987	60.0	1,750	490		0.974	3,960
112	Chilama III	Río Chilama	La Libertad	13.5367	89.3142	Inventory	INGENDEHSA	JICA Study Team	68.32	1.869	60.0	2,709	235		0.934	3,756
113	Tehuechode	Río Chichicalapa	San Salvador	13.5926	89.1514	Inventory	INGENDEHSA	JICA Study Team	7.72	0.252	160.0	2,638	315		0.339	1,267
114	Tizapa IV	Río Ajuluco	Cuscatlán	13.7649	88.9248	Inventory	INGENDEHSA	JICA Study Team	9.01	0.524	60.0	1,325	150		0.265	1,284
115	Quezalate	Río Quezalate	La Libertad	13.5989	89.2288	Inventory	INGENDEHSA	JICA Study Team	18.73	0.737	80.0	1,144	205		0.495	1,651
116	El Anonal	Río El Zonte	La Libertad	13.5565	89.4540	Inventory	INGENDEHSA	JICA Study Team	22.00	0.720	80.0	2,697	240		0.481	1,794
117	Mizata I	Río Mizata	La Libertad	13.5786	89.5516	Inventory	CEL-UCA 1989	JICA Study Team	23.28	0.637	80.0	2,397	405		0.421	1,727
118	Los Pueblos I	Río de Los Pueblos	Cabañas	13.8726	88.7215	Inventory	INGENDEHSA	JICA Study Team	35.16	1.273	40.0	2,078	355		0.412	2,081
119	El Cutal	Río Teostrife	Chalatenango	14.2258	89.0690	Inventory	INGENDEHSA	JICA Study Team	8.68	0.668	80.0	1,796	290		0.445	1,618

(Source: JICA Study Team)

Table S.7 List of Small Hydropower Potential Sites (3/4)

No.	Nombre de Proyecto / Project Name	Río / River	Departamento / Department	Latitud / Latitude (N)	Longitud / Longitude (W)	Etapa del Proyecto / Project Stage	Fuente Original / Original Source	Actualizado por / Updated by	Área de Drenaje / Catchment Area (km²)	Caudal Diseño / Design Discharge (m³/s)	Caida bruta / Gross Head (m)	Longitud de la Canal / Length of Canal (m)	Longitud de tubería de presión / Length of Pestock (m)	Area Natural Protegida / Natural Protect Area (SANP)	Potencia / Potential (MW)	Energía / Energy (MWh/Año)
120	Tepechapa	Río Tepechapa	Cuscatlán	13.7884	88.9756	Inventory	INGENDEHSA	JICA Study Team	14.03	0.690	40.0	1,216	105		0.232	1,224
121	El Silencio	Río Comalapa	La Páz	13.5940	89.1084	Inventory	INGENDEHSA	JICA Study Team	9.62	0.263	130.0	2,580	330		0.287	1,178
122	Concepción Los Planes	Río Comalapa	La Páz	13.5674	89.0916	Inventory	INGENDEHSA	JICA Study Team	18.48	0.604	90.0	1,540	465		0.450	1,680
123	El Rosario V	Río El Rosario	Ahuachapán	13.8182	89.8830	Inventory	INGENDEHSA	JICA Study Team	6.89	0.271	80.0	1,391	195		0.182	951
124	El Escalón	Río Aquiquisquillo	La Libertad	13.5564	89.2489	Inventory	INGENDEHSA	JICA Study Team	15.37	0.503	100.0	1,828	365		0.420	1,567
125	Cuitapán	Río Cuitapán	San Salvador	13.5969	89.1825	Inventory	INGENDEHSA	JICA Study Team	12.93	0.423	120.0	2,554	505		0.422	1,575
126	Río Ceniza (Presa 1 & 2)	Río Ceniza	Sonsonate	13.7712	89.7030	Inventory	INGENDEHSA	JICA Study Team	31.64	0.688	60.0	1,556	735		0.330	1,780
127	Papaleguayo (Presa 1 & 2)	Río Papaleguayo/ Río El Patashte	San Salvador	13.5649	89.1588	Inventory	INGENDEHSA	JICA Study Team	8.66	0.237	140.0	3,799	275		0.278	1,143
128	Guayapa VI	Río Guayapa	Ahuachapán	13.8328	89.9305	Inventory	INGENDEHSA	JICA Study Team	6.66	0.262	80.0	1,144	270	SANP	0.175	915
129	Cauta II	Río Cauta	Ahuachapán	13.7754	89.8604	Inventory	INGENDEHSA	JICA Study Team	13.60	0.455	60.0	2,192	485		0.223	1,259
130	Guayapa II	Río Guayapa	Ahuachapán	13.9284	89.9511	Inventory	INGENDEHSA	JICA Study Team	25.85	0.265	60.0	3,015	325		0.131	947
131	San Benito (Presa 1 & 2)	Río Huiza / Río Texis	La Libertad	13.5925	89.4340	Inventory	INGENDEHSA	JICA Study Team	14.75	0.581	100.0	2,611	375		0.483	1,613
132	Tecomate	Río Cuitapan	San Salvador	13.5794	89.1882	Inventory	INGENDEHSA	JICA Study Team	19.46	0.636	80.0	2,447	375		0.421	1,572
133	Tilapa III	Río Gran.d.e de Chalatenango	Chalatenango	14.2371	89.1150	Inventory	INGENDEHSA	JICA Study Team	6.39	0.578	100.0	2,066	465		0.480	1,619
134	San Rafael (Presa 1 & 2)	Río Los Trozos / Río Matatapa	La Libertad	13.6417	89.4770	Inventory	INGENDEHSA	JICA Study Team	5.07	0.139	200.0	2,370	690		0.232	955
135	Ayacachapa III	Río Ayacachapa	Sonsonate	13.6506	89.5371	Inventory	INGENDEHSA	JICA Study Team	11.34	0.371	100.0	1,540	195		0.312	1,166
136	Ayacachapa II	Río Ayacachapa	Sonsonate	13.9282	89.5561	Inventory	INGENDEHSA	JICA Study Team	16.97	0.668	80.0	2,618	175		0.448	1,495
137	Sunzacuapa I	Río Sunzacuapa	Ahuachapán	13.7237	89.8238	Inventory	INGENDEHSA	JICA Study Team	20.08	0.606	40.0	1,923	325		0.197	1,183
138	Tilapa I	Río Gran.d.e de Chalatenango	Chalatenango	14.2154	89.0780	Inventory	INGENDEHSA	JICA Study Team	40.32	3.101	40.0	1,330	230		1.025	3,680
139	Apancoyo II	Río Apancoyo	Sonsonate	13.6516	89.5709	Inventory	INGENDEHSA	JICA Study Team	12.61	0.496	100.0	2,310	250		0.416	1,388
140	Tizapa III	Río Camalote	Cuscatlán	13.7902	88.9363	Inventory	CEL-UCA 1989	JICA Study Team	2.87	0.235	100.0	592	140		0.198	800
141	Río Nejapa II	Río Nejapa	Ahuachapán	13.9203	89.8979	Inventory	CEL-UCA 1989	JICA Study Team	25.14	0.258	60.0	1,813	560		0.126	907
142	El Rosario III	Río El Rosario	Ahuachapán	13.7880	89.8750	Inventory	INGENDEHSA	JICA Study Team	14.93	0.586	40.0	621	190		0.195	994
143	Guayapa IV (Presa 1 & 2)	Río Guayapa / Qda. Los Chorros	Ahuachapán	13.8455	89.9282	Inventory	INGENDEHSA	JICA Study Team	3.92	0.176	100.0	769	150	SANP	0.149	713
144	Mizata II	Río Mizata	La Libertad	13.6137	89.5317	Inventory	INGENDEHSA	JICA Study Team	14.76	0.404	80.0	2,106	225		0.270	1,109
145	Sunzacuapa II	Río Sunzacuapa	Ahuachapán	13.7414	89.8198	Inventory	INGENDEHSA	JICA Study Team	17.61	0.589	40.0	1,749	275		0.193	1,090
146	El Tablón	Quebrada El Aguacate	La Libertad	13.5633	89.3746	Inventory	INGENDEHSA	JICA Study Team	4.37	0.143	160.0	1,879	140		0.194	723
147	El Diamante I	Río El Diamante	Ahuachapán	13.7310	89.9045	Inventory	INGENDEHSA	JICA Study Team	18.13	0.713	40.0	2,417	210		0.235	1,196
148	El Rosario VI	Río El Rosario	Ahuachapán	13.8262	89.8863	Inventory	CEL-UCA 1989	JICA Study Team	5.46	0.246	80.0	940	240	SANP	0.165	789
149	Talquezalar	Río Talquezalar	Chalatenango	14.2894	89.1316	Inventory	INGENDEHSA	JICA Study Team	4.30	0.502	100.0	832	265		0.421	1,238
150	El Cedro	Río Pepetapa	La Páz	13.5974	89.0623	Inventory	INGENDEHSA	JICA Study Team	6.82	0.269	150.0	2,700	590		0.336	1,119
151	Guayapa III (Presa 1 & 2)	Río Guayapa	Ahuachapán	13.9006	89.9135	Inventory	INGENDEHSA	JICA Study Team	16.65	0.144	80.0	2,714	705		0.093	733
152	Mizata III	Río Mizata	La Libertad	13.6247	89.5190	Inventory	CEL-UCA 1989	JICA Study Team	9.36	0.256	100.0	1,963	240		0.215	883
153	Ayacachapa I	Río Ayacachapa	Sonsonate	13.5938	89.5708	Inventory	INGENDEHSA	JICA Study Team	34.08	0.651	40.0	1,727	105		0.218	1,036
154	Comizapa	Río Comizapa	Cuscatlán	13.8587	88.9861	Inventory	INGENDEHSA	JICA Study Team	2.52	0.180	100.0	898	155		0.152	673
155	Las Mesas	Río El Najanjito	Ahuachapán	13.7906	89.9111	Inventory	INGENDEHSA	JICA Study Team	1.45	0.048	220.0	1,494	495		0.089	513
156	San Ignacio	Río San Ignacio	Chalatenango	14.3288	89.1968	Inventory	INGENDEHSA	JICA Study Team	7.50	0.875	60.0	1,023	190		0.441	1,269
157	Ashuquema II	Río Ashuquema	Ahuachapán	13.9226	89.9544	Inventory	INGENDEHSA	JICA Study Team	22.53	0.250	60.0	1,391	730		0.120	822
158	El Matazano	Río El Shilo	La Libertad	13.6098	89.5025	Inventory	INGENDEHSA	JICA Study Team	3.12	0.102	200.0	1,948	140		0.173	648
159	Siberia	Río El Zonte	La Libertad	13.5738	89.4538	Inventory	INGENDEHSA	JICA Study Team	17.41	0.476	60.0	1,625	180		0.240	965
160	Joya Verde	Río Taquillo	La Libertad	13.5367	89.4899	Inventory	INGENDEHSA	JICA Study Team	6.48	0.178	120.0	2,207	350		0.178	731
161	Aguachapío III	Río Aguachapío	Ahuachapán	13.7986	89.9593	Inventory	INGENDEHSA	JICA Study Team	3.36	0.133	100.0	1,986	190	SANP	0.112	583
162	Apancoyo III	Río Apancoyo	Sonsonate	13.6631	89.5479	Inventory	INGENDEHSA	JICA Study Team	5.65	0.155	120.0	1,457	210		0.156	641
163	Tazulá	Río Tazulá	Sonsonate	13.6682	89.5818	Inventory	INGENDEHSA	JICA Study Team	7.62	0.209	100.0	1,770	250		0.175	719
164	Metalío I	Río Metalío	Ahuachapán	13.7157	89.8581	Inventory	CEL-UCA 1989	JICA Study Team	7.39	0.138	60.0	3,015	325		0.068	517
165	Aguachapío II	Río Aguachapío	Ahuachapán	13.7850	89.9733	Pre Factibilidad	INGENDEHSA	INGENDEHSA	5.22	0.226	60.0	n.d.	n.d.		0.113	493
166	El Izcanal IV	Río Izcanal	Ahuachapán	13.8160	89.9612	Inventory	INGENDEHSA	JICA Study Team	2.89	0.088	110.0	1,983	395		0.080	487
167	Los Ausoles	Río Los Ausoles	Ahuachapán	13.9332	89.8165	Inventory	INGENDEHSA	JICA Study Team	13.33	0.137	60.0	2,022	345		0.068	490
168	Guayapa IV	Río Guayapa	Ahuachapán	13.8750	89.9183	Inventory	INGENDEHSA	JICA Study Team	5.02	0.052	140.0	1,022	840		0.060	430
169	Mizata IV	Río Mizata	La Libertad	13.6348	89.5063	Inventory	INGENDEHSA	JICA Study Team	7.08	0.231	100.0	848	560		0.191	715
170	El Izcanal III	Río Izcanal	Ahuachapán	13.8001	89.9746	Inventory	INGENDEHSA	JICA Study Team	5.53	0.131	60.0	1,766	285	SANP	0.065	444
171	Quebrada Hon.d.a	Quebrada Hon.d.a	Chalatenango	14.2323	89.2393	Inventory		JICA Study Team	3.74	0.266	80.0	1,541	330		0.177	649
172	Tihuicha I	Río Tihuicha	Ahuachapán	13.7397	89.8906	Inventory	INGENDEHSA	JICA Study Team	4.05	0.109	80.0	757	755		0.071	459
173	Río Nejapa III	Río Nejapa	Ahuachapán	13.8808	89.8880	Inventory	CEL-UCA 1989	JICA Study Team	10.94	0.121	60.0	1,780	340		0.060	412
174	El Izcanal I	Río Izcanal	Ahuachapán	13.7782	89.9959	Inventory	INGENDEHSA	JICA Study Team	11.14	0.180	40.0	922	495		0.058	462
175	La Soledad I	Río San Franscisco La Soledad	Ahuachapán	13.8361	90.0161	Inventory	INGENDEHSA	JICA Study Team	10.23	0.121	70.0	1,874	370		0.070	415
176	El Sauce (Presa 1 & 2)	Río El Carrizo/ Río de Cupa	La Libertad	13.5444	89.5244	Inventory	INGENDEHSA	JICA Study Team	16.25	0.263	60.0	2,382	645		0.127	641
177	La Soledad II	Río San Franscisco La Soledad	Ahuachapán	13.8511	90.0023	Inventory	INGENDEHSA	JICA Study Team	7.07	0.084	100.0	2,074	620	SANP	0.069	416
178	Metalío II	Río Metalío	Ahuachapán	13.7531	89.8526	Inventory	CEL-UCA 1989	JICA Study Team	2.74	0.108	80.0	1,252	220		0.072	378
179	Texispulco	Río Texispulco	Ahuachapán	13.7594	89.8017	Inventory	CEL-UCA 1989	JICA Study Team	4.17	0.126	60.0	1,880	285		0.063	378

(Source: JICA Study Team)

Table S.7 List of Small Hydropower Potential Sites (4/4)

No.	Nombre de Proyecto Project Name	Río River	Departamento Department	Latitud Latitude (N)	Longitud Longitude (W)	Etapa del Proyecto Project Stage	Fuente Original Original Source	Actualizado por Updated by	Área de Drenaje Catchment Area (km²)	Caudal Diseño Design Discharge (m³/s)	Caida bruta Gross Head (m)	Longitud de la Canal Length of Canal (m)	Longitud de tubería de presión Length of Pestock (m)	Area Natural Protegida Natural Protect Area (SANP)	Potencia Potential (MW)	Energía Energy (MWh/Año)
180	Ashuquema III (Presa 1 & 2)	Río Ashuquema / Río Ishcanelo	Ahuachapán	13.8865	89.9406	Inventory	INGENDEHSA	JICA Study Team	6.41	0.099	80.0	891	335		0.066	362
181	Río Chiquito	Río Chiquito	Cabañas	13.7794	88.8428	Inventory	CEL-UCA 1989	JICA Study Team	6.02	0.147	40.0	899	720		0.046	384
182	Casa de Piedra	Río Casa de Piedra	San Salvador	13.6277	89.2174	Inventory	INGENDEHSA	JICA Study Team	4.14	0.091	100.0	3,179	170		0.076	347
183	Tizapa V	Río Paso Hon.d.o	Cuscatlán	13.7607	88.9009	Inventory	CEL-UCA 1989	JICA Study Team	1.61	0.104	80.0	1,897	250		0.070	327
184	Los Milagros	Río San Antonio	Sonsonate	13.7511	89.7414	Inventory	INGENDEHSA	JICA Study Team	3.92	0.131	60.0	706	450		0.065	328
185	El Quequeishque II	Río El Quequeishque	Ahuachapán	13.8683	89.9955	Inventory	INGENDEHSA	JICA Study Team	4.23	0.081	100.0	1,430	240		0.068	309
186	El Izcanal II	Río Izcanal	Ahuachapán	13.7924	89.9876	Inventory	INGENDEHSA	JICA Study Team	8.50	0.144	40.0	3,580	495	SANP	0.045	355
187	La Soledad IV (Presa 1 & 2)	Río San Franscisco La Soledad	Ahuachapán	13.8681	89.9722	Inventory	INGENDEHSA	JICA Study Team	1.77	0.042	200.0	986	335	SANP	0.070	274
188	Tizapa I	Río El Rosario	Cuscatlán	13.8001	88.9611	Inventory	CEL-UCA 1989	JICA Study Team	2.10	0.136	60.0	1,639	225		0.068	311
189	Telescaligüe	Río Telescaligüe	Sonsonate	13.6287	89.5878	Inventory	INGENDEHSA	JICA Study Team	3.09	0.085	100.0	1,522	185		0.071	292
190	Los Infiernillos	Qda. Los Infiernillos	Chalatenango	14.2763	89.0697	Inventory	INGENDEHSA	JICA Study Team	0.97	0.051	160.0	1,320	685		0.067	279
191	La Soledad III	Río San Franscisco La Soledad	Ahuachapán	13.8559	89.9837	Inventory	CEL-UCA 1989	JICA Study Team	4.43	0.053	100.0	2,864	230	SANP	0.044	266
192	El Quequeishque I	Río El Quequeishque	Ahuachapán	13.8550	90.0095	Inventory	INGENDEHSA	JICA Study Team	7.25	0.120	60.0	791	325		0.060	289
193	Ayacachapa IV (Presa 1 & 2)	Río Estasuche / Río Cacaguayo	Sonsonate	13.6133	89.5533	Inventory	INGENDEHSA	JICA Study Team	6.65	0.127	60.0	1,843	285		0.063	300
194	Sunzapúa I	Río Sunzapúa	Sonsonate	13.6085	89.5990	Inventory	INGENDEHSA	JICA Study Team	3.73	0.102	80.0	1,658	250		0.068	279
195	Ojushico I	Río Ojushico	Sonsonate	13.6013	89.5935	Inventory	INGENDEHSA	JICA Study Team	5.40	0.119	60.0	2,495	155		0.060	267
196	Sihuapilapa I	Río Sihuapilapa	Sonsonate	13.5648	89.5780	Inventory	INGENDEHSA	JICA Study Team	3.29	0.053	100.0	1,633	550		0.044	225
197	Ojushico II	Río Ojushico	Sonsonate	13.6159	89.5744	Inventory	INGENDEHSA	JICA Study Team	1.27	0.050	160.0	2,469	270		0.067	224
198	Aguachapío I	Río Aguachapío	Ahuachapán	13.8213	89.9448	Inventory	INGENDEHSA	JICA Study Team	0.53	0.024	200.0	892	490	SANP	0.040	192
199	Apancoyo I (Presa 1 & 2)	Río Apancoyo / Río Telescaligüe	Sonsonate	13.6347	89.5904	Inventory	INGENDEHSA	JICA Study Team	20.42	0.112	40.0	1,056	800		0.034	232
200	Chagalapa I	Río Chagalapa	Ahuachapán	13.8606	90.0259	Inventory	INGENDEHSA	JICA Study Team	3.87	0.046	80.0	2,237	390		0.030	181
201	Cuilapa	Río Cuilapa	Ahuachapán	13.7669	89.9507	Inventory	INGENDEHSA	JICA Study Team	1.91	0.051	80.0	2,505	1,490		0.031	203
202	Sunzapúa II	Río Sunzapúa	Sonsonate	13.6193	89.5865	Inventory	CEL-UCA 1989	JICA Study Team	1.96	0.043	100.0	1,462	255		0.036	165
203	Chagalapa II	Río Chagalapa	Ahuachapán	13.8701	90.0058	Inventory	INGENDEHSA	JICA Study Team	1.77	0.042	120.0	1,871	530		0.042	164
204	Río Frío	Río Frío	Sonsonate	13.7425	89.7486	Inventory	INGENDEHSA	JICA Study Team	1.16	0.047	80.0	1,320	290		0.031	143
205	Tianmica	Río Tianmica	Ahuachapán	13.8783	90.0395	Inventory	INGENDEHSA	JICA Study Team	2.27	0.043	80.0	1,588	350		0.029	131
206	Tihuicha II	Río Tihuicha	Ahuachapán	13.7531	89.8910	Inventory	CEL-UCA 1989	JICA Study Team	0.28	0.006	100.0	900	485		0.005	36
207	Huiscoyol	Río Huiscoyol	Ahuachapán	13.8573	90.0152	Inventory	INGENDEHSA	JICA Study Team	0.32	0.006	100.0	1,712	480		0.005	25
208	Sihuapilapa II	Qda. El Tambor	Sonsonate	13.5758	89.5634	Inventory	INGENDEHSA	JICA Study Team	0.58	0.005	100.0	1,787	215		0.004	25
209	Quebrada Seca	Quebrada Seca	Sonsonate	13.5806	89.6045	Inventory	INGENDEHSA	JICA Study Team	0.77	0.004	80.0	1,589	445		0.003	20
	Totales													**20**	**180.759**	**756,000**
														Max.=	17.000	74,460
														Min.=	0.003	20

Note: Italic number was estimated values. N.d.: No dat.

(Source: JICA Study Team)

Table S.8 Financial Values of Small Hydropower Potential Sites (1/2)

No.	Nombre de Proyecto	Etapa del Proyecto	Area Natural Protegida	Potencia	Energía	Factor de planta	Inversión Total	Costo/kW	Generación de costos	Base del Proyecto (sin préstamo del Banco) Project Base (without Bank Loan)			Base del Inversionista (con préstamo del Banco) Investment Base (with Bank Loan)			Fase del proyecto
	Project Name	Project Stage	Natural Protect Area	Potential	Energy	Plant Factor	Investment Cost	Cost/kW	Generation Cost	TIR FIRR	VAN NPV	B/C	TIR FIRR	VAN NPV	B/C	Project Phase
			(SANP)	(MW)	(MWh/Año)		(x 1,000 US$)	(US$/kW)	(US$/kWh)	(%)	(x1,000 US$)		(%)	(x1,000 US$)		
1	El Calambre	Construcción		0.058	311	61%	146	2,512	? 0.062	16.5%	82	1.17	? 39.4%	? 207	? 1.83	1
2	Mirazalco	Construcción		3.370	? 14,762	? 50%	9,969	2,958	? 0.089	? 19.6%	? 8,830	? 1.67	? 29.3%	? 9,475	? 1.76	1
3	Gualpuca	Financiamiento		1.000	6,155	70%	1,475	1,475	? 0.032	26.0%	614	1.70	? 90.5%	? 5,893	? 2.94	1
4	Ilopango Aguacayo	Financiamiento		17.000	? 74,460	? 50%	? 51,000	? 3,000	? 0.090	? 19.7%	? 45,746	? 1.70	? 29.5%	? 49,047	? 1.80	1
5	San Luis IV	Bid Process		1.500	? 6,570	? 50%	? 5,250	? 3,500	? 0.105	? 16.3%	? 2,953	? 1.43	? 22.4%	? 3,293	? 1.50	1
6	Sumpul	De Registro SIGET		16.200	64,043	45%	? 48,600	? 3,000	? 0.100	? 17.9%	? 35,075	? 1.58	? 25.8%	? 38,221	? 1.67	1
7	Sucio, Los Tetuntes	De Registro SIGET		6.600	? 28,908	? 50%	? 19,800	? 3,000	? 0.090	? 19.5%	? 17,481	? 1.69	? 29.2%	? 18,762	? 1.78	1
8	La Joya	De Registro SIGET		3.000	? 13,140	? 50%	? 9,000	? 3,000	? 0.090	? 19.2%	? 7,696	? 1.65	? 28.6%	? 8,279	? 1.74	1
9	San Francisco	De Registro SIGET		1.000	? 4,380	? 50%	? 3,000	? 3,000	? 0.090	? 18.2%	? 2,261	? 1.53	? 26.4%	? 2,455	? 1.61	1
10	La Colmena (El Volcán)	De Registro SIGET		0.097	450	53%	290	2,986	? 0.085	15.3%	124	1.10	? 28.0%	? 259	? 1.63	1
11	Quebrada la Cueva / San Jose	De Registro SIGET		0.065	455	80%	294	4,527	? 0.085	13.2%	88	1.10	? 28.0%	? 262	? 1.63	1
12	Santa Rosa (El Riachuelo)	De Registro SIGET		0.038	260	78%	180	4,737	? 0.091	11.8%	30	1.00	? 22.7%	? 116	? 1.43	1
13	Atehuecillas (Rehabilitation)	Rehabilitación		0.630	? 2,759	? 50%	? 1,890	? 3,000	? 0.090	? 17.6%	? 1,300	? 1.46	? 25.0%	? 1,422	? 1.53	1
14	San Esteban	Rehabilitación		0.751	3,287	50%	4,858	6,472	? 0.195	? 8.3%	? -689	? 0.88	? 8.6%	? -374	? 0.93	1
15	Cucumacayan (Reconversion)	Reconversion		2.300	17,895	89%	2,225	967	? 0.016	42.0%	261	1.76	? 164.1%	? 19,707	? 4.25	1
16	Acahuapa (Rehabilitation)	Rehabilitación		0.120	? 526	? 50%	? 360	? 3,000	? 0.090	? 18.2%	? 270	? 1.53	? 26.4%	? 294	? 1.60	1
17	Sapuyo (Rehabilitation)	Rehabilitación		0.060	? 263	? 50%	? 180	? 3,000	? 0.090	? 16.6%	? 107	? 1.38	? 23.1%	? 119	? 1.44	1
18	Chorreron Jiboa	Factibilidad		2.000	? 8,760	? 50%	? 6,000	? 3,000	? 0.090	? 19.0%	? 4,979	? 1.62	? 28.1%	? 5,367	? 1.70	1
19	La Montañita	Factibilidad		0.900	? 3,942	? 50%	? 2,700	? 3,000	? 0.090	? 18.2%	? 2,034	? 1.53	? 26.4%	? 2,208	? 1.61	1
20	El Sapo	Factibilidad		0.060	? 263	? 50%	? 180	? 3,000	? 0.090	31.0%	11,010	3.32	? 23.1%	? 119	? 1.44	1
21	San Luis III	Factibilidad		0.600	? 2,628	? 50%	? 1,800	? 3,000	? 0.090	? 17.4%	? 1,218	? 1.45	? 24.8%	? 1,335	? 1.52	1
22	Sonzacate (Nahuizalco II)	Factibilidad		3.839	16,816	50%	9,450	2,461	? 0.074	22.3%	9,758	2.18	? 37.2%	? 12,427	? 2.00	1
23	Potrerillos	Factibilidad		0.320	2,600	93%	976	3,049	? 0.049	18.4%	257	1.50	? 59.1%	? 2,292	? 2.52	1
24	Guanijiquil - Poza Hon.d.a	Factibilidad		0.131	510	44%	345	2,637	? 0.089	14.7%	140	1.43	? 26.7%	? 287	? 1.61	1
25	La Cabaña	Factibilidad		0.980	4,300	50%	2,600	2,653	? 0.080	11.4%	181	1.40	? 31.4%	? 2,731	? 1.75	1
26	La Loma	Factibilidad		0.055	398	83%	270	4,905	? 0.089	16.0%	136	1.15	? 25.7%	? 212	? 1.56	1
27	El Progreso	Factibilidad		0.033	280	97%	200	6,061	? 0.094	11.8%	34	1.00	? 22.2%	? 124	? 1.42	1
28	Araute	Factibilidad		0.033	284	98%	? 99	? 3,000	? 0.046	? 30.6%	? 206	? 1.98	? 54.9%	? 212	? 2.05	1
29	Cumaro	Factibilidad		0.040	? 175	? 50%	? 120	? 3,000	? 0.090	? 15.0%	? 53	? 1.26	? 19.9%	? 61	? 1.30	1
30	El Naranjito	Factibilidad		0.031	146	54%	97	3,124	? 0.087	10.3%	2	0.85	? 18.9%	? 44	? 1.26	1
31	Quezalapa	Diseños Básicos		1.050	2,628	29%	? 3,150	? 3,000	? 0.158	? 9.9%	? -26	? 0.99	? 11.1%	? 178	? 1.05	1
32	Tihuapa 1	Diseños Básicos		1.315	3,870	34%	? 3,945	? 3,000	? 0.134	? 12.3%	? 794	? 1.16	? 15.1%	? 1,049	? 1.22	1
33	Tihuapa 2	Diseños Básicos		0.900	2,580	33%	? 2,700	? 3,000	? 0.138	? 11.6%	? 359	? 1.10	? 13.8%	? 534	? 1.16	1
34	San Simón 1	Diseños Básicos		0.900	2,040	26%	? 2,700	? 3,000	? 0.174	? 8.6%	? -304	? 0.91	? 9.1%	?- 130	? 0.96	1
35	San Simón 2	Diseños Básicos		0.915	2,484	31%	? 2,745	? 3,000	? 0.146	? 10.9%	? 201	? 1.06	? 12.6%	? 379	? 1.11	1
36	San Simón 3	Diseños Básicos		0.870	2,570	34%	? 2,610	? 3,000	? 0.134	? 11.9%	? 427	? 1.12	? 14.3%	? 596	? 1.18	1
37	Titihuapa 3	Diseños Básicos		2.100	6,802	37%	? 6,300	? 3,000	? 0.122	? 14.2%	? 2,305	? 1.29	? 18.4%	? 2,713	? 1.36	1
38	Titihuapa 5	Diseños Básicos		1.410	5,673	46%	? 4,230	? 3,000	? 0.098	? 17.2%	? 2,757	? 1.48	? 24.3%	? 3,031	? 1.56	1
39	Cuyuapa	Diseños Básicos		1.020	2,840	32%	? 3,060	? 3,000	? 0.142	? 11.2%	? 315	? 1.08	? 13.2%	? 513	? 1.13	1
40	Suquiapa	Diseños Básicos		3.530	13,630	44%	? 10,590	? 3,000	? 0.102	? 17.2%	? 6,886	? 1.51	? 24.2%	? 7,571	? 1.59	1
41	Gr. Chalatenango	Diseños Básicos		1.630	3,680	26%	? 4,890	? 3,000	? 0.175	? 9.3%	? -279	? 0.95	? 10.1%	? 37	? 1.01	1
42	Sucio 3	Diseños Básicos		2.025	11,149	63%	? 6,075	? 3,000	? 0.072	? 23.5%	? 7,849	? 1.91	? 38.1%	? 8,242	? 2.01	1
43	Polorós	Diseños Básicos		2.025	5,250	30%	? 6,075	? 3,000	? 0.152	? 11.2%	? 597	? 1.08	? 13.1%	? 991	? 1.14	1
44	Huiza 2	Diseños Básicos		2.100	6,009	33%	? 6,300	? 3,000	? 0.138	? 12.4%	? 1,330	? 1.17	? 15.3%	? 1,738	? 1.24	1
45	Santo Domingo (Presa 1 & 2 &3)	Pre Factibilidad		1.540	7,885	58%	2,958	2,881	? 0.087	23.4%	3,969	2.29	? 35.9%	? 5,579	? 1.92	1
46	Chacala Los Apantes (Presa 1 & 2)	Pre Factibilidad		1.500	8,126	62%	4,498	3,124	? 0.094	22.0%	3,492	2.14	? 36.8%	? 5,825	? 1.95	1
47	Santa Rita	Pre Factibilidad		8.357	36,603	50%	21,220	2,539	? 0.076	21.7%	20,688	2.11	? 36.3%	? 27,052	? 2.00	1
48	Milingo (Reconversion)	Pre Factibilidad		0.800	? 3,504	? 50%	2,225	2,781	? 0.084	42.0%	261	1.76	? 28.8%	? 2,061	? 1.66	1
49	Copinula I	Pre Factibilidad		0.603	2,641	50%	2,155	3,573	? 0.107	14.1%	653	1.35	? 19.6%	? 1,059	? 1.37	1
50	San José Loma	Pre Factibilidad		1.901	8,327	50%	7,797	4,101	? 0.123	13.1%	1,804	1.26	? 18.3%	? 3,354	? 1.37	1
51	Cara Sucia (Presa 1 & 2)	Pre Factibilidad	SANP	0.584	2,559	50%	2,560	4,382	? 0.132	11.1%	201	1.09	? 14.6%	? 624	? 1.19	
52	San Pedro II	Pre Factibilidad		0.397	1,739	50%	1,641	4,134	? 0.124	11.0%	117	1.08	? 18.1%	? 685	? 1.35	1
53	Copinula II	Pre Factibilidad		0.487	2,132	50%	2,266	4,655	? 0.140	10.0%	-7	1.00	? 15.5%	? 653	? 1.25	1
54	Qbda El Naranjito al Naranjo	Pre Factibilidad		0.080	? 350	? 50%	? 240	? 3,000	? 0.090	? 17.4%	? 162	? 1.45	? 24.7%	? 177	? 1.52	1
55	Qbda El Singual, al Cuyapo	Pre Factibilidad		0.058	? 254	? 50%	? 174	? 3,000	? 0.090	? 16.5%	? 102	? 1.37	? 22.9%	? 113	? 1.43	1
56	Venecia Prusia	Pre Factibilidad		1.200	? 5,256	? 50%	? 3,600	? 3,000	? 0.090	? 18.5%	? 2,804	? 1.56	? 27.0%	? 3,037	? 1.64	1
57	Las Pilonas	Pre Factibilidad		1.100	2,961	31%	3,268	2,971	? 0.145	9.9%	-17	0.99	? 12.8%	? 489	? 1.12	1
58	Copinula	Pre Factibilidad		0.241	1,055	50%	1,371	5,691	0.171	5.2%	-400	0.67	? 10.9%	? 67	? 1.04	1
59	Santa Emilia I	Pre Factibilidad		0.500	? 2,190	? 50%	? 1,500	? 3,000	? 0.090	? 17.0%	? 946	? 1.41	? 23.8%	? 1,044	? 1.47	1
60	Santa Emilia II	Pre Factibilidad		0.500	? 2,190	? 50%	? 1,500	? 3,000	? 0.090	? 17.0%	? 946	? 1.41	? 23.8%	? 1,044	? 1.47	1
61	Torola	Inventory		4.321	18,667	49%	4,710	1,090	0.033	26.0%	1,530	1.78	? 89.7%	? 18,607	? 3.20	2
62	Copinula III	Inventory		0.463	3,187	79%	1,636	3,533	0.068	24.9%	2,364	2.02	41.4%	2,470	2.11	2
63	La Calzadora I	Inventory		0.432	2,300	61%	1,308	3,028	0.075	22.6%	1,564	1.85	36.0%	1,648	1.94	2
64	Los Hervideros I	Inventory		0.993	5,457	63%	2,934	2,954	0.071	23.2%	3,688	1.85	37.3%	3,878	1.93	2
65	Los Hervideros II (Presa 1 & 2)	Inventory		0.435	3,136	82%	1,902	4,372	0.080	21.5%	2,064	1.80	33.6%	2,187	1.89	2
66	Malancola	Inventory		4.175	17,688	48%	10,926	2,617	0.081	21.3%	11,575	1.79	33.0%	12,282	1.88	2
67	Gran.d.e de San Miguel, Sn Juan	Inventory		4.500	19,710	50%	? 13,500	? 3,000	0.132	? 19.4%	? 11,773	? 1.67	? 29.0%	? 12,647	? 1.76	2
68	Gn.d.e de San Miguel, San José	Inventory		3.200	14,016	50%	? 9,600	? 3,000	0.132	? 19.3%	? 8,240	? 1.65	? 28.7%	? 8,861	? 1.74	2
69	Chilama I (Presa 1 & 2)	Inventory		2.623	7,840	34%	5,197	1,981	0.087	19.5%	4,562	1.64	29.1%	4,898	1.73	2
70	Guayapa II	Inventory	SANP	0.497	2,599	60%	1,791	3,604	0.091	19.1%	1,502	1.64	28.3%	1,618	1.72	
71	La Calzadora II	Inventory		0.457	2,434	61%	1,677	3,670	0.091	19.0%	1,401	1.63	28.2%	1,509	1.72	2
72	EL Jabio	Inventory		2.000	8,760	50%	? 6,000	? 3,000	0.132	? 19.0%	? 4,979	? 1.62	? 28.1%	? 5,367	? 1.70	2
73	El Rosario II	Inventory		0.498	2,606	60%	1,848	3,711	0.093	18.6%	1,460	1.60	27.2%	1,580	1.69	2
74	San Sebastián	Inventory		0.480	2,317	55%	1,656	3,449	0.094	18.4%	1,276	1.59	26.8%	1,383	1.67	2
75	Chilama II	Inventory		0.457	2,343	59%	1,695	3,708	0.095	18.2%	1,273	1.57	26.4%	1,383	1.66	2
76	El Molino I	Inventory		0.260	1,876	82%	1,345	5,175	0.094	18.2%	1,010	1.57	26.4%	1,097	1.65	2
77	Guayapa I	Inventory	SANP	0.450	2,353	60%	1,723	3,830	0.096	18.0%	1,260	1.56	26.0%	1,372	1.64	
78	El Refugio	Inventory		0.465	2,243	55%	1,649	3,545	0.097	17.9%	1,191	1.55	25.8%	1,298	1.64	2
79	Los Toles	Inventory		0.428	2,035	54%	1,503	3,511	0.097	17.8%	1,065	1.54	25.5%	1,163	1.62	2
80	El Peñon	Inventory		0.486	2,212	52%	1,645	3,384	0.098	17.7%	1,157	1.54	25.4%	1,263	1.62	2
81	Guayapa V	Inventory		0.486	2,310	54%	1,741	3,582	0.099	17.5%	1,192	1.53	25.0%	1,304	1.61	2
82	Río Frío / Agua Caliente	Inventory	SANP	0.958	6,906	82%	5,109	5,333	0.097	17.6%	3,535	1.52	25.1%	3,866	1.60	
83	El Charrerón	Inventory		0.418	1,903	52%	1,476	3,531	0.102	16.9%	927	1.48	23.8%	1,023	1.56	2
84	Santa Lucía	Inventory		0.966	3,609	43%	2,541	2,630	0.093	17.6%	1,766	1.49	25.2%	1,931	1.56	2
85	El Rosario I	Inventory		0.423	2,155	58%	1,800	4,255	0.110	15.9%	949	1.42	21.7%	1,065	1.49	2
86	Maishtapula	Inventory	SANP	0.320	1,528	55%	1,243	3,883	0.107	16.0%	674	1.42	22.0%	754	1.49	
87	Asesesco (Presa 1 & 2)	Inventory		0.435	2,105	55%	1,767	4,061	0.111	15.8%	917	1.41	21.5%	1,032	1.49	2
88	Miramundo	Inventory		0.480	1,877	45%	1,567	3,265	0.110	15.8%	814	1.41	21.5%	916	1.48	2
89	Tilapa II	Inventory		1.925	6,402	38%	5,234	2,719	0.108	15.9%	2,762	1.40	21.7%	3,100	1.48	2
90	El Faro (Presa 1 & 2)	Inventory		0.426	1,750	47%	1,476	3,465	0.111	15.6%	739	1.39	21.1%	834	1.47	2
91	Santa María	Inventory		0.874	3,264	43%	2,494	2,854	0.101	16.2%	1,384	1.40	22.2%	1,545	1.46	2
92	El Molino II	Inventory		0.221	1,523	79%	1,284	5,809	0.111	15.5%	631	1.38	20.9%	714	1.46	
93	San Pedro I	Inventory		0.344	1,944	65%	1,685	4,899	0.114	15.3%	791	1.37	20.5%	900	1.45	2
94	Ashuquema I	Inventory		0.189	1,361	82%	1,207	6,386	0.117	15.1%	545	1.36	20.1%	623	1.44	
95	El Caoba	Inventory		0.451	2,156	55%	1,898	4,209	0.116	15.1%	863	1.36	20.2%	986	1.44	2
96	El Rosario IV	Inventory		0.313	1,496	55%	1,290	4,122	0.114	15.2%	592	1.36	20.2%	675	1.43	2
97	Sunzacuapa III	Inventory		0.184	1,060	66%	941	5,116	0.117	14.9%	411	1.35	19.8%	472	1.42	
98	Tizapa II	Inventory		0.418	1,907	52%	1,701	4,069	0.118	14.9%	732	1.34	19.7%	842	1.42	2
99	San Isidro	Inventory		0.477	1,782	43%	1,600	3,354	0.118	14.7%	669	1.33	19.4%	772	1.41	3
100	Cauta	Inventory		0.191	971	58%	871	4,559	0.118	14.7%	364	1.33	19.4%	420	1.40	
101	Loma de San Juan	Inventory		0.954	3,837	46%	3,278	3,436	0.113	14.8%	1,391	1.32	19.5%	1,603	1.39	3
102	San Juan Buenavista	Inventory	SANP	0.918	3,063	38%	2,521	2,746	0.108	15.0%	1,112	1.32	19.9%	1,275	1.39	
103	Los Pozos	Inventory		0.827	2,791	39%	2,276	2,752	0.107	14.9%	996	1.31	19.8%	1,143	1.38	3
104	Los Pueblos II	Inventory		1.247	4,627	42%	4,075	3,267	0.116	14.5%	1,610	1.30	18.9%	1,873	1.37	3
105	El Jícaro (Presa 1 & 2)	Inventory		0.496	1,851	43%	1,736	3,500	0.124	14.1%	632	1.29	18.3%	744	1.36	3
106	Guarumo	Inventory		0.897	3,647	46%	3,192	3,559	0.115	14.4%	1,233	1.29	18.8%	1,440	1.36	3
107	Guascoran	Inventory		12.500	38,000	35%	? 38,000	? 3,040	0.132	? 13.7%	? 12,482	? 1.28	? 17.6%	? 14,942	? 1.35	3
108	El Diamante II	Inventory		0.218	1,333	70%	1,238	5,678	0.122	14.0%	439	1.28	18.1%	519	1.35	
109	Río Nejapa I	Inventory		0.132	1,000	86%	963	7,296	0.127	13.8%	317	1.27	17.6%	380	1.34	

(Source: JICA Study Team)

Table S.8 Financial Values of Small Hydropower Potential Sites (2/2)

No.	Nombre de Proyecto	Etapa del Proyecto	Area Natural Protegida	Potencia	Energía	Factor de planta	Inversión Total	Costo/kW	Generación de costos	Base del Proyecto (sin préstamo del Banco) Project Base (without Bank Loan)			Base del Inversionista (con préstamo del Banco) Investment Base (with Bank Loan)			Fase del proyecto
	Project Name	Project Stage	Natural Protect Area	Potential	Energy	Plant Factor	Investment Cost	Cost/kW	Generation Cost	TIR FIRR	VAN NPV	B/C	TIR FIRR	VAN NPV	B/C	Project Phase
			(SANP)	(MW)	(MWh/Año)		(x 1,000 US$)	(US$/kW)	(US$/kWh)	(%)	(x1,000 US$)		(%)	(x1,000 US$)		
110	Asuchío	Inventory	SANP	0.428	1,756	47%	1,725	4,031	0.129	13.5%	525	1.25	17.1%	637	1.32	
111	Agua Fría	Inventory		0.974	3,960	46%	3,678	3,776	0.122	13.7%	1,187	1.25	17.5%	1,425	1.31	3
112	Chilama III	Inventory		0.934	3,756	46%	3,491	3,738	0.122	13.6%	1,101	1.24	17.3%	1,327	1.31	3
113	Tehuechode	Inventory		0.339	1,267	43%	1,243	3,667	0.129	13.2%	352	1.23	16.7%	433	1.29	3
114	Tizapa IV	Inventory		0.265	1,284	55%	1,268	4,786	0.130	13.2%	351	1.22	16.6%	433	1.29	3
115	Quezalate	Inventory		0.495	1,651	38%	1,679	3,391	0.134	13.0%	437	1.21	16.2%	546	1.28	3
116	El Anonal	Inventory		0.481	1,794	43%	1,835	3,815	0.135	13.0%	474	1.21	16.2%	593	1.28	3
117	Mizata I	Inventory		0.421	1,727	47%	1,776	4,217	0.135	12.9%	445	1.21	16.0%	560	1.27	3
118	Los Pueblos I	Inventory		0.412	2,081	58%	2,176	5,281	0.138	12.8%	524	1.20	15.9%	665	1.27	3
119	El Cutal	Inventory		0.445	1,618	42%	1,675	3,764	0.136	12.8%	401	1.20	15.8%	509	1.26	3
120	Tepechapa	Inventory		0.232	1,224	60%	1,245	5,366	0.134	12.8%	298	1.19	15.8%	379	1.26	
121	El Silencio	Inventory		0.287	1,178	47%	1,201	4,184	0.134	12.7%	281	1.19	15.7%	358	1.25	3
122	Concepción Los Planes	Inventory		0.450	1,680	43%	1,766	3,924	0.138	12.6%	396	1.18	15.5%	510	1.25	3
123	El Rosario V	Inventory		0.182	951	60%	1,001	5,502	0.139	12.6%	224	1.18	15.5%	289	1.25	
124	El Escalón	Inventory		0.420	1,567	43%	1,641	3,908	0.138	12.6%	367	1.18	15.5%	474	1.25	3
125	Cuitapán	Inventory		0.422	1,575	43%	1,659	3,930	0.139	12.5%	362	1.18	15.4%	469	1.24	3
126	Río Ceniza (Presa 1 & 2)	Inventory		0.330	1,780	62%	1,898	5,751	0.140	12.4%	401	1.17	15.3%	524	1.24	3
127	Papaleguayo (Presa 1 & 2)	Inventory		0.278	1,143	47%	1,198	4,308	0.138	12.3%	241	1.16	15.1%	318	1.23	3
128	Guayapa VI	Inventory	SANP	0.175	915	60%	995	5,687	0.143	12.2%	185	1.15	14.8%	249	1.22	
129	Cauta II	Inventory		0.223	1,259	64%	1,377	6,175	0.144	11.9%	223	1.13	14.3%	312	1.20	
130	Guayapa II	Inventory		0.131	947	83%	1,061	8,096	0.148	11.8%	165	1.13	14.2%	234	1.19	
131	San Benito (Presa 1 & 2)	Inventory		0.483	1,613	38%	1,807	3,742	0.148	11.8%	276	1.13	14.1%	393	1.19	3
132	Tecomate	Inventory		0.421	1,572	43%	1,758	4,176	0.147	11.8%	269	1.13	14.1%	383	1.19	3
133	Tilapa III	Inventory		0.480	1,619	39%	1,817	3,785	0.148	11.8%	276	1.13	14.1%	393	1.19	3
134	San Rafael (Presa 1 & 2)	Inventory		0.232	955	47%	1,022	4,406	0.141	11.9%	165	1.13	14.3%	231	1.19	
135	Ayacachapa III	Inventory		0.312	1,166	43%	1,275	4,088	0.144	11.8%	199	1.13	14.2%	282	1.19	3
136	Ayacachapa II	Inventory		0.448	1,495	38%	1,674	3,737	0.148	11.7%	250	1.12	14.1%	358	1.19	3
137	Sunzacuapa I	Inventory		0.197	1,183	69%	1,377	6,987	0.153	11.5%	176	1.11	13.6%	265	1.17	
138	Tilapa I	Inventory		1.025	3,680	41%	3,954	3,858	0.142	11.6%	552	1.11	13.9%	808	1.17	3
139	Apancoyo II	Inventory		0.416	1,388	38%	1,589	3,819	0.151	11.4%	193	1.10	13.5%	296	1.16	3
140	Tizapa III	Inventory		0.198	800	46%	927	4,682	0.153	11.3%	104	1.09	13.4%	164	1.16	
141	Río Nejapa II	Inventory		0.126	907	82%	1,062	8,425	0.154	11.3%	116	1.09	13.3%	185	1.15	
142	El Rosario III	Inventory		0.195	994	58%	1,179	6,048	0.156	11.2%	118	1.08	13.1%	194	1.15	
143	Guayapa IV (Presa 1 & 2)	Inventory	SANP	0.149	713	55%	836	5,609	0.154	11.1%	78	1.08	13.0%	132	1.14	
144	Mizata II	Inventory		0.270	1,109	47%	1,288	4,771	0.153	11.1%	118	1.08	13.0%	202	1.14	3
145	Sunzacuapa II	Inventory		0.193	1,090	64%	1,322	6,848	0.160	11.0%	110	1.07	12.8%	196	1.13	
146	El Tablón	Inventory		0.194	723	43%	870	4,484	0.158	10.8%	60	1.06	12.5%	116	1.12	
147	El Diamante I	Inventory		0.235	1,196	58%	1,436	6,109	0.158	10.8%	94	1.05	12.5%	187	1.11	
148	El Rosario VI	Inventory	SANP	0.165	789	55%	960	5,819	0.160	10.8%	61	1.05	12.4%	123	1.11	
149	Talquezalar	Inventory		0.421	1,238	34%	1,501	3,565	0.160	10.7%	88	1.05	12.3%	185	1.11	3
150	El Cedro	Inventory		0.336	1,119	38%	1,348	4,012	0.159	10.7%	78	1.05	12.3%	165	1.11	3
151	Guayapa III (Presa 1 & 2)	Inventory		0.093	733	90%	899	9,663	0.161	10.6%	47	1.04	12.2%	105	1.10	
152	Mizata III	Inventory		0.215	883	47%	1,055	4,907	0.157	10.5%	47	1.04	12.1%	116	1.09	
153	Ayacachapa I	Inventory		0.218	1,036	54%	1,266	5,806	0.161	10.4%	48	1.03	11.9%	130	1.09	
154	Comizapa	Inventory		0.152	673	51%	845	5,559	0.165	10.3%	21	1.02	11.7%	76	1.08	
155	Las Mesas	Inventory		0.089	513	66%	633	7,109	0.163	10.2%	12	1.02	11.6%	53	1.07	
156	San Ignacio	Inventory		0.441	1,269	33%	1,636	3,711	0.170	10.0%	5	1.00	11.3%	111	1.06	3
157	Ashuquema II	Inventory		0.120	822	78%	1,080	9,003	0.173	9.9%	-5	1.00	11.1%	65	1.05	
158	El Matazano	Inventory		0.173	648	43%	840	4,856	0.171	9.9%	-6	0.99	11.1%	48	1.05	
159	Siberia	Inventory		0.240	965	46%	1,237	5,153	0.169	9.9%	-13	0.99	11.0%	67	1.05	
160	Joya Verde	Inventory		0.178	731	47%	984	5,525	0.177	9.6%	-31	0.97	10.6%	32	1.03	
161	Aguachapío III	Inventory	SANP	0.112	583	59%	791	7,065	0.179	9.4%	-42	0.96	10.2%	9	1.01	
162	Apancoyo III	Inventory		0.156	641	47%	879	5,635	0.181	9.3%	-49	0.95	10.2%	8	1.01	
163	Tazulá	Inventory		0.175	719	47%	997	5,697	0.183	9.3%	-57	0.95	10.1%	7	1.01	
164	Metalío I	Inventory		0.068	517	87%	731	10,743	0.186	8.9%	-70	0.92	9.4%	-22	0.97	
165	Aguachapío II	Pre Factibilidad		0.113	493	50%	697	6,192	0.186	-3.3%	-418	0.31	*? 9.4%*	*? -24*	*? 0.97*	
166	El Izcanal IV	Inventory		0.080	487	70%	693	8,663	0.187	8.7%	-72	0.91	9.3%	-28	0.96	
167	Los Ausoles	Inventory		0.068	490	82%	709	10,429	0.191	8.6%	-83	0.90	9.0%	-37	0.95	
168	Guayapa IV	Inventory		0.060	430	82%	615	10,247	0.189	8.5%	-74	0.90	9.0%	-34	0.95	
169	Mizata IV	Inventory		0.191	715	43%	1,079	5,648	0.199	8.5%	-136	0.89	8.9%	-66	0.94	
170	El Izcanal III	Inventory	SANP	0.065	444	78%	683	10,511	0.203	7.9%	-117	0.86	8.0%	-73	0.90	
171	Quebrada Hon.d.a	Inventory		0.177	649	42%	1,034	5,842	0.210	7.9%	-177	0.85	8.0%	-110	0.90	
172	Tihuicha I	Inventory		0.071	459	74%	721	10,152	0.207	7.8%	-132	0.84	7.8%	-86	0.89	
173	Río Nejapa III	Inventory		0.060	412	78%	677	11,288	0.217	7.3%	-151	0.81	7.1%	-107	0.86	
174	El Izcanal I	Inventory		0.058	462	91%	771	13,288	0.220	7.2%	-173	0.81	7.1%	-123	0.85	
175	La Soledad I	Inventory		0.070	415	68%	699	9,981	0.222	7.1%	-166	0.80	6.8%	-121	0.84	
176	El Sauce (Presa 1 & 2)	Inventory		0.127	641	58%	1,118	8,806	0.230	7.1%	-262	0.79	6.9%	-190	0.84	
177	La Soledad II	Inventory	SANP	0.069	416	69%	721	10,448	0.228	6.8%	-185	0.78	6.5%	-139	0.83	
178	Metalío II	Inventory		0.072	378	60%	651	9,042	0.227	6.8%	-170	0.78	6.4%	-128	0.82	
179	Texispulco	Inventory		0.063	378	68%	669	10,611	0.233	6.6%	-185	0.76	6.1%	-142	0.81	
180	Ashuquema III (Presa 1 & 2)	Inventory		0.066	362	63%	651	9,870	0.237	6.4%	-190	0.75	5.9%	-148	0.79	
181	Río Chiquito	Inventory		0.046	384	95%	718	15,609	0.246	6.1%	-222	0.73	5.5%	-175	0.78	
182	Casa de Piedra	Inventory		0.076	347	52%	683	8,989	0.260	5.7%	-237	0.70	4.9%	-193	0.74	
183	Tizapa V	Inventory		0.070	327	53%	664	9,480	0.267	5.4%	-243	0.68	4.5%	-200	0.72	
184	Los Milagros	Inventory		0.065	328	58%	680	10,454	0.273	5.2%	-257	0.67	4.3%	-213	0.71	
185	El Quequeishque II	Inventory		0.068	309	52%	642	9,444	0.274	5.2%	-247	0.67	4.2%	-205	0.71	
186	El Izcanal II	Inventory	SANP	0.045	355	90%	758	16,842	0.281	5.1%	-293	0.66	4.2%	-244	0.70	
187	La Soledad IV (Presa 1 & 2)	Inventory	SANP	0.070	274	45%	584	8,340	0.280	4.8%	-237	0.65	3.8%	-199	0.69	
188	Tizapa I	Inventory		0.068	311	52%	671	9,869	0.284	4.9%	-270	0.65	3.9%	-226	0.69	
189	Telescaligüe	Inventory		0.071	292	47%	635	8,949	0.287	4.8%	-261	0.64	3.7%	-220	0.68	
190	Los Infiernillos	Inventory		0.067	279	48%	614	9,161	0.290	4.6%	-259	0.63	3.5%	-219	0.67	
191	La Soledad III	Inventory	SANP	0.044	266	69%	584	13,277	0.289	4.6%	-248	0.63	3.5%	-210	0.67	
192	El Quequeishque I	Inventory		0.060	289	55%	645	10,743	0.294	4.6%	-274	0.63	3.5%	-232	0.67	
193	Ayacachapa IV (Presa 1 & 2)	Inventory		0.063	300	54%	674	10,690	0.296	4.6%	-286	0.63	3.5%	-242	0.67	
194	Sunzapúa I	Inventory		0.068	279	47%	656	9,647	0.310	4.2%	-295	0.60	3.0%	-253	0.64	
195	Ojushico I	Inventory		0.060	267	51%	661	11,023	0.326	3.9%	-315	0.58	2.6%	-272	0.62	
196	Sihuapilapa I	Inventory		0.044	225	58%	587	13,339	0.343	3.4%	-300	0.55	2.0%	-262	0.59	
197	Ojushico II	Inventory		0.067	224	38%	601	8,967	0.354	3.2%	-315	0.54	1.7%	-276	0.57	
198	Aguachapío I	Inventory	SANP	0.040	192	55%	552	13,795	0.378	2.7%	-310	0.51	1.1%	-274	0.54	
199	Apancoyo I (Presa 1 & 2)	Inventory		0.034	232	78%	712	20,929	0.405	2.6%	-403	0.49	1.0%	-357	0.52	
200	Chagalapa I	Inventory		0.030	181	69%	562	18,733	0.409	2.2%	-333	0.48	-	-296	0.51	
201	Cuilapa	Inventory		0.031	203	75%	639	20,623	0.415	2.3%	-375	0.48	0.6%	-333	0.51	
202	Sunzapúa II	Inventory		0.036	165	52%	548	15,231	0.437	1.8%	-340	0.45	-	-304	0.48	
203	Chagalapa II	Inventory		0.042	164	44%	581	13,843	0.468	1.5%	-371	0.43	-	-334	0.46	
204	Río Frío	Inventory		0.031	143	53%	539	17,394	0.497	1.1%	-359	0.41	-	-324	0.43	
205	Tianmica	Inventory		0.029	131	52%	542	18,690	0.543	0.7%	-376	0.38	-	-341	0.40	
206	Tihuicha II	Inventory		0.005	36	82%	439	87,880	1.612	-	-402	0.18	-	-380	0.19	
207	Huiscoyol	Inventory		0.005	25	58%	445	88,900	2.305	-	-420	0.15	-	-399	0.15	
208	Sihuapilapa II	Inventory		0.004	25	71%	442	110,575	2.334	-	-418	0.15	-	-397	0.15	
209	Quebrada Seca	Inventory		0.003	20	78%	440	146,533	2.844	-	-421	0.13	-	-401	0.14	
	Totales		**20**	**180.759**	**756,000**	**48%**	**586,000**	**3,242**	**0.105**							**123**
	Note: Italic number was estimated values.	N.d.: No dat.	Max.=	17.000	74,460		51,000								Phase I	**59**
			Min.=	0.003	20		96.85								Phase-II	**31**
															Phase-III	**33**

*Note: (Generation Cost) = (Intestment Cost) / (Annual Enrgy) * (Annual Cost Factor)

(Source: JICA Study Team)