The Republic of El Salvador
Consejo Nacional de Energía

The Project for Master Plan for the Development of Renewable Energy In The Republic of El Salvador

Final Report (Summary)

March 2012

Japan International Cooperation Agency

Nippon Koei Co., Ltd.
Japan Metals & Chemicals Co., Ltd.
KRI International Corp.

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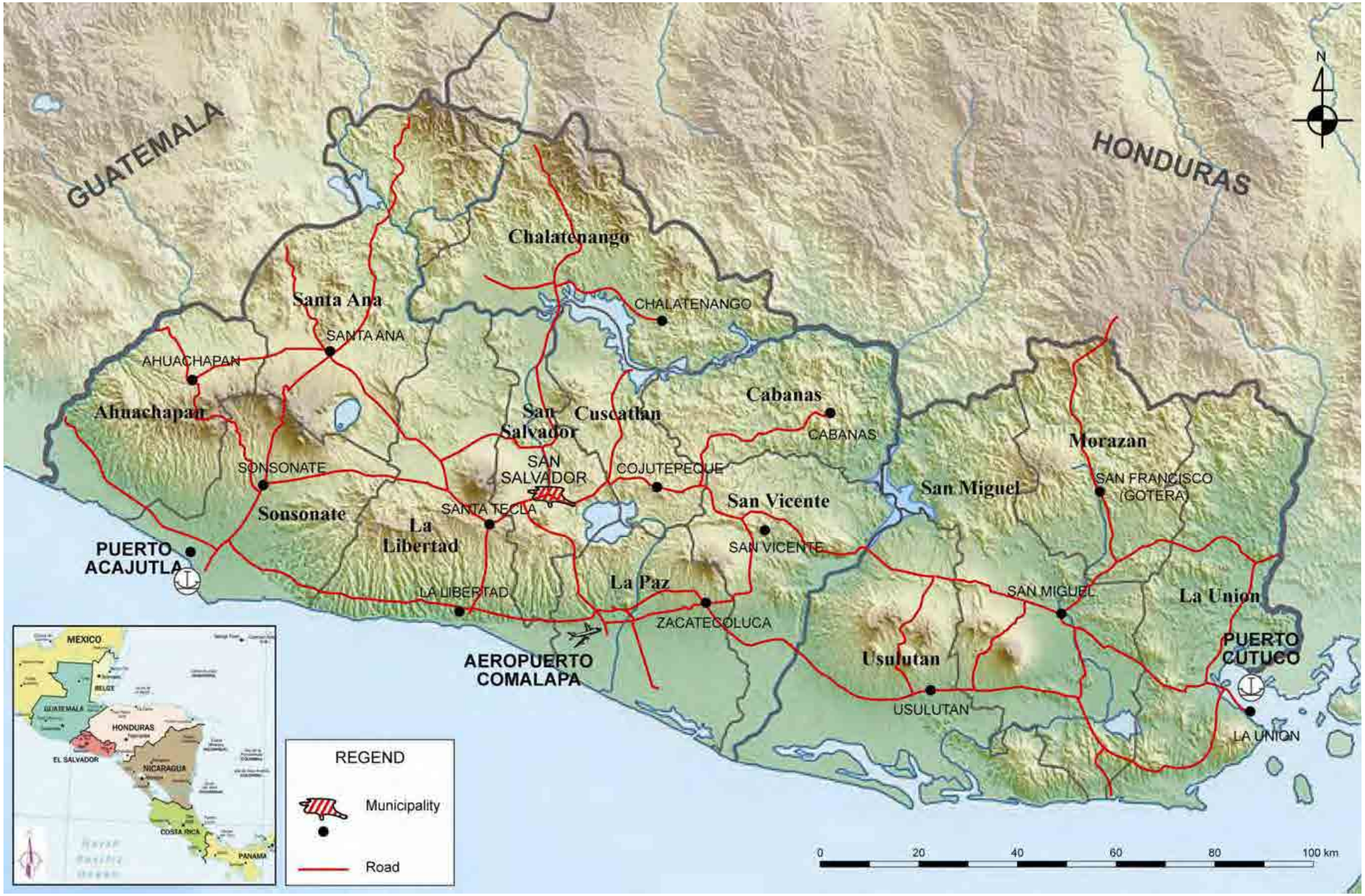
Currency conversion rate

1US $ = 80.0 yen

(As of February 22, 2012)



Study Area (Whole of El Salvador)

The Republic of El Salvador

The Project for Master Plan for the Development of Renewable Energy

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Abbreviations

Abbreviation	Spanish	English
AEA	Alianza en Energía y Ambiente con Centroamérica	Energy and Environment Partnership (EEP) in Central America
ANDA	Administración Nacional de Acueductos y Alcantarillados	National Administration of Aqueducts and Sewers
ARECA	La aceleración de Energía Renovable en Centroamérica	Accelerating Renewable Energy in Central America
B/C	Razón Beneficio / Costo	Benefit / Cost Ratio
BCIE(CABEI)	Banco Centroamericano de Integración Económica	Central American Bank for Economic Integration (CABEI)
CAESS	Compañía de Alumbrado Público de San Salvador S. A. de C. V.	Public Lighting Company of San Salvador Inc.
CASSA	Compañía Azucarera Salvadoreña S.A	El Salvador Sugar Company
CCAD	Comisión Centroamericana de Ambiente y Desarrollo	Central American Commission for Environment and Development
CDM	Mecanismo de Desarrollo limpio	Clean Developemnt Mechanism
CECSA	Compañía Eléctrica Cucumacayán S.A. de C.V.	Cucumacayán Electric Company Inc
CEL	Comisión Ejecutiva Hidroeléctrica del Río Lempa	Hydroelectric Executive Committee of the Lempa River
CEPAL	Comisión Económica para América Latina y el Caribe	Economic Commission of Latin America and Caribbean
CIDA		Canadian International Development Agency
CLESA	Compañía de Alumbrado Eléctrico de Santa Ana	Electric Lighting Company of Santa Ana
CNE	Consejo Nacional de Energía	National Energy Commision
CNR	Centro Nacional de Registros	National Registration Center
CRS	Los sistemas centrales de receptor	Central Receiver Systems
CSP	Energía solar por concentración	Concentrating Solar Power
DEE	Dirección de Energía Eléctrica	Office of Electricity Energy
DELSUR	Distribuidora de Electricidad del Sur, S.A. de C.V.,	Distributor of electricity of South Variable Capital Company
EE	Energía Eólica	Wind Energy
EG	Energía Geotérmica	Geothermal Energy

Abbreviation	Spanish	English
EIA	Evaluación de Impacto Ambiental	Environmental Impact Assessment
ENEL	Ente Nazionale per l'Energia eLettrica	Ente Nazionale per l'Energia eLettrica
ER	Energía Renovable	Renewable Energy
EsIA	Estudio de Impacto Ambiental	Environmental Impact Study
ETESAL	Empresa Transmisora de El Salvador S.A. de C.V.	El Salvador Transmission Company
F/S	Estudio de factibilidad	Feasibility Study
FA	Formulario Ambiental	Environmental Form
FINET	Fondo de Inversión Nacional en Electricidad y Telefonía	National Investment Fund for Electricity and Telephone
GDP (PIB)	Producto Interno Bruto	Gross Domestic Product
GEF	Fondo para el Medio Ambiente Mundial	Global Environment Facility
GEL	Ley General de Electricidad (LGE)	General Electricity Law (GEL)
GHG	Gases de efecto invernadero	Green House Gas
GIS (SIG)	Sistema de Información geográfica (SIG)	Geographical Information System
GIZ	Cooperación Alemana para el Desarrollo	German Society for International Cooperation (Deutsche Gesellschaft für Internationale Zusammenarbeit)
GW	Gigawatts (=1,000,000 kW)	gigawatt (=1,000,000 kW)
GWh	Gigawatts hora	gigawatt hour
HHV		Higher Heating Value
IDB (BID)	Banco Interamericano de Desarrollo	Inter-American Development Bank
IEA		International Energy Agency
INE	Inversiones Energéticas S. A.	Energy Investment
IRR	Tasa Interna de Retorno (TIR)	Internal Rate of Return
KfW	Reconstrucción Instituto de Crédito	Kreditanstalt für Wiederaufbau (Reconstruction Credit Institute)
kW	Kilowatt	kilowatt
kWh	Kilowatt hora	kilowatt hour
LaGeo	La Geotérmica	
LFG		Landfill Biogas
LMA	Ley del Medio Ambiente	Environmental Law
MARN	Ministerio de Medio Ambiente y Recursos Naturales	Ministry of Environment and Natural Resources

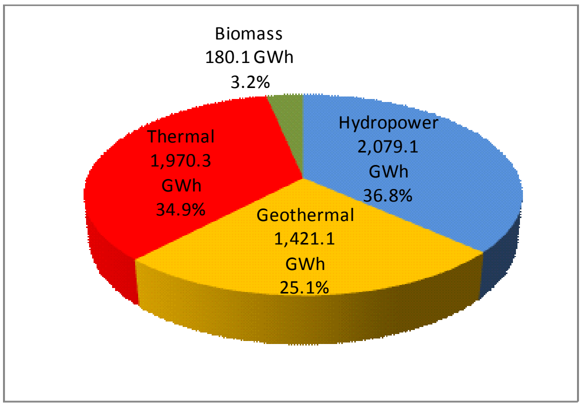
Abbreviation	Spanish	English
MINEC	Ministerio de Economía	Ministery of Economy
MRS	Mercado Regulador del Sistema	Market System Controller
MW	Megawatts (=1,000 kW)	megawatt (=1,000 kW)
MWh	Megawatts hora	megawatt hour
NEC	Código Eléctrico Nacional	National Electric Code
NFPA		National Fire Protection Association
NGO	Organización no gubernamental	Non-Governmental Organization
NPV	Valor Actual Neto (VAN)	Net Present Value
NREL	Laboratorio Nacional de Energías Renovables en EE.UU.	National Renewable Energy Laboratory in US
NRV	Valor Nuevo de Re-emplazo (VNR)	New Replacement Value (NRV)
OCAD	Cooperación Austriaca para el Desarrollo	Austrian Development Cooperation (ADC)
OPAMSS	Office of Planning for San Salvador Metropolitan Area	Oficina de Planificación del Área Metropolitana de San Salvador
PCH (SHP)	Pequeñas Centrales Hidroeléctricas (PCH)	Small Hydropower (SHP)
PMA	Programa de Manejo Ambiental	Environmental Management Program
PMASISO	Programa de Manejo Ambiental y Seguridad Industrial y Salud Ocupacional	Environmental Management and Industrial Safety and Occupational Health Program
Pre-F/S	Estudio de Pre-factibilidad	Pre-Feasibility Study
PSFV	Paneles Solares Fotovoltaicos	Solar Photovoltaic Panel
RPS	Energías Renovables Portfolio Standard	Renewables Portfolio Standard
SABES	Asociación Saneamiento Básico, Educación Sanitaria y Energías Renovables (ONG)	Sanitation, Health Education and Renewable Energy Association (NGO)
SHS	Sistemas Solares Domésticos	Solar Home System
SIA	Sistema de Información Ambiental	Environment Information System
SICA	Sistema de Integración Centroamericana	Central American Integration System
SIGET	Superintendencia General de Electricidad y Telecomunicaciones	General Superintendency of Electricity and Telecommunications

Abbreviation	Spanish	English
SINAMA	Sistema Nacional de Gestión Ambiental	National Environmental Management System
SNET	Servicio Nacional de Estudios Territoriales	National Service of Territorial Studies
ST	Solar Térmica	Solar Thermal
SWERA	Evaluación de Recursos de Energía Eólica y Solar	Solar and Wind Energy Resource Assessment
TOR	Términos de referencia	Terms of Reference
UCA	Universidad Centroamericana "José Simeón Cañas"	Central American University "José Simeón Cañas"
UNDP (PNUD)	Programas de las Naciones Unidas para el Desarrollo	United Nations Development Programme
UNEP	Programa de las Naciones Unidas para el Medio Ambiente	United Nations Environmental Programme
US DOE	Estados Unidos Departamento de Energía	United States Department of Energy
USGS	Centro geológico de los Estados Unidos	United States Geological Survey
USTDA		United States Trade and Development Agency
UT	Unidad de Transacciones, S.A.	Transactions Unit
WGC	Congreso geotérmico Mundial	World Geothermal Congress

Chapter 1 Introduction

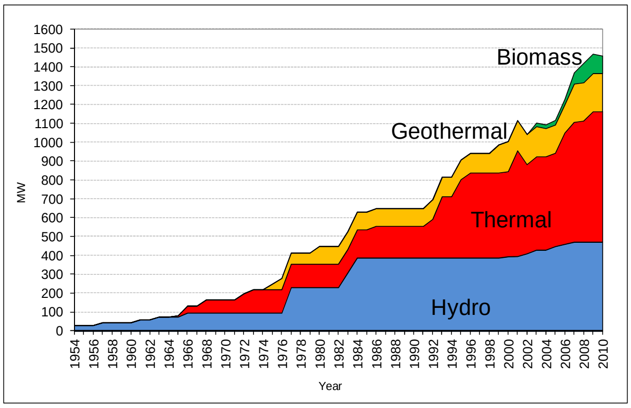
1.1 Background Information

According to a study performed by Consejo Nacional de Energía (CNE), the electricity demand in El Salvador is expected to increase at an average rate of 4.7% per year towards 2026[1]. In 2010, the total power generated was 5,650.6 GWh, which consists of the following: hydropower at 2,079.1 GWh (36.8%), thermal power at 1,970.3 GWh (34.9%), geothermal power at 1,421.1 GWh (25.5%), and biomass at 180.1 GWh (3.2%)[2] as show in Figure 1.1.1. Although the percentage of generation with renewable energy sources (currently composed by hydropower, geothermal and biomass) is higher than the rate of generation with thermal energy sources, the dependency on thermal power generation has been increasing every year. By comparing the installed capacities by energy source, the dependency on thermal power is more significant, as show in figure 1.1.2



(Source: Data from Electrical Statistics Bulletin No 12 (SIGET, 2010))

Figure 1.1.1 Power Generation by Source (2010)



(Source: Data from Electrical Statistics Bulletin No12, (SIGET, 2010))

Figure 1.1.2 Change of Installed Capacity by Type

In El Salvador, 100% of fossil fuel is imported. Due to the energy crisis caused by the accelerated rise in fossil fuel prices, the expansion of renewable energy introduction has become much more important. This approach matches the global trend of importance on the reduction of greenhouse gas (GHG) emissions. On the other hand, after liberalization of the power market in 1999 through separation of generation and transmission, the ratio of fossil fuel use has increased. In spite of government efforts to introduce renewable energy sources by state-owned or private power producers, the ratio of renewable energy introduction is still limited.

One of the reasons for this limited rate of renewable energy sources is the lack of a master plan on the introduction of this type of energy. The high rate of energy generation from fossil fuels is achieved due to its less initial investment cost and at the same time because it offers and stable income for independent power producers (IPPs).

[1] Final Report – Indicative Plan for Power Generation Expansion in El Salvador 2012 – 2026 (CNE, 2011)
[2] Electric Statistical Bulletin N° 12 (SIGET, 2010)

Under such circumstances, the Legislative Assembly approved the creation of the National Energy Council (Consejo Nacional de Energía; CNE for its acronym in Spanish) in 2007 as a normative and regulatory institution to develop policies and strategies for the social and economic development by the promotion of the production and rational use of energy sources. In the National Energy Policy announced in June 2010, the following six points are positioned as the most important:

(1) Diversification of energy sources through the expansion of renewable energy sources

(2) Strengthening of institutional arrangement of the energy sector for the protection of users

(3) Promotion of energy savings and facilitation of incentives toward the introduction of energy saving technologies

(4) Expanded coverage of electricity access and more economical rates

(5) Innovation and technological development

(6) Regional energy integration

In view of the promotion of renewable energy introduction by both public and private sectors, a request was made from the Government of El Salvador to the Government of Japan. Such request is on the project for formulation of the renewable energy master plan in El Salvador, which includes confirmation of potentials on each renewable energy source, and preparation of guidelines required for the promotion of renewable energy introduction.

In reply to the request, the Japan International Cooperation Agency (JICA) conducted a detailed planning survey in March 2010 to confirm the appropriateness of implementation of the development study type technical cooperation. This study is conducted based on the scope of works (S/W) and minutes of meeting (M/M) concluded between CNE and JICA in July 2011.

1.2 Objectives of the Study

The objective of the study is to formulate a master plan on renewable energy for power generation use in El Salvador for 15 years, from 2012 to 2027.

In addition, for the promotion of renewable energy introduction in El Salvador, workshops will be organized to introduce technologies, institutional arrangements, and promotion measures of renewable energy in Japan for information sharing and transfer to related organizations.

1.3 Counterpart Agency

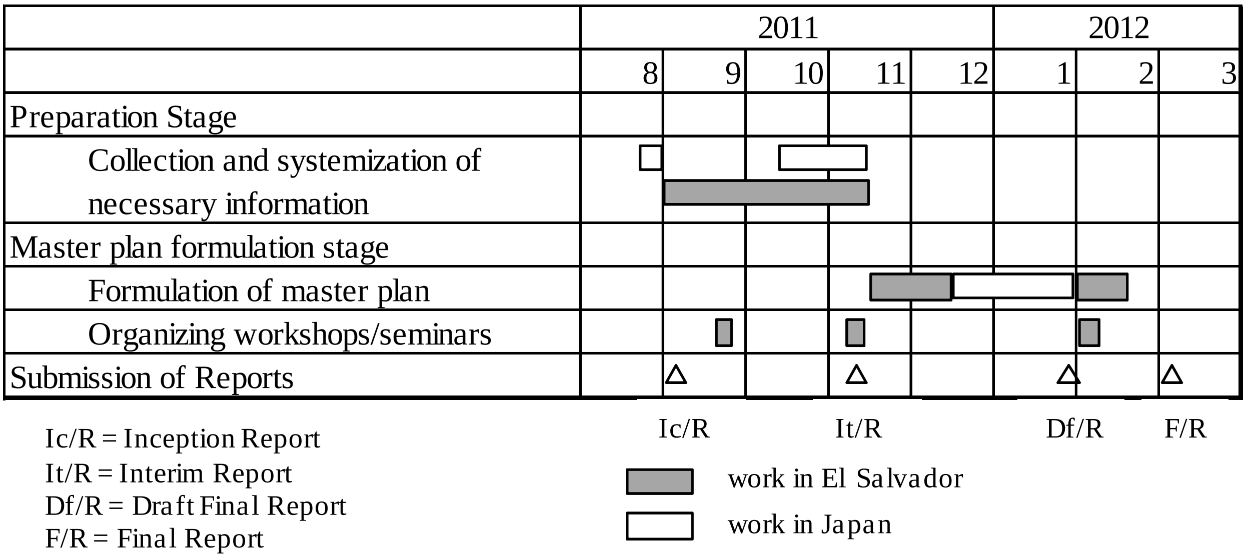
CNE shall act as the counterpart agency to the JICA Study Team.

1.4 Study Area

The study area is the entire territory of El Salvador. Security information should be confirmed by both CNE and JICA prior to the site visit.

1.5 Schedule of the Study

The study period is from the end of August 2011 until the beginning of March 2012, which is for about seven months. Figure 1.5.1 shows the overall schedule of the study.



(Source: JICA Study Team)

Figure 1.5.1 Overall Schedule of the Study

Chapter 2 Power Sector Overview and Roles of Renewable Energy

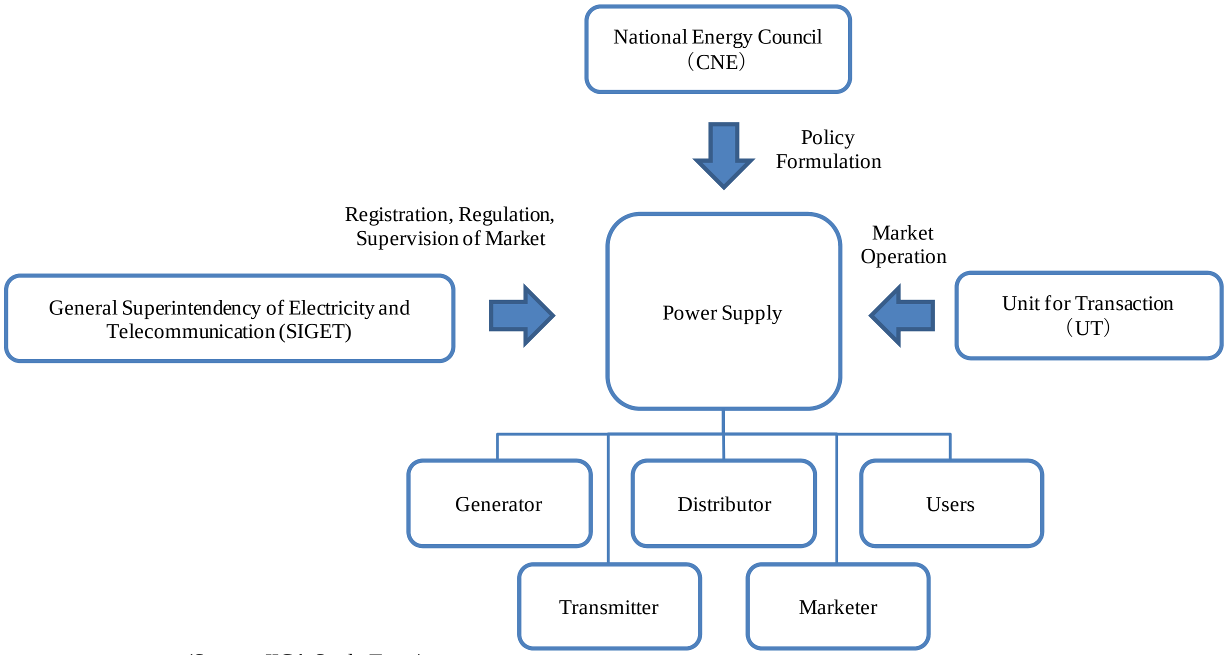
2.1 Power Sector Overview

2.1.1 Power Supply System

2.1.1.1 Power Supply System

The power supply system of El Salvador was changed from that being supplied by a single national power company (Comisión Hidroeléctrica del Río Lempa: CEL) to the new system of the wholesale electricity market, where power supply roles were divided into subsectors of generation, transmission, distribution and marketing.

The roles of the government and private sectors in terms of the wholesale market are as shown in Figure 2.1.1.



(Source: JICA Study Team)

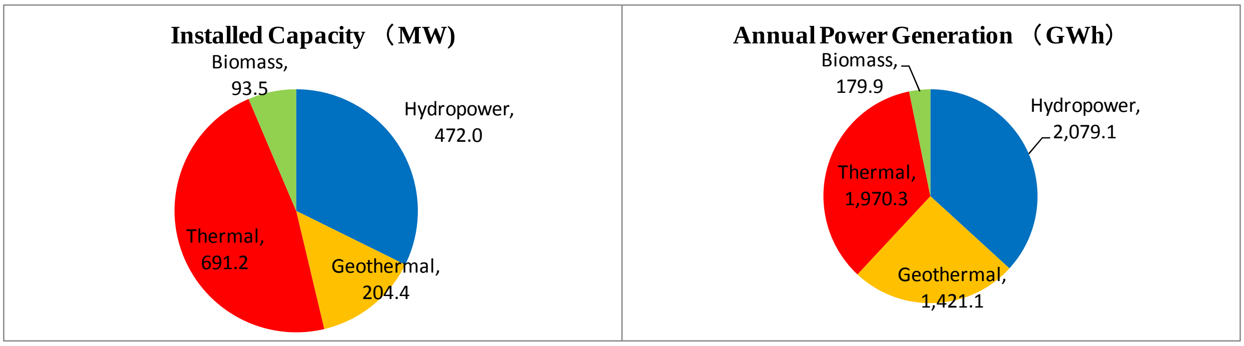
Figure 2.1.1 Roles of the Government and Private Sectors in the Wholesale Market

2.1.1.2 Installed Capacity and Power Generation

According to the statistical bulletin of SIGET (2010), the amount of generated electricity injected to the wholesale electricity market in 2010 was 5,650.4 GWh. The installed capacity and power generation amount by energy source are as follows:

- Hydropower: four locations, installed capacity of 472.0 MW (32.3%), generation of 2,079.1 GWh (36.8%)
- Geothermal: two locations, installed capacity of 204.4 MW (14.0%), generation of 1,421.1 GWh (25.1%)

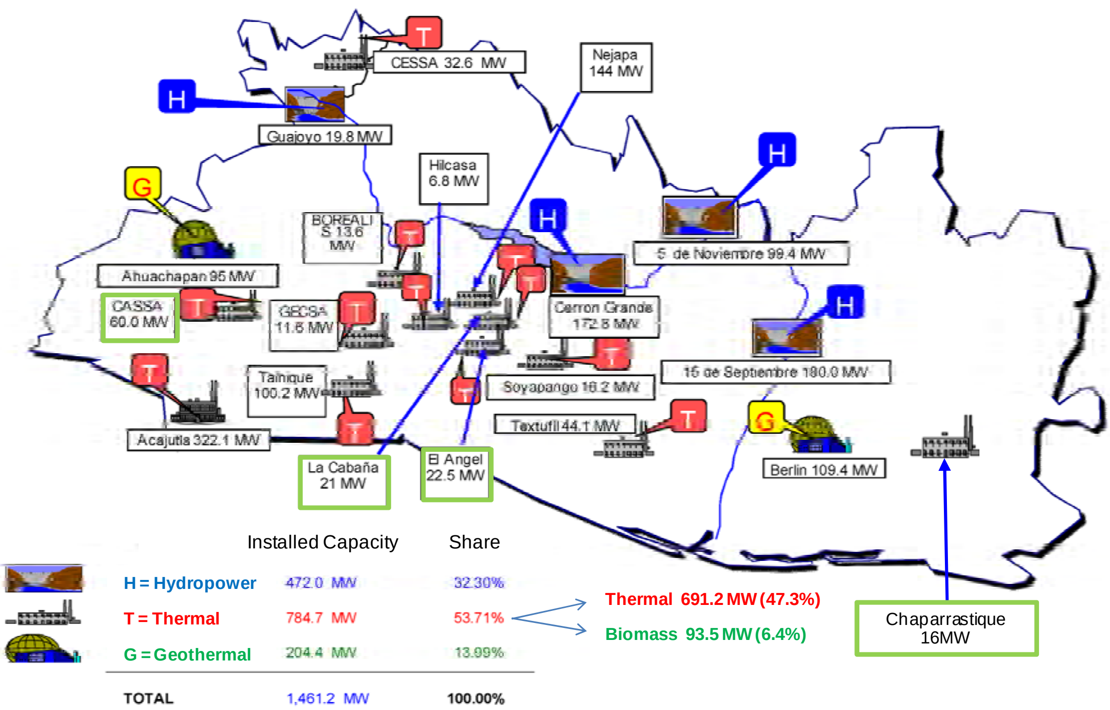
- Thermal: nine locations, installed capacity of 691.2 MW (47.3%), generation of 1,970.3 GWh (34.9%)
- Biomass: three locations, installed capacity of 93.5 MW (6.4%), generation of 179.9 GWh (3.2%)



(Source: SIGET Statistical Bulletin 2010)

Figure 2.1.2 Installed Capacity and Annual Power Generation (2010)

Figure 2.1.3 and Table 2.1.1 shows the approximate locations of power stations presented in the statistical bulletin of SIGET (2010), and their respective installed capacity (MW).



(Source: SIGET Statistic Bulletin 2010)

Figure 2.1.3 Locations of Power Stations in El Salvador and Their Installed Capacity

Table 2.1.1 Type, Installed Capacity and Effective Capacity of Power Stations in El Salvador

No.	Name of Power Station	Number of Units	Installed Capacity (MW)	%	Effective Capacity (MW)	%
	Hydropower		**472.0**	**32.3%**	**472.0**	**34.0%**
1	Guajoyo	(1x19.8)	19.8	1.36	19.8	1.43
2	Cerrón Grande	(2x86.4)	172.8	11.83	172.8	12.44
3	5 de Noviembre	(3x20)+(1x18.0)+(1x21.40)	99.4	6.8	99.4	7.15
4	15 de Septiembre	(2x90)	180	12.32	180	12.96
	Geothermal		**204.4**	**14.0%**	**183.8**	**13.2%**
1	Ahuachapán	(2x30.00)+(1x35.00)	95	6.5	80	5.76
2	Berlín	(2x 28.12)+(1x44)+(1x9.2)	109.4	7.49	103.8	7.47
	Thermal		**691.2**	**47.3%**	**657.5**	**47.3%**
1	Duke Energy		338.3	23.2	312.0	22.5
	(a) Acajutla	Steam (1x30.0)+(1x33.0)	63	4.31	61	4.39
		Gas (1x82.1)	82.1	5.62	64	4.61
		Diesel (6x16.5)+(3x17.0)	150	10.27	145	10.44
		Diesel (1x27)	27	1.85	27	1.94
	(b) Soyapango	Diesel (3x5.4)	16.2	1.11	15	1.08
2	Nejapa Power	Diesel (27x5.33)	144	9.86	141	10.15
3	Cemento de El Salvador	Diesel (3x6.40)+(2x6.70)	32.6	2.23	32.6	2.35
4	Inversiones Energéticas	Diesel (3x16.5) + (6x8.45)	100.2	6.9	100.2	7.2
5	Textufil	Diesel (2x3.6)+(2x7.05)+(1x7.38)+(2x7.72)	44.1	3.0	40.5	2.9
6	GECSA	Diesel (3x3.8704)	11.6	0.8	11.0	0.8
7	Energía Borealis	Diesel (8x1.7)	13.6	0.9	13.4	1.0
8	HILCASA Energy	Diesel (4x1.7)	6.8	0.5	6.8	0.5
	Biomass					
			93.5	**6.4%**	**76.0**	**5.5%**
1	CASSA	(1x25)+(1x20)+(2x7.5)	50.0	3.4	45.0	3.2
2	Ingenio El Angel	(1x10)+(1x12.5)	22.5	1.5	13.0	0.9
3	Ingenio La Cabaña	(1x1.5)+(1x2)+(1x7.5)+(1x10)	21.0	1.4	18.0	1.3
	Total		**1,461.1**	**100.0%**	**1,389.3**	**100.0%**

(Source: SIGET Statistic Bulletin 2010)

Four hydropower stations are owned by the state-owned company CEL. The other power stations utilizing renewable energy sources such as geothermal, thermal and biomass are owned by private companies.

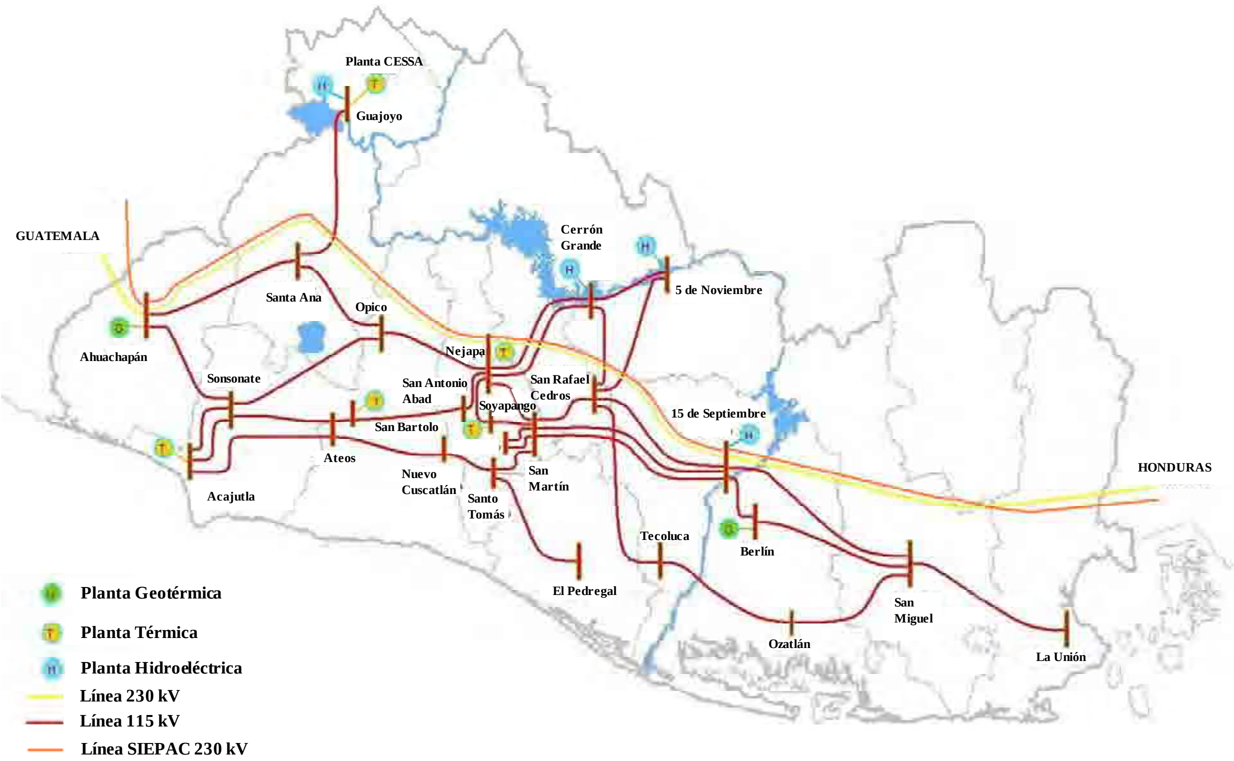
2.1.1.3 Transmission and Distribution Facilities

Figure 2.1.4 shows the transmission networks of El Salvador. The transmission netowrks are composed of domestic high voltage transmission lines (115 kV), and international (interregional) transmission lines (230 kV). Only one transmission company, the El Salvador Transmission Company (ETESAL), is in charge of maintenance of the transmission networks.

Eight companies are in charge of distribution of electricity, mainly by regions, as listed below:

(1) CAESS, (2) AES-CLESSA, (3) AES-EEO, (4) AES-DEUSEM, (5) DELSUR, (6) EDESAL,
(7) B&D, and (8) Abruzzo.

Of the above, (1) to (4) are group companies of AES, which is renowned worldwide. Table 2.1.2 shows the list of companies along with their respective number of customers, and share of sales. Figure 2.1.5 shows the areas where these companies provide their services. The sales share of the AES group companies are more than 70%. Among (5) to (7), the most share of sales is from DELSUR.



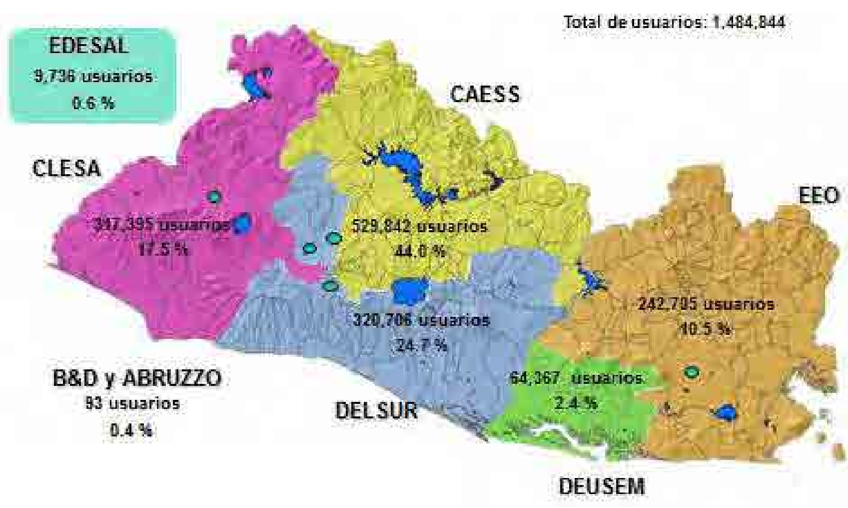
(Source: SIGET, CNE)

Figure 2.1.4 Locations of Power Stations and Layout of Transmission Lines

Table 2.1.2 Number of Customers and Sales Share of Distribution Companies

No.	Distribution Company	Number of Customers	Share against Total Sales	Remarks
1	CAESS	529,842	44.0	AES Group Company
2	AES-CLESSA	317,395	17.5	AES Group Company
3	AES-EEO	242,705	10.5	AES Group Company
4	AES-DEUSEM	64,367	2.4	AES Group Company
5	DELSUR	320,706	24.7	
6	EDESAL	9,736	0.6	
7	B&D, Abruzzo	93	0.4	
	Total	1,484,844	100.0	

(Source: SIGET Statistical Bulletin 2010)



(Source: SIGET Statistical Bulletin 2010)

Figure 2.1.5 Areas of Service for Distribution Companies, Number of Customers and Share

2.1.2 Electricity Tariff

The electricity tariff is revised by SIGET every three months based on actual power generation costs in the wholesale market. The categories of electricity tariff are divided into three based on maximum demand, i.e., small-scale users (less than 10 kW), medium-scale users (10 to 50 kW), and large-scale users (more than 50 kW).

Electricity tariff is calculated according to three categories namely, base tariff, usage charge and distribution charge. There are rates set for each usage step of: 1 to 99 kWh, 100 to 199 kWh, and equal to or more than 200 kWh.

In the case of small-scale users, if the monthly usage is less than 200 kWh, a constant subsidy is provided by the government. Subsidy is paid through the National Investment Fund for Electricity and Telephone (FINET).

2.1.3 Electrification Ratio

The electrification ratio of El Salvador is 96.9% in urban area, 81.5% in provinces area, and 91.6% in total, which is higher ratio among the Central American states. The Government aims for increasing the ratio, and is executing the electrification program by installation of solar PV system in the un-electrified area.

2.2 Roles of Renewable Energy in the Power Sector

2.2.1 Roles of Renewable Energy Sources

From the abovementioned roles in terms of installed capacity and generation amount, the roles of renewable energy can be summarized as follows

A. Hydropower

During the period when water resources are abundant, hydropower is injected to the wholesale market prior to other sources, as its generation cost is the cheapest among others, for supplying low cost energy. However, during the period when water is scarce such as the dry season, deficit is covered by thermal and other sources.

B. Geothermal

Geothermal supplies stable energy throughout the year and covers about one fourth of the total supplied energy. Geothermal is considered as one of the most important energy sources.

C. Biomass

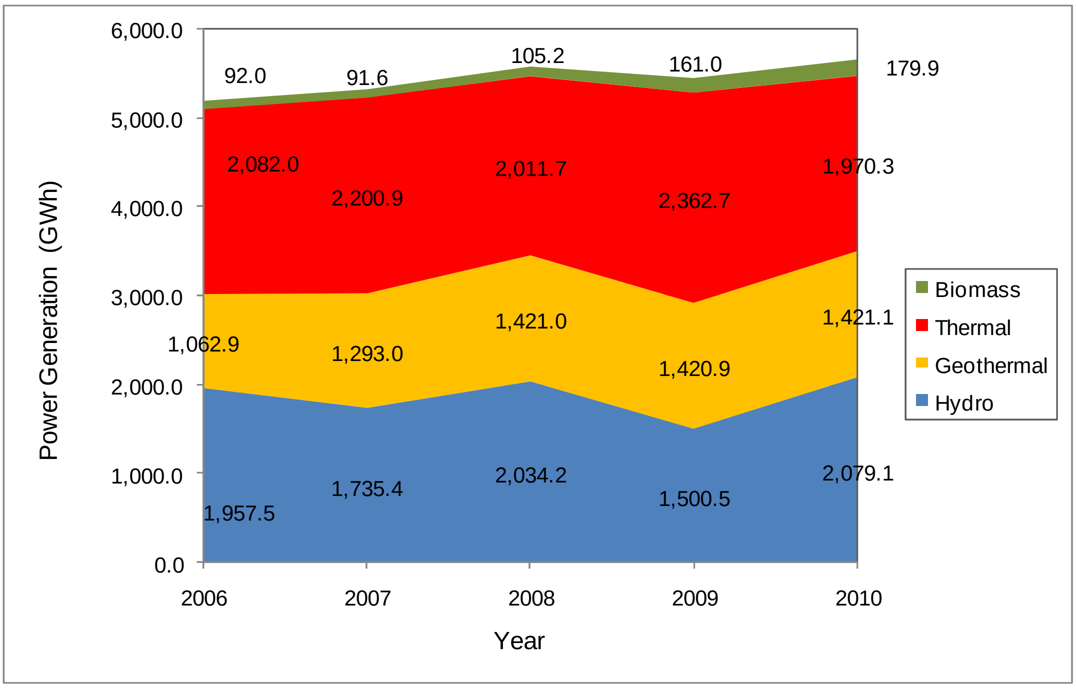
In terms of ratio in installed capacity and power generation, biomass is relatively small. Existing power plants use bagasse for power generation, which is only possible for six months during the sugarcane harvest season from November to April. During such periods, biomass covers the deficit of hydropower although the amount is not that siginficant.

2.2.2 Roles in Annual Power Generation

Figure 2.2.1 and Table 2.2.1 show the transition of annual power generation by energy source, which was injected into the wholesale market during the period from 2006 to 2010. Annual power generation increased at about 1.7% per annum for the past five years. Energy sources consist of the following: hydropower and thermal (30 to 40% each), geothermal (about 25%) and biomass (the rest).

The following characteristics of energy sources were observed:

- Geothermal and biomass supply stable power for base loads
- Hydropower fluctuates to some extent due to hydrological conditions
- Fluctuation of hydropower is compensated by thermal power



(Source: UT Annual Report 2006 to 2010)

Figure 2.2.1 Transition of Annual Power Generation Amount by Energy Source

Table 2.2.1 Transition of Annual Power Generation Amount by Energy Source

	2006	2007	2008	2009	2010
Hydro	1,957.5	1,735.4	2,034.2	1,500.5	2,079.1
Geothermal	1,062.9	1,293.0	1,421.0	1,420.9	1,421.1
Thermal	2,082.0	2,200.9	2,011.7	2,362.7	1,970.3
Biomass	92.0	91.6	105.2	161.0	179.9
Total	5,194.4	5,320.9	5,572.1	5,445.1	5,650.4

(Source: UT Annual Report 2006 to 2010)

2.2.3 Roles in Monthly Power Generation

Tables 2.2.2 and 2.2.3 show the monthly power generation status in 2009 and 2010, respectively. Graphs for the same are as presented in Figures 2.2.2 and 2.2.3.

Table 2.2.2 Monthly Power Generation in 2009

(Unit: GWh)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hydro	102.0	102.2	111.9	106.8	137.2	193.4	166.0	109.5	121.6	111.8	130.5	107.4	1,500.3
Geothermal	129.7	93.4	101.9	107.4	126.7	123.0	129.9	129.6	103.9	116.1	126.9	132.5	1,421.0
Thermal	179.6	174.9	192.5	202.1	188.4	153.0	181.6	218.0	225.4	248.5	192.1	206.6	2,362.7
Biomass	38.1	35.4	37.3	19.6	0.0	0.0	0.0	0.0	0.0	0.0	3.9	26.7	161.0
Total	449.4	405.9	443.6	435.9	452.3	469.4	477.5	457.1	450.9	476.4	453.4	473.2	5,445.0

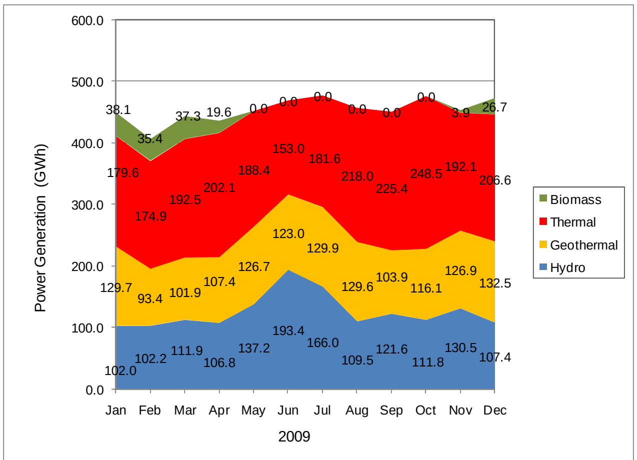
(Source: UT Annual Report 2009)

Table 2.2.3 Monthly Power Generation in 2010

(Unit: GWh)

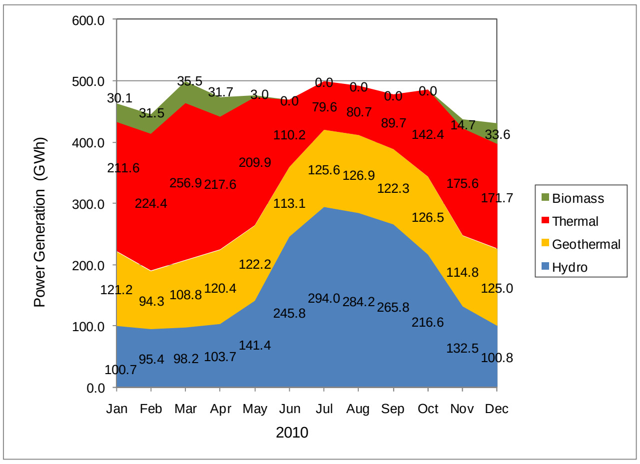
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hydro	100.7	95.4	98.2	103.7	141.4	245.8	294.0	284.2	265.8	216.6	132.5	100.8	2,079.1
Geothermal	121.2	94.3	108.8	120.4	122.2	113.1	125.6	126.9	122.3	126.5	114.8	125.0	1,421.1
Thermal	211.6	224.4	256.9	217.6	209.9	110.2	79.6	80.7	89.7	142.4	175.6	171.7	1,970.3
Biomass	30.1	31.5	35.5	31.7	3.0	0.0	0.0	0.0	0.0	0.0	14.7	33.6	180.1
Total	463.6	445.6	499.4	473.4	476.5	469.1	499.2	491.8	477.8	485.5	437.6	431.1	5,650.6

(Source: UT Annual Report 2010)



(Source: UT Annual Report 2009)

Figure 2.2.2 Monthly Power Generation (2009)



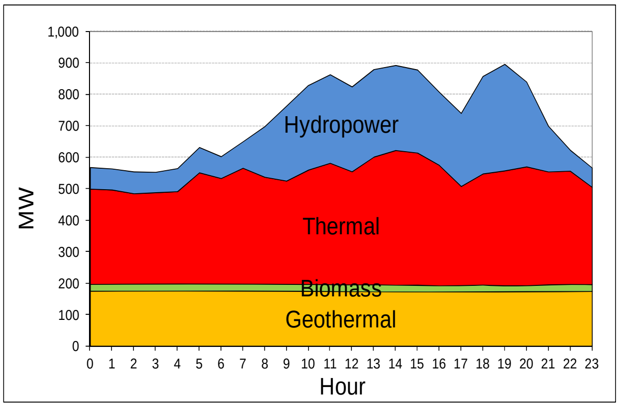
(Source: UT Annual Report 2010)

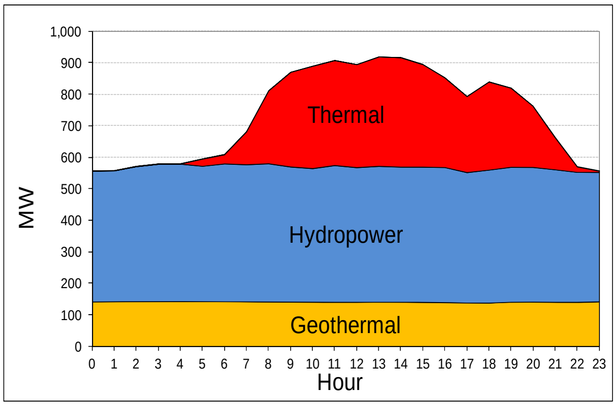
Figure 2.2.3 Monthly Power Generation (2010)

Since the unit generation cost for hydropower is cheaper than thermal, hydropower is brought in to the wholesale market first, while the balance will be covered by thermal power. On the other hand, geothermal sources supply constant power output throughout the year. Biomass is brought in only during the period from November to April, which is the harvest season for sugarcane.

2.2.4 Daily Load Curves

Figure 2.2.4 shows the typical daily load curves (weekdays) in the dry and rainy seasons of 2011. The shape of daily load curves are similar. The two peaks are that of daytime (10 am to 3 pm), and evening (7 pm to 8 pm). In the rainy season (October), geothermal and hydropower supply base loads of about 550 MW, and increased amount at peak hours is supplied by thermal power. In the dry season (March), geothermal, thermal and biomass provide base loads. Due to the decrease of river discharge, power output from hydropower also decreases; however, reservoir type hydropower stations are operated to satisfy peak demands. Since biomass power stations use bagasse, generation is limited to the period from November to April. No power is generated for the other periods.





(Source: Injections and Exports Report, Transaction Unit, 2011)

(a) Daily Load Curve in the Dry Season March 8, 2011 (Tuesday)

(b) Daily Load Curve in the Rainy Season October 4, 2011 (Tuesday)

Figure 2.2.4 Daily Load Curves and Ratio of Injection by Source

Chapter 3 Related Laws and Regulations

3.1 Laws and Regulations and Organizations Related to the Environment

3.1.1 Laws and Regulations

The laws and regulations related to the environment of El Salvador must be taken into account in developing renewable energy projects. Under the Constitution of the Republic, the Environmental Law establishes the legal framework such as policies, procedures and institutions. The legislative regulations related to environmental and social considerations are shown in Table 3.1.1 below.

Table 3.1.1 Legislation Related to Environmental and Social Considerations

Legislation	Function
<Environment Issues>	
Constitution of the Republic of El Salvador	- Prescribe environmental and social issues in a general manner (Articles 36, 60, 65, 69, 101, 102, 113 and 117). - Recognizes property as an inviolable right and establishes the cases in which a person can be deprived of property due to a legally proven matter of public interest and upon fair indemnification.
Environmental Law	- Prescribe environmental and social issues. - Articles. 16-27 and 29 refer to everything related to environmental impact assessment (EIA); Articles 62-65 are about the use of natural resources; and Article 86 contemplates all those actions considered as environmental infringements, etc.
General Regulations of the Environmental Law	- Prescribe that MARN is responsible for preparing the terms of reference (TOR); according to the magnitude of the activities, works or projects, the head officer must prepare the environmental impact evaluation, EIA, or not. Articles 12, 20 and 32 are on public consultation; Article 22 is on environmental classification; Article 19 is on the environmental evaluation process; Article 21 is on environmental form; Articles 23-28 are on contents of EIA and its components; and Articles 34-39 on environmental permits, finances and audit.
Project Categorization According to the Environmental Law	- Present criteria to environmentally categorize projects under Articles 21, 22, etc.
Irrigation and Drainage Law	- Prescribe the use of water, soil, flora and fauna, mineral and energy resources, environmental sanitation and natural resources.
Municipal Ordinances and Code	- All ordinances issued by the municipality: environmental management ordinances, ordinances about specific taxes for the activity to be carried out, etc. - Prescribes the territorial planning of the municipality, covering forests, water, soil, flora and fauna, mineral and energy resources and environmental sanitation.
Penal Code	- Establish the corresponding penalties for infringements to environmental legislation
<Pollution and Residues>	
Special Regulations of Technical Standards for Environmental Quality	- Establishes the standards for environmental quality, noise control, contaminated odor control, water quality, soil quality and final disposals. Article 6 limits on dumping and emissions, Article 19 is on water quality of receiving media; and Articles 20 and 21 are on waters.
Special Regulations on Residual Waters	- Ensure that residual waters do not alter the quality of receiving media in order to contribute to the recovery, protection and sustainable use of hydric resource with respect to the effects of pollution.
Regulations on Water Quality, Dumping Control and Protection Zones	- Prescribe the discharges of solid, liquid or gaseous residues into different aquatic media; sanitary sewers and treatment facilities cannot be implemented without prior authorization of competent authority.
NSO 13.11.01:01 Mandatory Salvadorian Standards for Environmental Air Quality.	- Prescribe the standards in establishing emission limits of air pollutants, which ensure that the quality of air is acceptable to health and human life in particular and for wildlife in general. (Official Gazette 156 Vol. 360 of 26/08/2003)

Legislation	Function
Atmospheric Emissions	
NSO 13.49.01:09 Mandatory Salvadorian Standards for Water. Residual Waters Discharged Into a Receiving Body.	- Prescribe the standards in establishing the characteristics and allowable physical-chemical, microbiological and radioactive values that residual water must show in order to protect and rescue the receiving bodies. (Official Gazette 48 Vol. 382 of 11/03/2009)
“ANDA” Law	- Have the preference of using any body of water or other assets of national or private property that are considered necessary for the supply of discharge water of sanitary sewers, over any rights that with the same purpose natural or legal persons, and official or semi-official organizations had or claimed to have.
Civil Code	- Prescribe water discharges.
Special Regulations on Matters of Hazardous Substances, Residues and Waste	- Prescribe the Environmental Law with respect to activities related to hazardous substances, residues and wastes.
Special Regulations on the Comprehensive Management of Solid Waste	- Prescribe the management of solid waste. The scope will be the management of solid waste from residential, commercial, services or institutional origins, either from the cleaning of public areas, or industrial areas similar to residential areas, and of non-hazardous sanitary solids.
<Nature Conservation and Forest>	
Natural Protected Areas Law	- Prescribe the establishment, management, handling and increase of natural protected areas to preserve biodiversity.
Forest Law and Its Regulations	- Establish the provisions that allow the increase, management and use in a sustainable manner of forest resources: Article 23 on restricted-use areas, Article 21 on regulations for transportation-storage of forest products and extraction of vegetation.
Official List of Wildlife Species that are Threatened or Endangered, and IUCN-2010 Red List of Threatened and Endangered Species	- Protect the status of endangered and threatened species, etc. (Official list of MARN 2009. Official Gazette No. 103, Vol. 383 of June 5, 2009)
Wildlife Conservation Law	- Establishes protection of all species that are part of the country’s biological diversity.
<Urban Development and Land Use>	
Urban Planning and Construction Law and Its Regulations	- Prescribe and control urban development, requesting environmental permits or compliance with environmental procedures. - Establish the need for implementation of collective resettlements.
Law for the Expropriation and Occupation of Property by the State	- Prescribe the expropriation and occupation of property due to public interest motives.
Special Law for the Protection of the Cultural Heritage of El Salvador and Its Regulations	- Establish the need for conservation of Salvadorian cultural heritage, as well as the procedure for obtaining a license for a project in case of archaeological findings in the project area. This procedure must be channeled through the Secretariat of Culture.
Law of Agrarian Reform	- It describes the Law of Agrarian Reform as the transformation of the agricultural structure in the country, through the incorporation of the rural population to the economic, social and political development of the nation and the equitable distribution of land with the system of ownership, tenure and exploitation enabling an appropriate organization for credits and assistance to producers. Agrarian reform is national application and affects all properties by nature, adherence and destination of agricultural, livestock and forestry use. The ISTA (Salvadoran Institute for Agrarian Transformation) is responsible for administering this Act.
<Public Health and Sanitation>	
Sanitation Code	- Rules related to environmental sanitation.
Health Code	- Rules that refer to the adequate disposal of excretions and sewage waters, the elimination of garbage and other waste, the elimination and control of vector insects, rodents, and other harmful animals, as well as food hygiene, sanitation and the good quality of construction in general, work hygiene and safety, the elimination and control of pollutants in drinking water, soil and air, and the elimination and control of environmental risks.

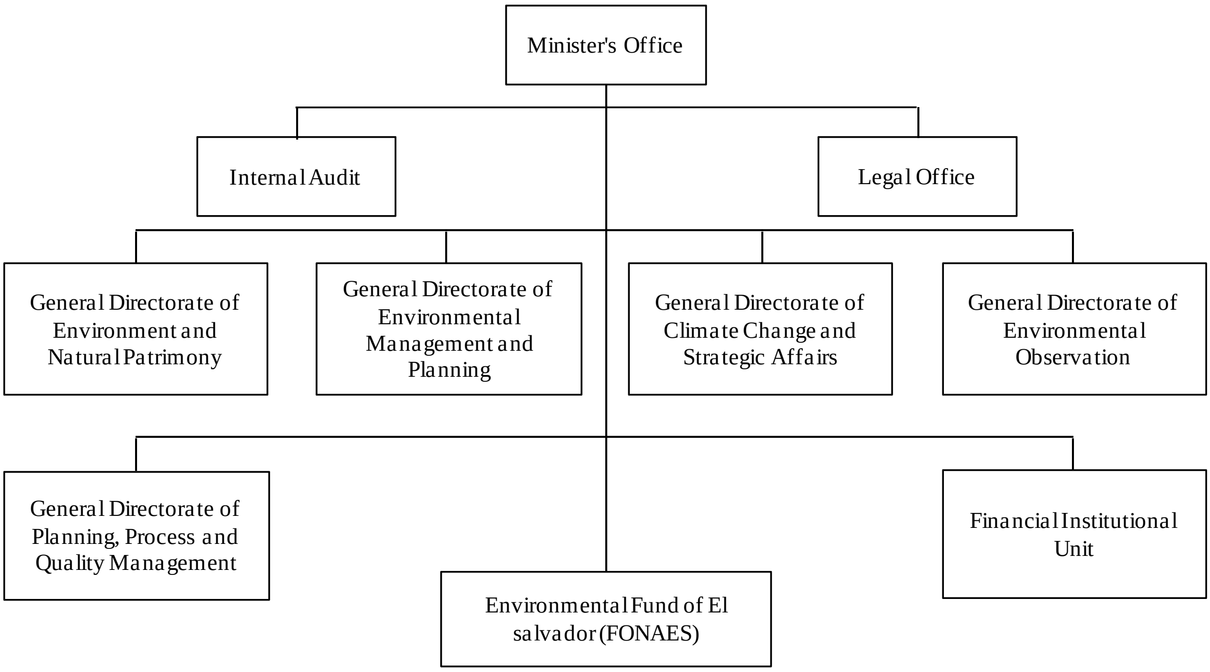
Legislation	Function
<Power and Electricity>	
General Law of Electricity, SIGET	- Prescribes the fundamental issues related to electricity. This law prescribes the activities on generation, transmission, distribution and commercialization of electrical energy. - Article 13 states that an EIA is required to obtain concession previously approved by competent authorities on this matter. Article 106.
Law of the Creation of the National Energy Council, CNE	- Proposes, requests, and contributes with corresponding organizations for the approval of energy strategies that contribute to the country's socioeconomic development in harmony with the environment. (Legislative Decree No. 404, of November 2007) - According the Article 5, the joint directorate is conducted by Ministry of Economy, Ministry of Housing, Ministry of Environment, Ministry of Public Works and Technical Secretary of the President.

(Source: JICA Study Team)

3.1.2 Organizations Related to the Environment

3.1.2.1 Structure of MARN

The structure of MARN is shown in Figure 3.1.1.



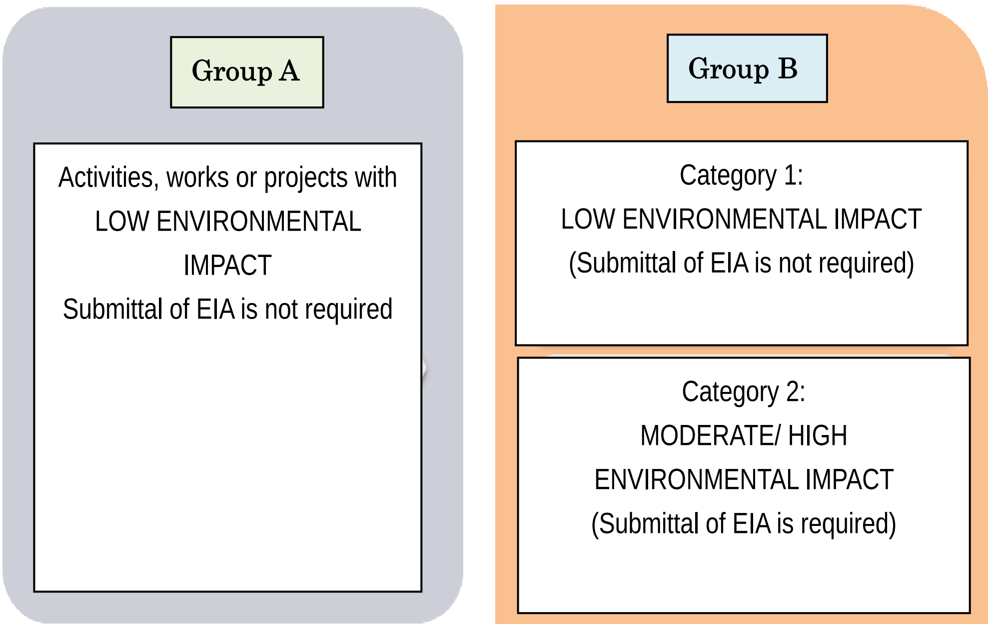
(Source: MARN)

Figure 3.1.1 MARN Organizational Structure

3.2 Procedures on EIA

3.2.1 Project Categorization

This section is based on the instrument of Classification of Activities, works and projects prepared by MARN. The main purpose is to comply with Article 22 of the Environmental Law, which is related to Articles 18, 19, 20, 21 and 24 of the said law. Article 22 of the Environmental Law establishes that MARN will classify the activity, work or project, according to its magnitude and to the nature of the potential impact. With that, the type of environmental documentation that the holder must submit, technically and legally, could be determined. Thus this facilitates the EIA, understood as the process or collection of procedures that allows the state, based on such EIA, to evaluate the environmental impacts that the execution of a specific work, activity or project can cause to the environment. This is also intended to ensure the carrying out and follow-up of environmental measures that can prevent, eliminate, correct, take care of, compensate or enable, as the case may be, such environmental impacts. This instrument divides activities into Group A: *low environmental impact,* which means that the holder of the project *need not* submit environmental documentation; Group B: Category 1: low potential environmental impact, *which does not require the submittal of an EIA;* and Category 2: moderate or high potential environmental impact, *requiring the submittal of EIA.*



(Source: JICA Study Team, based on the General Regulations of the Environmental Law, MARN documents)

Figure 3.2.1 Project Classification According to the Level of Potential Environmental Impact

3.2.2 Environmental Categorization

In El Salvador, an EIA is carried out based on the environmental law and its regulations. As mentioned above, in case the project requires an EIA, the executing agency should implement related activities to obtain environmental permit from MARN. The steps required and the sample case of the durations experienced by LaGeo and CEL in obtaining such permit, are presented in Table 3.2.1.

Table 3.2.1 Steps and Estimated Duration to Obtain Environmental Permit

	Steps to Obtain the Environmental Permit	Responsible Agency	Average Duration Real case LaGeo (days)	Average Duration Real case CEL (days)
1	Submittal of environmental form to MARN	Executive Corporation	30	30
2	Queue time for on-site inspection (MARN)	MARN	50	45
3	Issuance of TOR for EIA	MARN	50	45
4	Preparation of EIA	Executive Corporation	60	60
5	Submittal of EIA to MARN	Executive Corporation	2	2
6	Revision of EIA and notification of comments	MARN	55	50
7	Resolution of comments and remittance to MARN of the resolved comments	Executive Corporation	60	45
8	Notification of format for publication of public consultation	MARN	15	15
9	Request for publication of format of public consultation	Executive Corporation	10	10
10	Prepare and carry out public consultation	Executive Corporation / MARN	12	12
11	Comments on the results of public consultation	MARN	51	51
12	Reply of the ministries related to the comments from public consultation and finishing of EIA report	Project holder	20	20
13	Notification of environmental compliance bond	MARN	10	10
14	Bidding process for the acquisition of environmental compliance bond	Project holder	30	30
15	Submittal of bond to MARN	Project holder	2	2
16	Issuance of environmental permit	MARN	14	15
	Average process time		471	442

(Source: JICA Study Team, LaGeo and CEL)

3.3 Regulations Related to Land Use

3.3.1 Land Use Decree 855

Regulations on land use in El Salvador are provided through the "Law of Territorial Development and Organization of the Metropolitan Area and Surrounding Municipalities in San Salvador[1]" (hereinafter called as "Land Use Decree 855"). Land Use Decree 855 is controlled by Oficina de Planificación del Área Metropolitana de San Salvador (OPAMSS) and applied to the Metropolitan Area of San Salvador and its 14 surrounding municipalities.

For other areas, local governments of each department have relevant divisions in charge of controlling land use. The divisions in charge in the local government refer to Land Use Decree 855 and control such land use by applying the corresponding municipal bylaw in their offices.

3.3.2 Protected Natural Areas

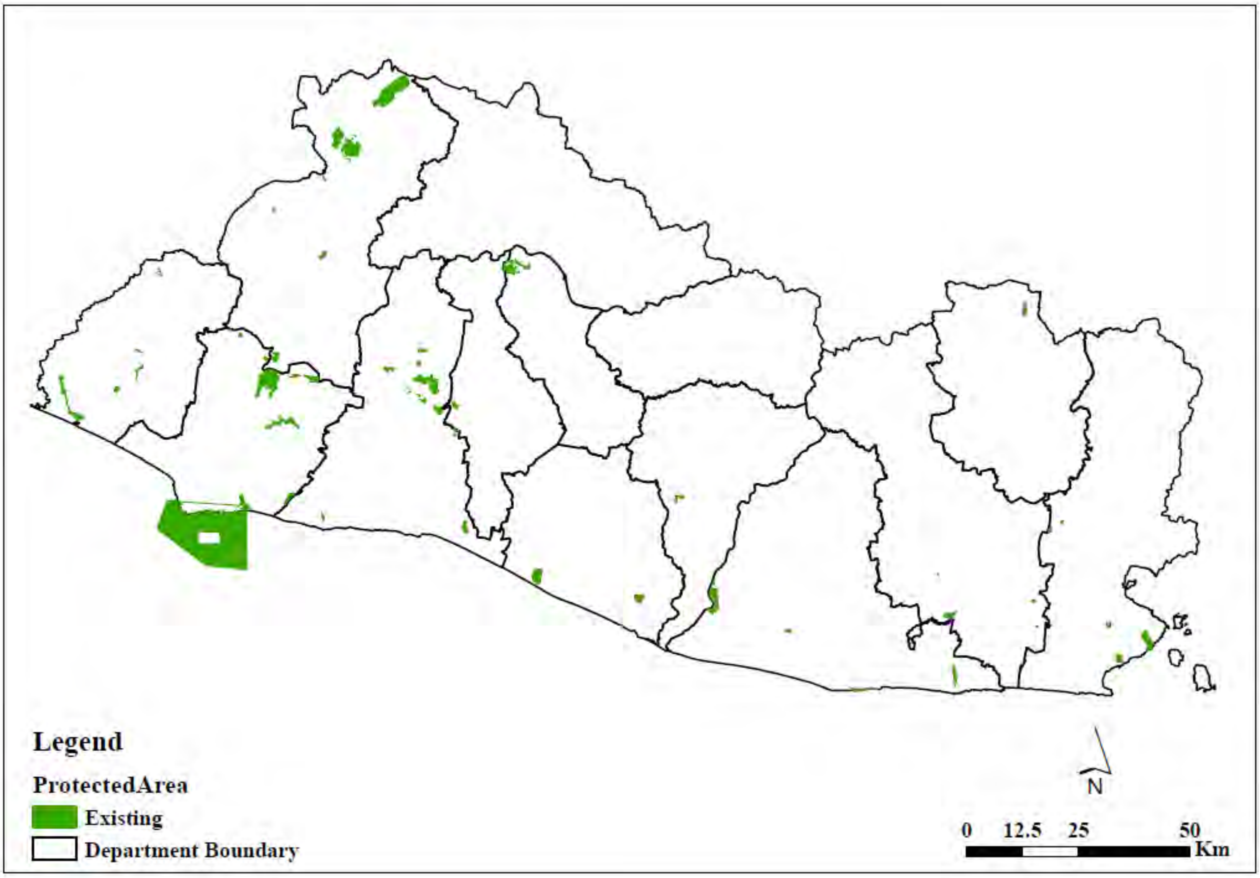
Environmental Law, which was established by Legislative Decree No. 579 on 15 February 2006, in Articles from 78 to 81 and from 85 to 95 refers to the protected natural areas. The following three points

1 Official Gazette No. 18, Volume 322, published on January 26, 1994, revised in 2009 as Decree 855

are emphasized in particular.

- to establish legal system, management system and specification of the target areas related to protected natural areas for conservation of biological diversity,
- to conserve ecosystem in the protected natural areas, and
- to enhance sustainability of ecosystem in the protected natural area with appropriate control.

As of January 2012, the sixty-nine (69) protected natural areas are specified by MARN as shown in the map below.



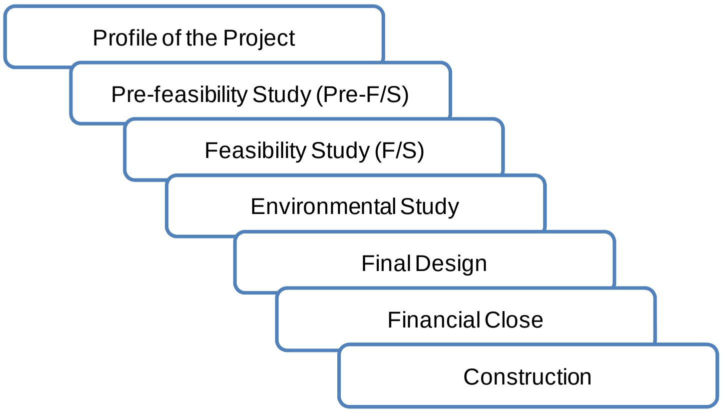
(Source: MARN)

Figure 3.3.1 Locations of Protected Natural Areas

3.4 Regulations Related to Participation of Private Power Developers

3.4.1 Flow of Renewable Energy Development

In case private power developers intend to participate in the electricity market, necessary procedures as shown in Figure 3.4.1 should be followed. The procedures cover profiling of the project, and required studies toward construction of the project.



(Source: JICA Study Team)

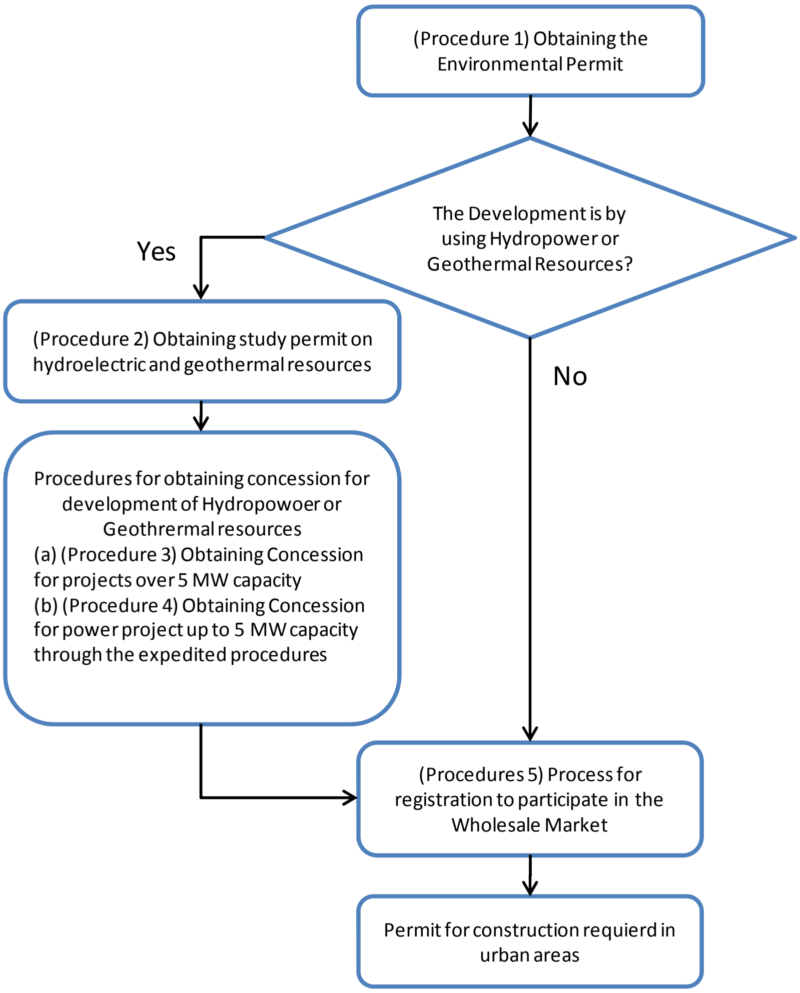
Figure 3.4.1 Flow Chart for Project Implementation

3.4.2 Required Procedures

The required procedures to realize the abovementioned power development by renewable energy can be categorized into five major procedures as follows:

(Procedure 1) Obtaining the environmental permit
(Procedure 2) Obtaining study permit on hydroelectric and geothermal resources
(Procedure 3) Obtaining concession for projects over 5 MW capacity
(Procedure 4) Obtaining concession for power project up to 5 MW capacity through expedited procedures
(Procedures 5) Process for registration to participate in the wholesale market

The five major procedures mentioned above are depicted in Figure 3.4.2 according to the type and size of the development of relevant energy sources.

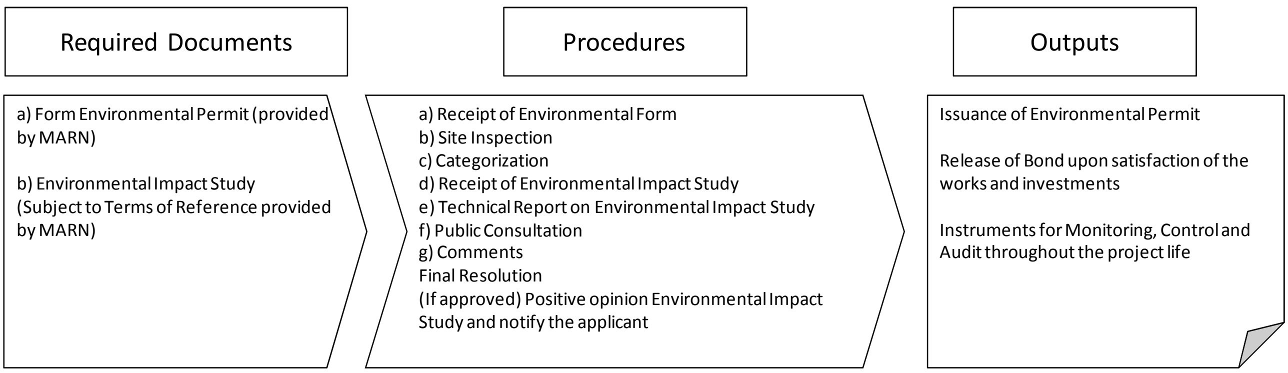


(Source: JICA Study Team)

Figure 3.4.2 Flow Chart for Registration of Power Producers in the Electricity Market

Required procedures such as submission of required documents, flow of procedures and outputs in each step are described below:

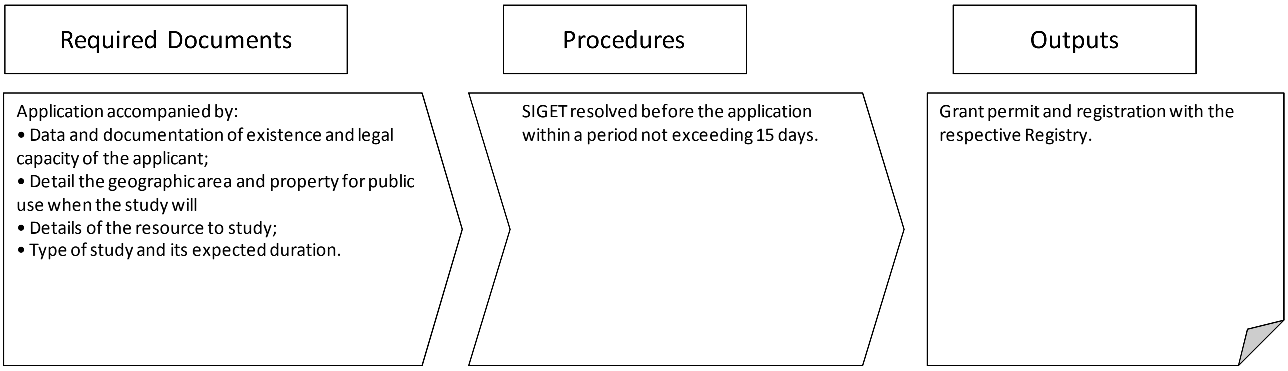
(Procedure 1) Obtaining the environmental permit



(Source: SIGET, ARECA Report)

Figure 3.4.3 Procedures to Obtain an Environmental Permit

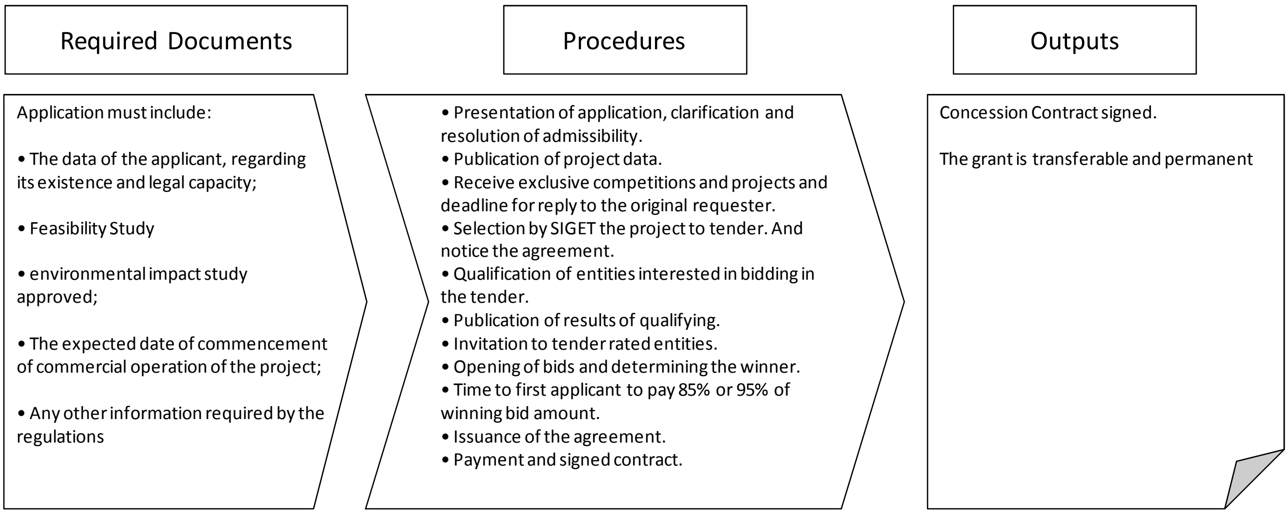
(Procedure 2) Obtaining study permit on hydroelectric and geothermal resources



(Source: SIGET, ARECA Report)

Figure 3.4.4 Procedures to Obtain Study Permit on Hydroelectric and Geothermal Resources

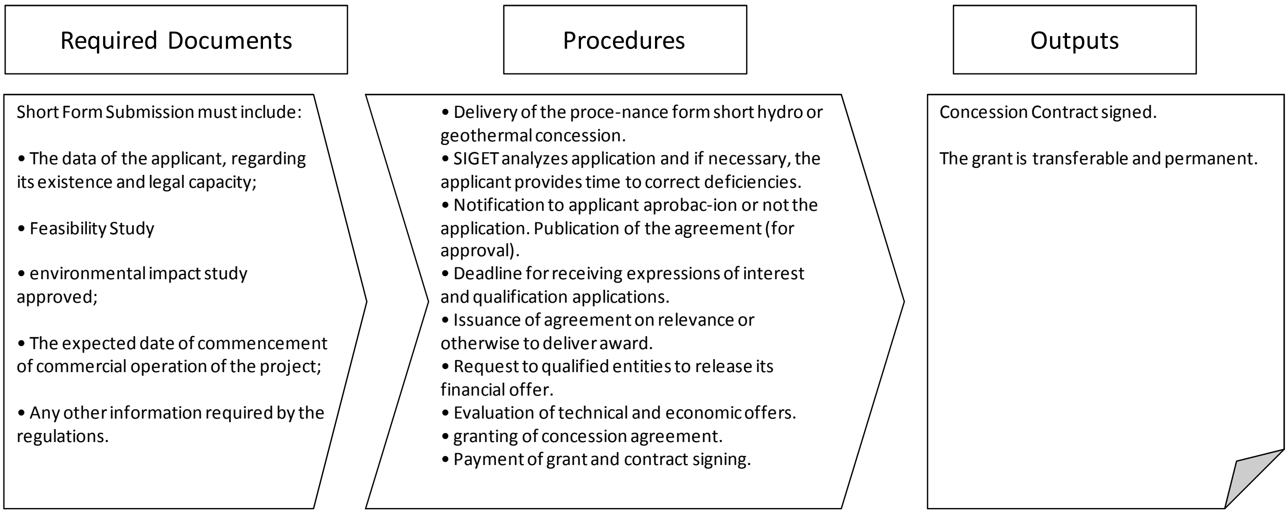
(Procedure 3) Obtaining concession for projects over 5 MW capacity



(Source: SIGET, ARECA Report)

Figure 3.4.5 Procedures to Obtain Concession for Projects Over 5 MW Capacity

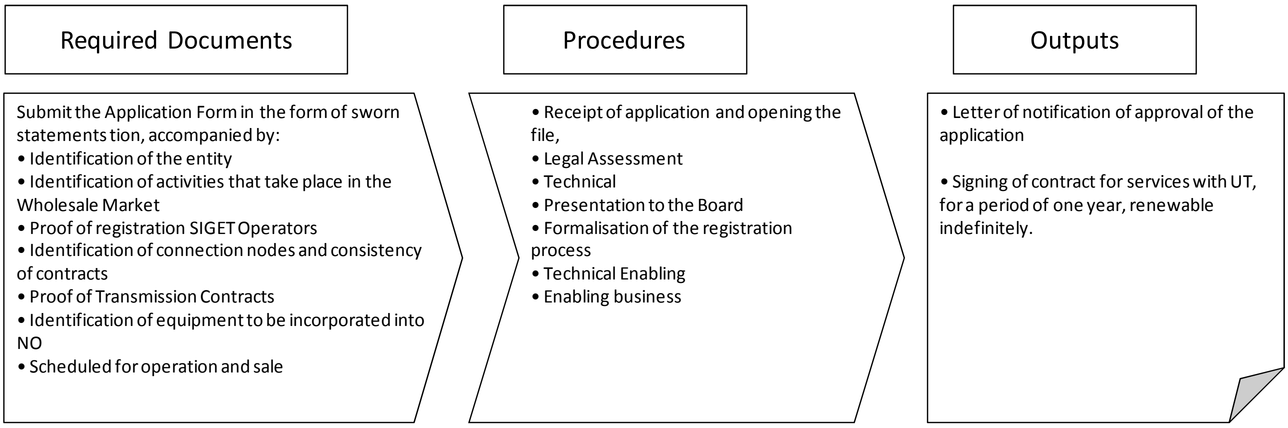
(Procedure 4) Obtaining concession for power project of up to 5 MW capacity through expedited procedures



(Source: SIGET, ARECA Report)

Figure 3.4.6 Procedures to Obtain Concession for Projects of up to 5 MW Capacity Through Expedited Procedures

(Procedures 5) Process for registration to participate in the wholesale market



(Source: SIGET, ARECA Report)

Figure 3.4.7 Procedures for Registration to Participate in the Wholesale Market

3.4.3 The Current Incentives

As the current incentives for renewable energy introduction, there is an incentive measure called as "TAX INCENTIVES ACT TO PROMOTE RENEWABLE ELECTRICITY GENERATION (Decree No. 462)" that took effect in December 2007.

The target activities are: new investment or construction of new power generation plant etc. using renewable energy sources. Tax incentives are applied as exemption of import and income taxes, of which details are described as below:

(Exemption of Import Tax)

(1) During the first ten years applicants shall enjoy exemption from payment of import taxes on machinery, equipment, materials and supplies used exclusively for work in the pre-investment and investment in the construction of the works of power for electricity generation including construction of necessary sub-transmission line to carry power from the generation plant to the transmission and/or power distribution.

(2) The exemption from payment of import taxes shall apply to projects of up to 20 megawatts (MW) and must be requested from the Ministry of Finance 15 days prior to importation of machinery, equipment, materials and supplies needed and used exclusively to develop renewable energy projects, in accordance with project documentation endorsed in the certification issued by the Superintendency of Electricity and Telecommunications (SIGET).

(Exemption of Income Tax)

(1) Exemption from income tax for a period of five (5) years for projects between 10 and 20 megawatts (MW) and ten (10) years for projects of less than 10 megawatts MW in both cases, after the commercial operation of the Project for the fiscal year that earn revenue.

(2) Total exemption from payment of all taxes on income derived directly from the sale of "certified emission reductions" (CERs) under the Clean Development Mechanism (CDM) or similar carbon markets, obtained by qualified projects and beneficiaries.

Chapter 4 Existing and Ongoing Projects Related to Renewable Energy

4.1 Current Status

As of 2010, power stations utilizing renewable energy sources are as listed in Table 4.1.1.

Table 4.1.1 Installed Capacity of Power Stations Utilizing Renewable Energy Sources

Type of Power Station	Installed Capacity (MW)
Hydropower (≥ 20 MW): three locations	452
Small Hydropower Station (< 20 MW): 17 locations (≥ 5MW: one location, < 5MW: 16 locations)	35
Geothermal Power Station: two locations	204
Biomass Power Station: three locations	104
Total	795

(Source: SIGET Bulletin 2010)

The following power stations are connected to the high voltage line (transmission line: 115 kV) in order to sell electricity to the entire market: hydropower stations providing more than or equal to 20 MW (at three locations), small hydropower station providing more than or equal to 5 MW (at one location), and geothermal power stations (at two locations). On the other hand, small hydropower stations providing less than 5 MW (at 16 locations) are connected to the medium voltage line (distribution lines: 46 kV, 23kV or 13.2 kV) in order to sell directly to distribution companies.

The detailed descriptions of each renewable energy source are given in the following sections.

4.2 Small Hydropower Plants

According to a review of previous studies, a total of 12 sites for capacities of over 20 MW and 86 sites for capacities of less than 20 MW were identified for potential hydropower projects.

In El Salvador, the total hydropower potential is 2,235 MW and the potential of small hydropower projects (capacity of less than 20 MW) is 158 MW. According to previous studies, the average annual energy production of potential sites was estimated at 7,624 GWh/year in total and 675 GWh/year for small hydropower plants (capacity of less than 20 MW). Since the estimated annual energy includes calculated values using an assumed plant factor at 50%, further examination is necessary.

4.2.1 Current Status

The existing hydropower stations in El Salvador are shown in Table 4.2.1 and Figure 4.2.1. A total of 20 hydropower plants with a total capacity of 487 MW was installed in 2011; of which 17 are small hydropower plants (capacity of less than 20 MW) with a total capacity of 35 MW.

Table 4.2.1 Existing Hydropower Stations

No.	*Hydropower Station Central Generadora*	*Department Location Departamento Localización*	*Installed Capacity (MW)*	*Annual Energy Inyección (MWh)*	*State / Private Estatal/Privada*
1	Guajoyo	Metapán, Santa Ana	19.80	51,200	State-CEL
2	Cerrón Grande	Chalat./Cuscatlán/Cabañas	172.80	401,000	State-CEL
3	5 de Noviembre	Cabañas/Cuscatlán	99.40	474,100	State-CEL
4	15 de Septiembre	San Vicente/Usulután	180.00	574,100	State-CEL
5	Cucumacayán	Sonsonate	2.30	11,687	State - CECSA
6	Río Sucio	Santa Ana	2.50	8,230	State - CECSA
7	Milingo	San Salvador	0.80	2,639	State - CECSA
8	Bululú	Sonsonate	0.70	3,283	State - CECSA
9	Atehuasías	Ahuachapán	0.60	0	State - CECSA
10	Cutumay Camones	Santa Ana	0.40	672	State - CECSA
11	Sonsonate	Sonsonate	0.20	899	State - CECSA
12	San Luis I	Santa Ana	0.60	3,178	State - CECSA
13	San Luis II	Santa Ana	0.74	0	State - CECSA
14	Sensunapán Nahizalco)	Sonsonate	2.80	17,246	Private - Sensunapán
15	La Calera	La Union	1.50	5,310	Private - De Matheu
16	Papaloate	Sonsonate	2.00	7,306	Private - Papaloate
17	La Chacra	Morazán	0.017	N.D.	Private- SABES
18	Carolina	San Miguel	0.05	N.D.	Private- SABES
19	El Junquillo	Morazán	0.014	N.D.	Private- SABES
20	Miracapa	San Miguel	0.034	N.D.	Private- SABES
		Total	487.255	1,560,849	

(Source: Compile Consultancy on Renewable Energy Studies for their validation, March 2011, GIZ-CNE)
Note: N.D.: No Data

4.2.2 Barriers to Introduction

The following are the barriers to the development of small hydropower stations in El Salvador at present:

A. Lack of subsidy or grant for the study or development of small hydropower stations from the government
B. Lack of hydrological data (number of hydrological stations are limited and the observed periods are short at some stations)
C. Expensive cost of hydrological data from the National Service of Territorial Studies (SNET)
D. Nationwide hydropower potential survey was conducted in 1989 (more than 30 years ago) by the Comisión Ejecutiva Hidroeléctrica del Rio Lempa (CEL) and Universidad Centroamericana "José Simeón Cañas" (UCA). The hydropower potentials, costs and economic values at each potential site must be updated.
E. Limited consultants or engineers for the planning of hydropower in El Salvador
F. Complexity of various procedures and long duration of acquiring a permit from MARN, the General Superintendency of Electricity and Telecommunications (SIGET) and for grid connection, etc.
G. Absence of an environmental categorization for renewable energy projects
H. Lack of incentives for power purchase of renewable energy such as “Renewable Energy Portfolio Standard” (RPS)

4.2.3 Existing and Ongoing Related Studies and Projects

The following hydropower potential studies were conducted to date:

A. “Primer Plan Nacional de desarrollo Energético Integrado 1988-2000”, CEL, Enero 1988
B. “Pequeñas Centrales Hidroeléctricas en El Salvador”, Estudio conjunto CEL-UCA, 1989
C. “Inventario de Ríos con Potencial Hidroeléctrico”, Ing. Córdova, UCA, Mayo 1998.

D. "Electrifición con base en Recursos de Energía Renovable", Transénergie, UNDP-GEF, 2002

E. “Consultoría para Recopilar Estudios Realizados sobre Energías Renovables para su Validacíon Estimado el Potencial Actual de Recursos Renovables para ser Utilizados en Proyectos de Generación de Electricidad Menores a 20 MW en El Salvador”, F. Lozano, GIZ, CNE, Marzo 2011

Project studies and ongoing projects are summarized in below:

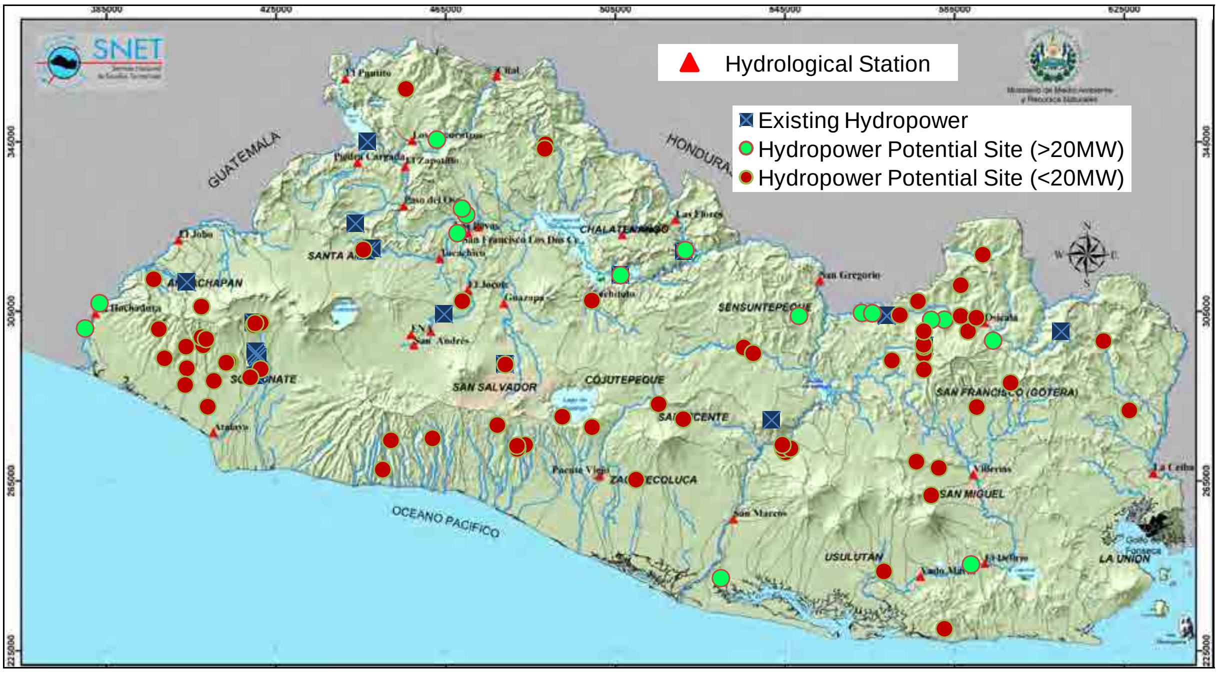
A. Project study by Energy and Environment Partnership with Central America (AEA)

B. Project study by CEL

C. Project study by Cucumacayán Electric Company, Inc. (CECSA)

4.2.4 Future Development Plan

According to the previous studies the hydropower potential sites and projects in El Salvador are shown in Tables 4.2.3. The existing hydropower plants and potential sites are shown in Figure 4.2.1. The total capacity of hydropower potential is summarized in Table 4.2.2.



(Source: JICA Study Team. (Prepared by using available previous studies))

Figure 4.2.1 Existing and Potential Hydropower Sites

Table 4.2.2 Summary of Hydropower Potential in El Salvador

Category	Number of Projects	Total Capacity (MW)	Annual Energy (GWh/year)	Implementing Unit
≥ 20 MW	18	2,077	6,949	CEL/ Government / Private Corporate
< 20 MW	86	158	675	Private Investment
TOTAL	**104**	2,235	7,624	

Note: The annual energy includes estimated values by using assumed average plant factor at 0.5
(Source: JICA Study Team. (Prepared by using available previous studies))

Table 4.2.3 List of Small Hydropower Potential (< 20 MW) (1/2)

No.	Proyect of Energy *Proyecto de Energia*	River Río	Departament Departamento	Potential (MW) Potencial (MW)	Energy (kWh/year) Energía (kWh/año)	Status Etapa	*Source* Fuente
	AEA PROYECTS						
1	El Calambre	El Calambre	Morazán	0.058	311	Under Const.	http://appext.sica.int/
2	Guanijiquil - Poza Honda	Sapo	Morazán	0.131	510	F/S	http://appext.sica.int/
3	La Loma	Osicala	Morazán	0.055	398	F/S	http://appext.sica.int/
4	Gualpuca	Gualpuca	Morazán	1.000	6,155	F/S	http://appext.sica.int/
5	Santa Rosa	Riachuelo	San Miguel	0.038	260	F/S	http://appext.sica.int/
6	La Cabaña	Grande de San Miguel	Usulután	0.980	4,300	F/S	http://appext.sica.int/
7	El Progreso	Aruate	Morazán	0.033	280	F/S	http://appext.sica.int/
8	Potrerillos	Las Lajas y El Arco	Morazán	0.320	2,600	F/S	http://appext.sica.int/
9	La Colmena	El Volcán	San Miguel	0.097	450	F/S	http://appext.sica.int/
10	El Naranjito	El Naranjito	Ahuachapan	0.031	146	F/S	http://appext.sica.int/
11	La Joya	San Jose Curuña		N.D.	N.D.		http://appext.sica.int/
12	Venecia Prusia			N.D.	N.D.	Pre-F/S	http://appext.sica.int/
13	Milingo (Reconversion)	Acelhuate	San Salvador	0.800	*3,500*	Operating	http://appext.sica.int/
14	Santa Emilia I			N.D.	N.D.	Pre-F/S	http://appext.sica.int/
15	Santa Emilia II			N.D.	N.D.	Pre-F/S	http://appext.sica.int/
	With Pre-F/S Studies						
16	El Sapo	Sapo	Morazán	2.400	8,961	F/S	INGENDEHSA S.A DE C.V.
17	Santo Domingo (Presa 1)	Tepechapa	Sonsonate	1.500	7,884	Pre-F/S	INGENDEHSA S.A DE C.V.
18	Santo Domingo (Presa 2)	Cacahuata	Sonsonate	1.500	7,884	Pre-F/S	INGENDEHSA S.A DE C.V.
19	Santo Domingo (Presa 3)	Quebrada El Camote	Sonsonate	1.500	7,884	Pre-F/S	INGENDEHSA S.A DE C.V.
20	Río Rosario - Metapan	Rosario	Santa Ana	1.000	3,110	Pre-F/S	INGENDEHSA S.A DE C.V.
21	Río Rosario	Rosario	Ahuachapan	0.200	*0*	Inventory	INGENDEHSA S.A DE C.V.
22	Copinula	Copinula	Ahuachapan	0.464	*2,030*	Inventory	INGENDEHSA S.A DE C.V.
23	Malancola	Jiboa	La Paz	5.400	*23,650*	Inventory	INGENDEHSA S.A DE C.V.
24	San José Loma	Jiboa	La Paz	2.500	*10,950*	Inventory	INGENDEHSA S.A DE C.V.
25	Santa Rita	Jiboa	La Paz	9.600	*42,050*	Inventory	INGENDEHSA S.A DE C.V.
26	Ocuila	Ocuila	Sonsonate	2.000	*8,760*	Inventory	INGENDEHSA S.A DE C.V.
27	Cauta	Cauta	Ahuachapan	0.511	2,697	Inventory	INGENDEHSA S.A DE C.V.
28	Ahuachapio	Ahuachapio	Ahuachapan	0.500	*2,190*	Inventory	INGENDEHSA S.A DE C.V.
29	Sumpul	Sumpul	Chalatenango	16.700	64,043	Pre-F/S	INGENDEHSA S.A DE C.V.
30	El Naranjo	El Naranjo	Ahuachapan	0.790	4,187	Inventory	INGENDEHSA S.A DE C.V.
31	Las Pilonas	Huiza	San Salvador	1.000	5,256	Pre-F/S	INGENDEHSA S.A DE C.V.
32	Sonzacate (Nahuizalco II)	Grande de Sonsonte	Sonsonate	2.300	*10,070*	F/S	2011 GIZ
33	Hacienda Vieja	Jiboa	San Salvador	14.500	*63,510*	Inventory	INGENDEHSA S.A DE C.V.
34	Mirazalco	Grande de Sonsonate	Sonsonate	4.000	17,520	Financing	INGENDEHSA S.A DE C.V.
35	La Calzadora I	Quebrada La Calzadora	Usulután	0.940	4,117	Inventory	INGENDEHSA S.A DE C.V.
36	La Calzadora II	Quebrada La Calzadora	Usulután	0.910	3,986	Inventory	INGENDEHSA S.A DE C.V.
37	Huiza	Huiza	San Salvador	1.500	4,468	Pre-F/S	INGENDEHSA S.A DE C.V.
38	El Jabio	Grande de Sonsonate	Sonsonate	1.500	*6,570*	Inventory	CECSA
39	San Esteban	San Esteban	San Miguel	0.310	*1,360*	Rehabilitation	CECSA
40	Acahuapa	Acaahuapa	San Vicente	0.120	*530*	Rehabilitation	CECSA
41	Sapuyo	Sapuyo	La Paz	0.060	*260*	Rehabilitation	CECSA
42	San Luis III	Suquiapa	La Libertad	0.425	*1,860*	F/S	CECSA
43	Chacala Los Apantes (Presa 1)	Chacala	Ahuachapan	1.500	8,126	Pre-F/S	INGENDEHSA S.A DE C.V.
44	Chacala Los Apantes (Presa 2)	Los Apantes	Ahuachapan	1.500	8,126	Pre-F/S	INGENDEHSA S.A DE C.V.
45	Ilopango Aguacayo	Aguacayo	San Salvador	16.600	60,000	Financing	INGENDEHSA S.A DE C.V.

Note: The Italicized value of annual energy was estimated by using assumed average plant factor at 0.5
(Source: JICA Study Team. (Prepared by using available previous studies))

Table 4.2.3 List of Small Hydropower Potential (< 20 MW) (2/2)

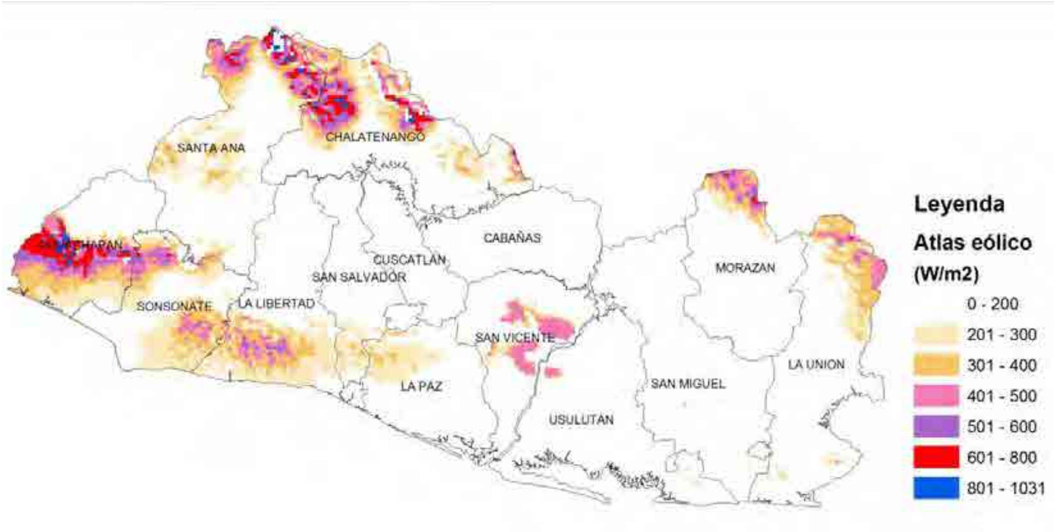
No.	Proyect of Energy *Proyecto de Energia*	River Río	Departament Departamento	Potential (MW) Potencial (MW)	Energy (kWh/year) Energía (kWh/año)	Status Etapa	*Source* Fuente
	Without study						
46	Chilama	Rio Chilama	La Libertad	0.932	*4,080*	Invetroty	CEL-UCA 1989
47	Comalapa	Rio Comalapa	La Paz	0.401	*1,760*	Potemcial	CEL-UCA 1989
48	Grande de Chalatenango	Grande de Chalatenango	Chalatenango	1.795	7,754	Inventory	2011 GIZ
49	Nejapa	Rio Nejapa	Ahuachapán	0.553	2,488	Inventory	2011 GIZ
50	Polorós	Rio Polorós	La Unión	3.162	13,660	Inventory	2011 GIZ
51	Quezalapa	Rio Quezalapa	Cabañas	2.037	8,800	Inventory	2011 GIZ
52	Quezalapa	Rio Quezalapa	Cabañas	0.809	*3,540*	Inventory	CEL-UCA 1989
53	Quezalapa	Rio Quezalapa	Cabañas	0.782	*3,430*	Inventory	CEL-UCA 1989
54	San Antonio	Rio San Antonio	Sonsonate	0.805	*3,530*	Inventory	CEL-UCA 1989
55	San Antonio	Rio San Antonio	Sonsonate	0.696	*3,050*	Inventory	CEL-UCA 1989
56	San Francisco	Rio San Francisco	Morazán	0.227	*990*	Inventory	CEL-UCA 1989
57	San Simón	Rio San Simón	Usulután	2.976	12,856	Inventory	2011 GIZ
58	San Simón	Rio San Simón	Usulután	2.173	9,387	Inventory	2011 GIZ
59	Sunzacuapa	Rio Sunzacuapa	Ahuachapán	0.313	*1,370*	Inventory	CEL-UCA 1989
60	Sunzacupa y Sucio	Rio Sunzacupa y Sucio	Sonsonate	0.527	2,277	Inventory	2011 GIZ
61	Sunzal- Tamanique	Rio Sunzal-Tamanique	La Libertad	0.436	2,277	Inventory	2011 GIZ
62	Sunzal-Tamanique	Rio Sunzal-Tamanique	La Libertad	0.527	*2,310*	Inventory	CEL-UCA 1989
63	Tacuba	Rio Tacuba	Ahuachapán	0.388	*1,700*	Inventory	CEL-UCA 1989
64	Tihuapa	Rio Tihuapa	La Paz	1.315	*5,760*	Inventory	CEL-UCA 1989
65	Tihuapa	Rio Tihuapa	La Paz	1.041	*4,560*	Inventory	CEL-UCA 1989
66	Titihuapa	Rio Titihuapa	Cabañas	1.434	*6,280*	Inventory	CEL-UCA 1989
67	Titihuapa	Rio Titihuapa	Cabañas	1.175	*5,150*	Inventory	CEL-UCA 1989
68	Titihuapa	Rio Titihuapa	Cabañas	0.882	*3,860*	Inventory	CEL-UCA 1989
69	Titihuapa	Rio Titihuapa	Cabañas/Sn Vicente	0.156	*680*	Inventory	CEL-UCA 1989
70	Toronjo	Rio Toronjo	Morazán	1.160	*5,080*	Inventory	CEL-UCA 1989
71	Zonte	Rio Zonte	La Libertad	0.468	2,190	Inventory	CEL-UCA 1989
72	Zonte	Rio Zonte	La Libertad	0.466	*2,040*	Inventory	CEL-UCA 1989
73	Zonte	Rio Zonte	La Libertad	0.478	*2,090*	Inventory	CEL-UCA 1989
74	Zonte	RioZonte	La Libertad	0.507	*2,220*	Inventory	CEL-UCA 1989
75	Araute	Rio Araute	Morazán	0.050	284	Inventory	2011 GIZ
76	Gnde de San Miguel, San José	Gnde de San Miguel, San José	Usulután	3.200	*14,020*	Inventory	CEL-UCA 1989
77	Grande de San Miguel, Sn Juan	Grande de San Miguel, Sn Juan	Usulután	4.500	*19,710*	Inventory	CEL-UCA 1989
78	Qbda El Singual, al Cuyapo	Qbda El Singual, al Cuyapo	Morazan	0.058	*250*	Inventory	CEL-UCA 1989
79	Qbda El Volcán/Rio Sn Juan	Qbda El Volcán/Rio Sn Juan	San Miguel	0.097	*420*	Inventory	CEL-UCA 1989
80	La Montañita	Rio La Montañita	Morazan	0.900	3,942	Inventory	CEL-UCA 1989
81	El Riachuelo	El Riachuelo	San Miguel	0.038	256	Inventory	2011 GIZ
82	Cumaro	Rio Cumaro	Morazán	0.039	168	Inventory	2011 GIZ
83	La Joya, Río Acahuapa	La Joya, Acahuapa	San Vicente	3.000	*13,140*	Inventory	CEL-UCA 1989
84	Grande de Chalatenango	Grande de Chalatenango	Chalatenango	0.690	*3,020*	Inventory	CEL-UCA 1989
85	Goascorán	Goascorán	La Unión	12.500	54,750	Inventory	2011 GIZ
86	Sucio, Los Tetuntes	Sucio, Los Tetuntes	La Libertad	6.600	*28,910*	Inventory	CEL-UCA 1989
			TOTAL	157.566	675,000		

Note: The Italicized value of annual energy was estimated by using assumed average plant factor at 0.5
(Source: JICA Study Team. (Prepared by using available previous studies))

4.3 Wind Power

4.3.1 Current Status

In El Salvador, wind power for generating electricity has not been developed yet. In accordance with the wind potential map created under SWERA, limited areas were classified as suitable areas for wind power development.



(Source: SWERA)

Figure 4.3.1 Wind Power Potential Map (SWERA)

4.3.2 Barriers to Introduction

It is necessary to consider the following issues on the introduction of a wind power generation system.

4.3.2.1 Technical Regulations / Guidelines

It is necessary to prepare technical regulations or guidelines before implementing wind power projects. The following issues have to be considered as items of technical regulations or guidelines in El Salvador:

A. Power Factor
B. Voltage Flicker
C. Harmonics and Interharmonics
D. Safety

4.3.2.2 Engineers

Capacity development is one of the most important issues for the future development of wind power. Technology should be transferred to Salvadoran engineers through actual installation, especially operations and maintenance skills. Also, the enhancement of the curriculum or training courses on renewable energy in a university or vocational school will be one of the most suitable options for human resources development.

4.3.2.3 Operations and Maintenance Cost

The operations and maintenance (O&M) costs have to be considered and prepared before the installation. The O&M costs constitute a sizeable share of the total annual costs of a wind turbine.

4.3.3 Related Existing and Ongoing Studies and Projects

4.3.3.1 Nationwide Wind Map

SWERA is a GEF sponsored project. SWERA produced a range of solar and wind datasets and maps at better spatial scales of resolution than previously available in 2005.

4.3.3.2 Feasibility Study

"Wind Speed Measurement in El Salvador 2006-2007 for Wind Energy Assessment" was conducted by the Finnish Meteorological Institute. Wind monitoring was carried out and power outputs were estimated using WAsP, a wind power simulation software.

4.3.4 Future Development Plan

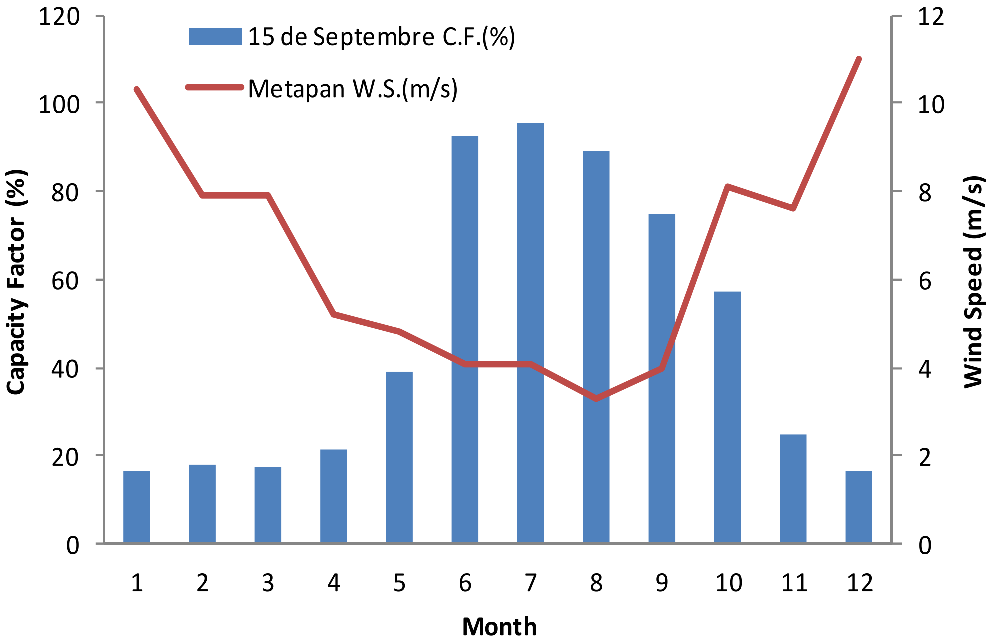
CEL has future plans on developing wind farms. Table 4.3.1 shows the annual average wind speed at 60 m above ground level and the installed capacity at candidate sites under the wind farm plans of CEL.

Table 4.3.1 Candidate Wind Farms

	Annual Average Wind Speed @ 60 m agl (m/s)	Planned Capacity (MW)
Metapan	6.43	42 MW
San Julian	5.38	30 MW

(agl: above ground level)
(Source: CEL)

Figure 4.3.2 shows a seasonal complementary relation between the monthly capacity factor of the hydropower plant at "15 de Septiembre" and the monthly wind speed at Metapan. At Metapan, wind potentials are higher from October to April while the capacity factor of "15 de Septiembre" is lower.



(Source: JICA Study Team)

Figure 4.3.2 Wind Speed (Metapan) and Capacity Factor (15 de Septiembre, Hydropower)

4.4 Solar PV

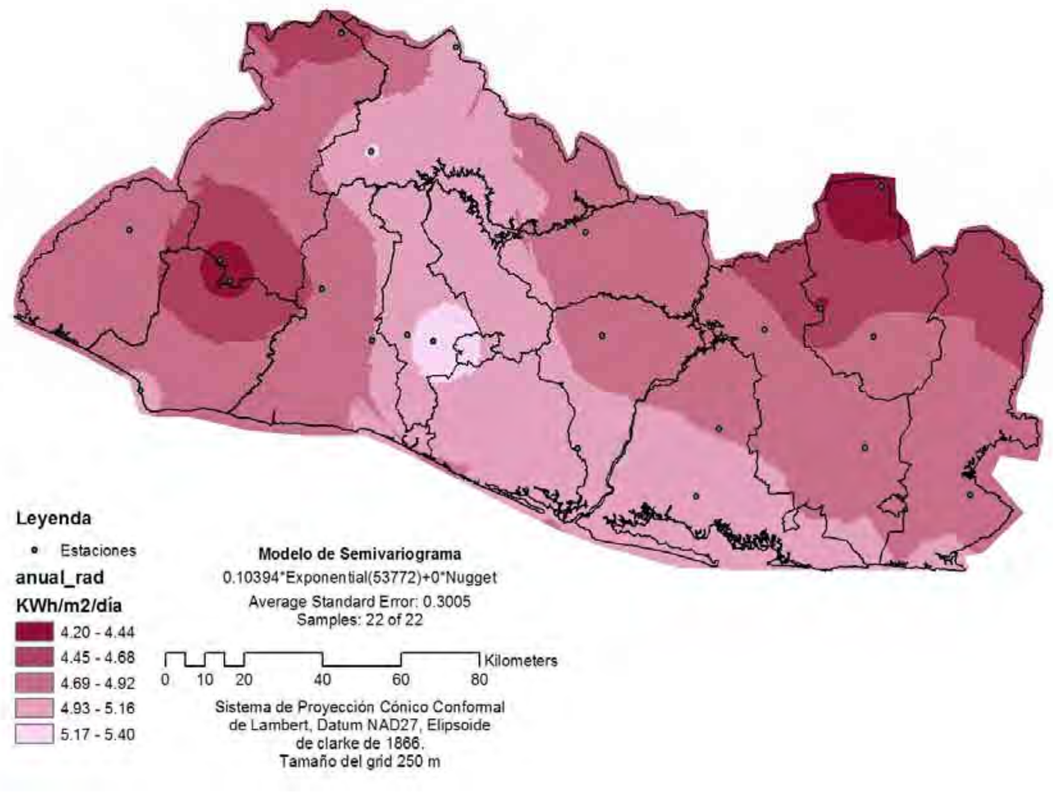
There are numerous isolated solar PV systems introduced mainly in rural and mountainous regions. The cost of a PV system is still high and this prevents the dissemination of PV systems. There is a future plan to install 17.8 MW of solar PV systems in the country.

4.4.1 Current Status

Solar irradiation in El Salvador is high at 5.3 kWh/m^2/d as compared to that in Tokyo at 3.3 kWh/m^2/day. A solar irradiation map in El Salvador was created under the SWERA project. This map, which shows the potential annual average solar irradiation, is shown in Figure 4.4.1. Solar irradiation is high in the central region of El Salvador, especially around the San Salvador Metropolitan Area.

Table 4.4.1 shows a list of solar PV systems in the country. Most of them are isolated systems with battery bank which are used as Solar Home Systems (SHSs). There are a limited number of grid-connected solar PV systems.

Figure 4.4.3 shows a map of the distribution of solar PV systems in El Salvador. SHSs are located in mountainous regions and rural areas. On the other hand, most of the grid-connected PV systems are located in the San Salvador Metropolitan Area.



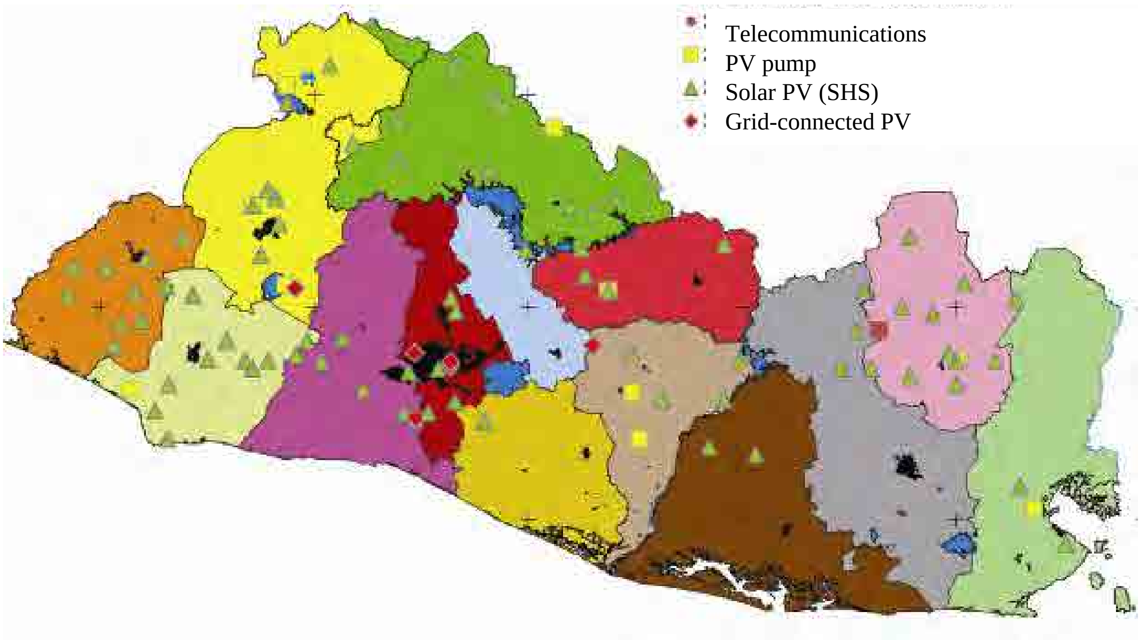
(Source: SWERA)

Figure 4.4.1 Solar Irradiation Map of El Salvador

Table 4.4.1 Solar PV Systems in El Salvador

Application	Number of Systems	Installed Capacity (Wp)
PV Pump	21	9,695
Solar PV (SHS)	2,950	287,956
Grid-connected PV	12	163,940
Street lighting	246	15,090
Portable water	2	280
Radio communication	15	n.a.
Telecommunications	6	n.a.
TOTAL	**3,252**	**476,961**

(Source: CNE)



(Source: JICA Study Team)

Figure 4.4.2 Solar PV System Map of El Salvador

4.4.2 Barriers to Introduction

4.4.2.1 Cost of PV System

Grid-connected solar PV systems have not been introduced widely in El Salvador. Most of the PV systems are installed in public facilities such as government buildings and schools. In the promotion of rooftop solar PV systems, high initial investment cost is a major problem.

More expensive grid-connected system prices are often associated with modification or integration of the roof, and the figures can also relate to a single project. Also, the prices include government subsidy of each country. The price of solar PV systems has been decreasing in recent years. However, it is still expensive for individual users especially without government subsidy.

4.4.2.2 Technical Guidelines

The National Electrical Code (NEC) of the USA has been applied as the national electric regulation of El Salvador. However, practical guidelines for electrical technicians on interconnection of rooftop solar PV have not been prepared in El Salvador.

4.4.2.3 Engineers

Capacity development is one of the most important issues for future development of solar power. Enhancing the curriculum or training courses on renewable energy in universities is one of the options for capacity development in the solar PV sector.

4.4.3 Related Existing and Ongoing Studies and Projects

4.4.3.1 CEL

CEL has installed solar PV systems on the rooftops of buildings with a total capacity of 24.57 kW. CEL has been monitoring the power output of each type of PV system as well as solar irradiation and other metrological data.

4.4.3.2 SWERA

SWERA produced a range of solar and wind datasets and maps at better spatial scales of resolution than previously available in 2005.

4.4.3.3 Rural Electrification

SHSs have been introduced for rural electrification through NGOs and other organizations. Suministros Eléctricos y Electrónicos, SA de CV (SEESA) has delivered over 400 solar PV electrical systems since the beginning of 2004. Most solar PV systems are for rural homes which have been invested in by E+Co of the USA. E+Co is a non-profit organization that invests in clean energy enterprises in developing countries. Its mission is to empower small- and medium-sized enterprises.

4.4.3.4 United States Trade and Development Agency (USTDA)

There is a solar PV project "CEL Solar Photovoltaic Power Pilot Project Feasibility Study" financed by the USTDA which is still under the preparatory stage.

4.4.4 Future Development Plan

There are plans to install a centralized grid-connected solar PV system by CEL. Table 4.4.2 shows the candidate sites and capacities. CEL owns a large area near the hydropower stations which is suitable for the installation of solar PV systems.

Table 4.4.2 Future Development Plan of Solar PV by CEL

Location	Capacity (MW)
PV power to be installed at Guajoyo	3.6
PV power to be installed at 15 de Septiembre	14.2
Total power	17.8

(Source: JICA Study Team)

4.5 Solar Thermal

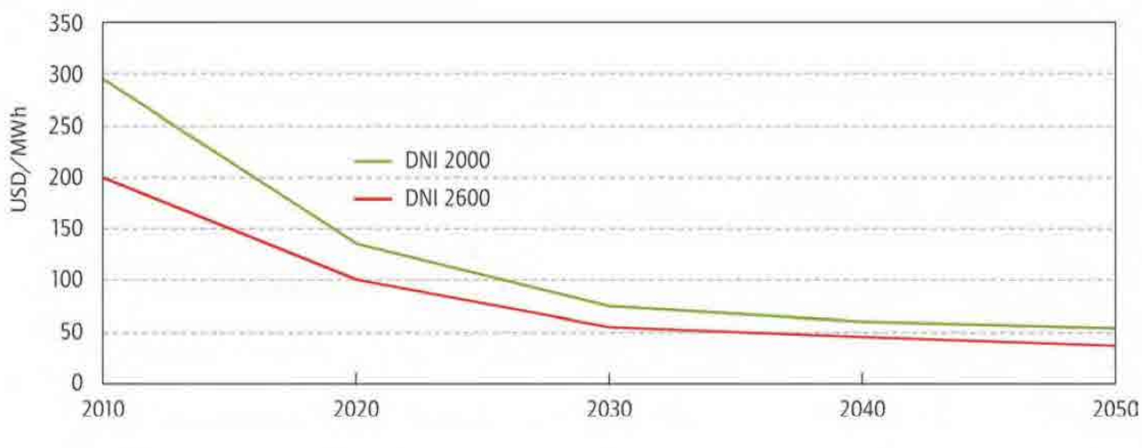
Several studies and pilot tests on solar thermal power systems are being conducted for future implementation. The potential for solar thermal power is high in El Salvador. However, the initial investment cost for such systems is still high at present. La Geo has future plans for the development of solar thermal power systems with a total capacity of 35 MW by 2020.

4.5.1 Current Status

In El Salvador, a parabolic trough-type solar thermal plant is already installed as a pilot plant for geothermal and solar thermal hybrid system at the Ahuachapán geothermal field. Pilot testing is being carried out since March 2007. The parabolic trough solar system is an external heat source that is combined with an existing geothermal facility. The solar field consists of four parabolic trough solar concentrators that is 4 m wide and 10 m long.

4.5.2 Barriers to Introduction

High initial investment cost is one of the most serious barriers for promoting CSP in El Salvador. The United States Department of Energy (US DOE) has set an objective for its CSP Programme in order to reach competitiveness with fossil fuels by 2015 at around US$100/MWh of power production cost, and by 2020 at around US$50/MWh. According to the roadmap of the US DOE, competitiveness is more likely to be achieved by 2020 for intermediate loads and 2025 to 2030 for base loads. Table 4.5.4 shows US DOE's projected electricity cost from CSP plants.



Note: DNI = direct normal irradiance

(Source: Technology Roadmap Concentrating Solar Power / IEA)

Figure 4.5.1 Projected Electricity Cost from CSP Plants

4.5.3 Existing and Ongoing Related Studies and Projects

A Spanish development subsidiary of Solar Millennium AG signed a contract with Inversiones Energéticas S.A. de C.V. (INE) for a feasibility study on a parabolic trough power plant.

LaGeo has been conducting research and development activities on solar thermal power. Currently, LaGeo is conducting the monitoring of solar heat and irradiation at some areas in the country.

4.5.4 Future Development Plan

La Geo has future plans for the development of solar thermal power plants in El Salvador. The total target capacity is 35 MW by 2020. The candidate sites for installing such power plants are at San Miguel, Usulutan, Jiquilisco, Comalapa and Ahuachapan.

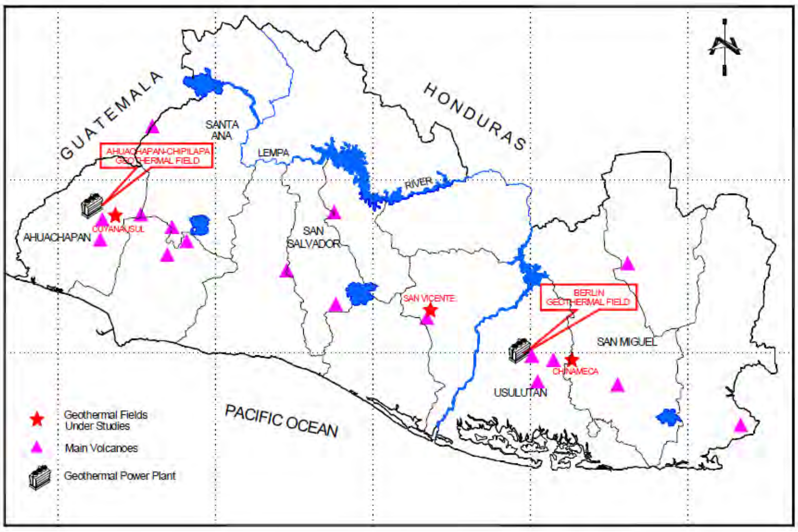
4.6 Geothermal

Geothermal power generation in El Salvador started in 1975 and has been increasing steadily since. The current total output is 204 MW. It is competitive in the power market. There are no serious problems with the development and utilization of geothermal energy in El Salvador from an engineering viewpoint. LaGeo, a sole private company in charge of geothermal power development, has a plan for developing additional capacity of 60 to 89 MW by around 2017. LaGeo is also considering the possibility of developing another 10 MW, however its timing has not been planned yet. The expected total geothermal power generation capacity in El Salvador in the future ranges from 300 to 400 MW based on current information.

4.6.1 Current Status

4.6.1.1 History and Current Status of Geothermal Power Generation in El Salvador

The first geothermal power station in Central America started commercial power generation at Ahuachapán in 1975. The second geothermal power station in El Salvador started its commercial power generation at Berlín in 1992. The locations of Ahuachapán and Berlín are shown in Figure 4.6.1.



(Source: World Geothermal Congress 2005, El Salvador Country Update (2005))

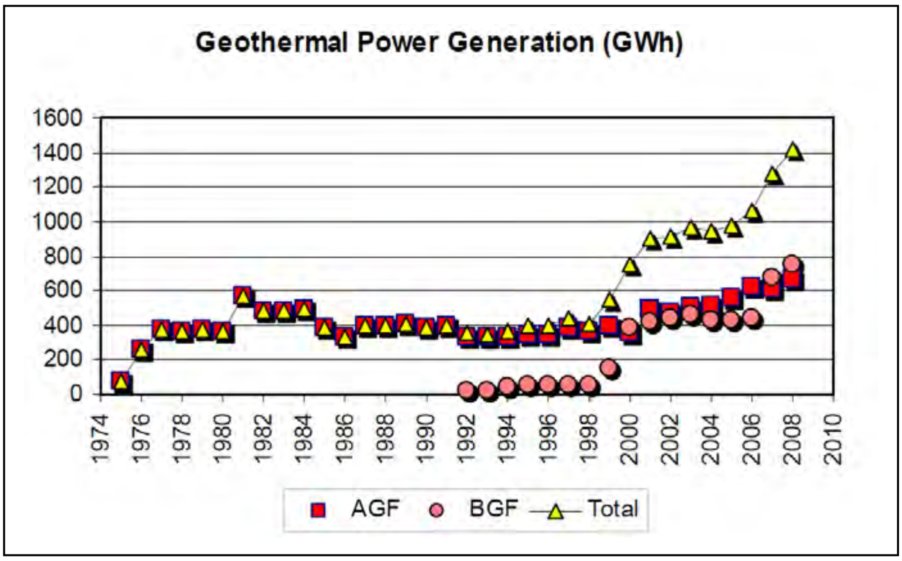
Figure 4.6.1 Location Map of Geothermal Power Stations in El Salvador

Geothermal development in El Salvador has been carried out by CEL. However in November 1999, the company was broken up and privatized, and became LaGeo. At first CEL held 100% share of LaGeo, but in June 2002, Ente Nazionale per l'Energia eLettrica (ENEL), an Italian energy conglomerate, joined LaGeo as a strategic partner. The current shareholding ratio of CEL is 64% and that of ENEL Green Power, a subsidiary of ENEL, is 36%.

Geothermal power development in El Salvador has steadily continued since then. At present, there are two geothermal power stations held and operated by LaGeo, one in Ahuachapán and another in Berlín. The total installed capacity in Ahuachapán (three units) is 95 MW. Its running capacity at the end of 2009 was reported at 84 MW, which is 88% of the rated value.

LaGeo reported the statistics of their geothermal development and power production at the World Geothermal Congress 2010 (WGC2010). Based on the report, the capacity factors at Ahuachapán, Berlín and the total average in 2009 were 80%, 79% and 79%, respectively. These values are good and show relatively high performance among the geothermal power stations in the world.

The history of generated electric energy at the two geothermal power stations in El Salvador is shown in Figure 4.6.2. Power generation at Ahuachapán once decreased from about 1982. Based on the report at the WGC2010, problems occurred first when the reservoir pressure dropped, and then by reinjection. Then, a new reinjection area was established in Chipilapa, which is located next to Ahuachapán area. As a result, those problems were solved and the output started to recover from 1999. On the other hand, power generation at Berlín has been very successful.



(Source: World Geothermal Congress 2010, El Salvador Country Update (2010))

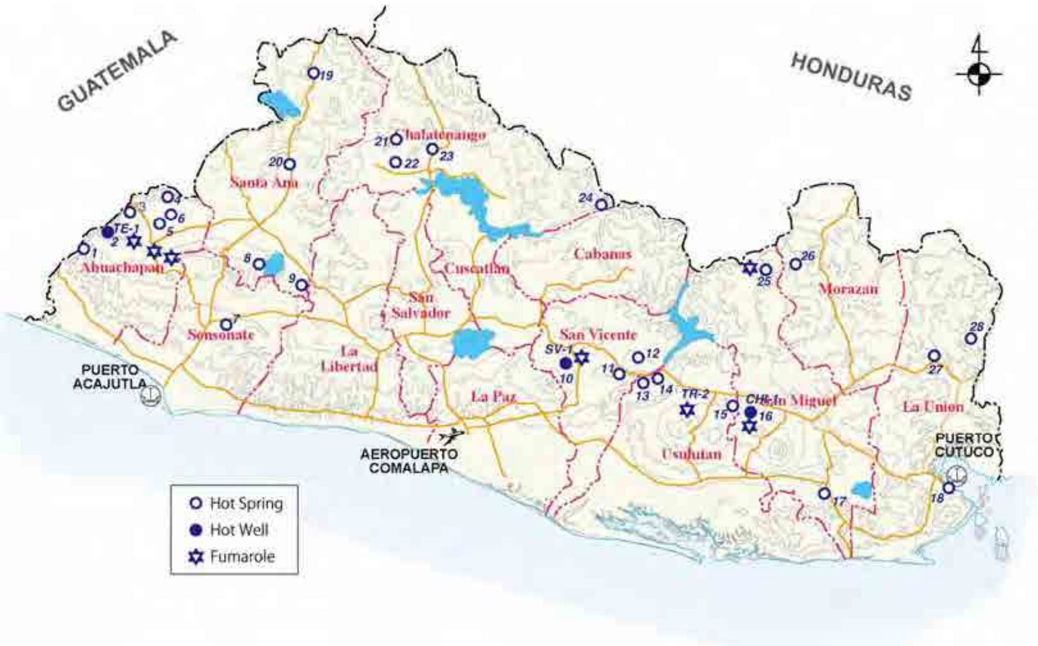
Figure 4.6.2 History of Generated Electric Power from Geothermal Power Stations in El Salvador

4.6.1.2 Geothermal Resources of El Salvador

Since El Salvador is located on the Pacific Ring of Fire (Pacific Volcanic Belt), there are a lot of volcanic activities in El Salvador. In El Salvador, there are two geothermal belts associated with its alignment of volcanoes, namely, the northern and southern geothermal belts(refer to Figure 4.6.3).

It is possible for geothermal power generation to utilize steam and/or hot water from high-enthalpy geothermal fields, as shown in Figure 4.6.3. As seen in this figure, all are located on the southern geothermal belt.

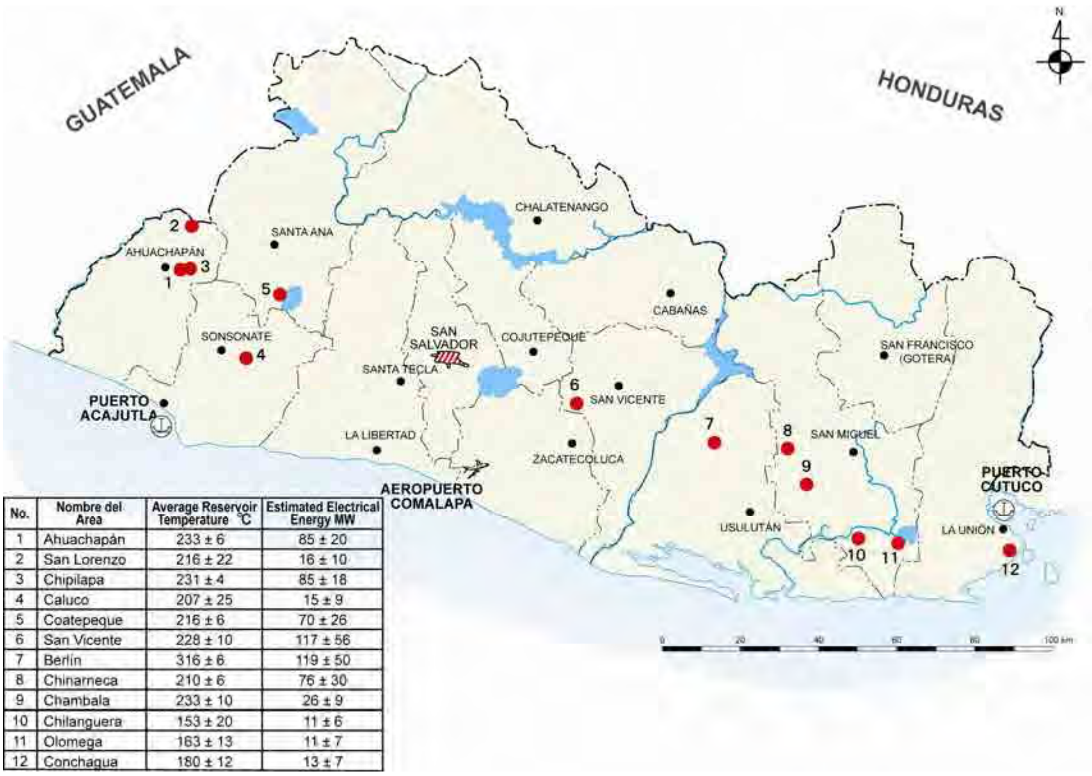
On the other hand, it is possible for power generation of small-scale binary-cycle systems to utilize hot water from low-enthalpy geothermal fields, as shown in Table 4.6.1. Based on information from LaGeo, there are some more fields possible for binary-cycle geothermal power generation.



No.	Hot Spring area
1	Durazneño
2	Los Toles
3	Los Salitres
4	San Lorenzo
5	Playón -El Salitre
6	La Ceiba
7	Caluco
8	Coatepeque
9	Agua Caliente
10	San Vicente
11	Obrajuelo -Lempa
12	Parras Lempa
13	San Simón
14	Las Burras
15	Jucuapa
16	Chinameca
17	Chilanguera
18	Conchagua
19	Metapán
20	Texistepeque
21	Agua Caliente
22	Obrajuelo
23	El Salitre
24	Nombre de Jesús
25	Carolina
26	San Isidro
27	Santa Rosa
28	El Sauce

(Source: Geothermal resources of El Salvador by Campos (1988))

Figure 4.6.3 Location of 28 Hot Springs and 7 Fumarolic Areas in El Salvador



No.	Nombre del Area	Average Reservoir Temperature ℃	Estimated Electrical Energy MW
1	Ahuachapán	233 ± 6	85 ± 20
2	San Lorenzo	216 ± 22	16 ± 10
3	Chipilapa	231 ± 4	85 ± 18
4	Caluco	207 ± 25	15 ± 9
5	Coatepeque	216 ± 6	70 ± 26
6	San Vicente	228 ± 10	117 ± 56
7	Berlín	316 ± 6	119 ± 50
8	Chinameca	210 ± 6	76 ± 30
9	Chambala	233 ± 10	26 ± 9
10	Chilanguera	153 ± 20	11 ± 6
11	Olomega	163 ± 13	11 ± 7
12	Conchagua	180 ± 12	13 ± 7

(Source: Estado Actual y Desarrollo de los Recursos Geotérmicos en Centroamérica (2009))

Figure 4.6.4 Location of 12 High-Enthalpy Geothermal Areas in El Salvador

Table 4.6.1 Inventory of High-Enthalpy Geothermal Resources in El Salvador (Campos, 1988)

No.	Area	Location	Average Reservoir Temperature (°C)	Average Reservoir Volume (km³)	Estimated Electrical Energy (Geothermal Potential) (MWe 25 years)
1	Ahuachapán	Ahuachapán	233±6	10±2	85±20
2	San Lorenzo	Ahuachapán	216±22	2±1	16±10
3	Chipilapa	Ahuachapán	231±4	10±2	85±18
4	Caluco	Sonsonate	207±25	2±1	15±9
5	Coatepeque	Santa Ana	216±6	9±3	70±26
6	San Vicente	San Vicente	228±10	14±6	117±56
7	Berlín	Usulután	316±6	10±4	119±50
8	Chinameca	San Miguel	210±6	10±4	76±30
9	Chambala	San Miguel	233±10	3±1	26±9
10	Chilanguera	San Miguel	153±20	2±1	11±6
11	Olomega	San Miguel	163±13	2±1	11±7
12	Conchagua	La Unión	180±12	2±1	13±7
				TOTAL	644±248
				RANGE	396 - 892

(Source: Campos, T. (1988) Geothermal resources of El Salvador, Preliminary assessment. Geothermics, Vol.17, p.319-332.)

Table 4.6.2 Inventory of Low-Enthalpy Geothermal Resources in El Salvador (Campos, 1988)

No.	Area	Location	Average Reservoir Temperature (°C)	Average Reservoir Volume (km³)	Estimated Electrical Energy (Geothermal Potential) (MWe 25 years)
1	Toles	Ahuachapán	126±6	3±1	13
2	Güija	Santa Ana	119±9	2±1	8
3	Los apoyos	Santa Ana	133±7	2±1	9
4	Agua Caliente	Chalatenango	123±7	2±1	9
5	El Paraiso	Chalatenango	133±7	2±1	9
6	Nombre de Jesús	Chalatenango	151±8	3±1	16
7	Tihuapa	La Libertad	128±11	2±1	9
8	El Salitral	La Paz	123±10	2±1	8
9	Obrajuelo	San Vicente	133±14	2±1	9
10	Carolina	San Miguel	141±11	3±1	15
11	Santa Rosa	La Unión	126±12	8±1	34
12	El Sauce	La Unión	118±12	2±1	8
				TOTAL	147

(Source: Campos, T. (1988) Geothermal resources of El Salvador, Preliminary assessment. Geothermics, Vol.17, p.319-332.)

The estimated geothermal potentials shown in Tables 4.6.1 and 4.6.2 are 644 MW and 147 MW, respectively, resulting in a total of 791 MW. Since the installed capacity of geothermal power generation in El Salvador is currently 204.4 MW, the ratio of the installed capacity to the geothermal potential is 25.8%.

4.6.2 Barriers to Introduction

Based on the information from LaGeo, geothermal power generation is competitive in the liberalized power market in El Salvador. LaGeo pointed out the following barriers to the further utilization of geothermal energy:

A. A lot of legal and administrative procedures and length of time to complete them.

B. Land purchase is sometimes difficult and takes a long time.

C. Sometimes, there are a lot of inhabitants in an exploration area because of high population density. Accordingly, it sometimes takes a long time to get their agreement on geothermal exploration and development.

D. Availability of water for well drilling is sometimes not favorable.

E. Success rate of exploration wells in new geothermal fields is around 25%.

4.6.3 Existing and Ongoing Related Studies and Projects

Currently, LaGeo is the only entity engaged in geothermal power development in El Salvador. Based on an interview with LaGeo on October 10, 2011, the existing plan to increase geothermal power generation is as shown in Table 4.6.3.

Table 4.6.3 Plans on New Development, Expansion and Modification by LaGeo

Location	Plan	Addition (MW)	Feasibility	Timing (year)
Ahuachapán	Modification of Unit-2	5-9	A	2015
Berlín	Expansion by Unit-5	25-30	A	2017
Chinameca	New Development	30-50	B	2017
San Vicente	New Development	10	C	N/A
-	Total (All)	70-99	-	-
-	Total (by 2017)	60-89	-	-

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

As shown in Table 4.6.4, LaGeo is planning to increase their geothermal power generation by 60 to 89 MW by 2017. An additional increase of 10 MW capacity was also planned at San Vicente but its implementation has not been scheduled yet because of remaining uncertainty of resources.

Table 4.6.4 Development Plan of Geothermal Power Generation (New Development, Expansion, Modification, etc.) by LaGeo in El Salvador

No.	Field Name	Location	Develop. Status	Reservoir Existence Possibility	Installed Capacity (MWe)	Existing Dev. Plan (MWe)	Possible Addition (MWe)	Total Potential (MWe)	Development Plan (New, Expansion, Retrofit etc.) (MWe) and Its Possibility*																Remarks
									2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	
1	Ahuachapán	Ahuachapán	OP	1	95	5-9 [A]	?	100-104+				5-9 [A]													
2	San Lorenzo	Ahuachapán	RE	NE																					
3	Chipilapa	Ahuachapán	OP	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	a part of Ahuachapá
4	Caluco	Sonsonate	RE	NE																					
5	Coatepeque	Santa Ana	RE	NE																					
6	San Vicente	San Vicente	EX	1		10 [C]	?	10+							Specific development plan has not been formulated yet										
7	Berlín	Usulután	OP	1	109.4	25-30 [A]	?	134-139+						25-30 [A]											
8	Chinameca	San Miguel	F1	1		30-50 [B]	?	30-50						30-50 [B]											
9	Chambala	San Miguel	RE	NE																					
10	Chilanguera	San Miguel	RE	NE																					
11	Olomega	San Miguel	RE	NE																					
12	Conchagua	La Unión	RE	NE																					

Development Status: RE: Unexplored or regional reconnaissance only; EX: Exploration wells in progress; OP: Power plant in operation; S1: Local surface exploration done; F1: Pre-feasibility studies done; S2: Detailed surface exploration done; F2: Feasibility studies done (complete)

Reservoir Existing Possibility: 1 : Confirmed by well(s); 2 : Inferred mainly by geochemi; 3 : Inferred by geoscientific data; Low : Low possibility or low temp.; NE : Not enough data for evaluation

Development Feasibility: [A] : Proven (Definite); [B] : Probable; [C] : Possible

Total Potential (+) indicates further possibility

(Note) Shaded area represents possible delay due to resource uncertainty and/or some other reasons.

(Information Source/Date) LaGeo/Oct. 10, 2011

(Source: LaGeo)

4.6.4 Future Development Plan

Currently, LaGeo has no definite plan for new power development after 2017.

It becomes 440 MW by deducting those at Ahuachapán and Berlín since they are already developed. It then becomes 587 MW by adding 147 MW which describes low-enthalpy geothermal fields. This value is called the “remaining geothermal potential”. Assuming the maximum ratio of future power generation capacity to the remaining geothermal potential as 20 to 30%, possible additional power generation capacity in the future is estimated at 117 to 176 MW. Therefore, the possible total geothermal power generation capacity in the future is estimated at 321 to 380 MW by adding the existing installed capacity (204 MW). By rounding off the value, the maximum level of total geothermal power generation in El Salvador in the future is estimated at 300 to 400 MW.

This value is the sum of the estimates of flash-cycle power generation in high-enthalpy geothermal fields and the estimates of binary-cycle power generation in low-enthalpy geothermal fields. This value is only tentative at the moment. It should be revised periodically according to the advancement of geothermal exploration and development in El Salvador.

4.7 Biomass

For biomass resources, the potential of sugarcane, coffee husk and rice husk has been examined. The potential of coffee husk and rice husk is too small to generate electricity at a processing factory. Sugarcane has more potential, and the capacity of a power generation system using bagasse can be increased a little more through a market-driven approach.

4.7.1 Current Status

In the agricultural sector of El Salvador, the main agricultural crops include coffee, sugar, corn, rice and sorghum. It is recommended to install a biomass power plant in agricultural product processing factories such as sugarcane factories.

4.7.1.1 Sugarcane

Biomass power generation systems were already introduced in some sugarcane factories in El Salvador. Generated power is consumed in the factories and excess power is supplied to the power grid. Table 4.7.1 shows the installed capacity of biomass power generation which utilizes bagasse in El Salvador.

Table 4.7.1 Installed Capacity of Biomass Generation Utilizing Bagasse in El Salvador

Year	CASSA (MW)	EL ANGEL (MW)	LA CABAÑA (MW)	TOTAL (MW)
2003	20.0			20.0
2004	20.0			20.0
2005	25.0			25.0
2006	29.0			29.0
2007	60.0			60.0
2008	60.0	22.5	21.0	103.5
2009	60.0	22.5	21.0	103.5
2010	50.0	22.5	21.0	93.5
2011	50.0 16.0 (Chaparrastique)	22.5	21.0	109.5

(Source: SIGET)

4.7.1.2 Coffee

Table 4.7.2 shows the possible potential power output from coffee husk based on coffee production (2010/2011) in each department. The potential power generation from coffee husk in the Western Region is highest among the three regions. The potential of 12-hour operations for 300 days in the region is around 290 kW. The potential in the Central Region is around 250 kW, and that of the Eastern Region is the lowest at 60 kW.

Western Region: 1,053 (MWh/year) / 12 hours / 300 days = 0.29 (290 kW)

Central Region: 911 (MWh/year) / 12 hours / 300 days =0.25 (250 kW)

Eastern Region: 206 (MWh/year) / 12 hours / 300 days =0.06 (60 kW)

It is considered that there are no coffee production facilities which have enough production of coffee husk to operate an over 0.5 MW class of steam turbine type generator. On the other hand, it is possible to install an under 100 kW class of biomass gasification system for power generation.

Table 4.7.2 Coffee Production and Potential for Power Generation in Each Department

Department	Farms	Area Coffee (ha)	Coffee Red (ton)	Husk (ton)	Estimated Power Output (MWh/Year)	Potential* (MW)
Ahuachapán	128	8,344	26,350	1,133	340	0.09
Santa Ana	141	8,455	32,813	1,411	423	0.12
Sonsonate	86	8,247	22,494	967	290	0.08
Western Region Total	**355**	**25,047**	**81,657**	**3,511**	**1,053**	**0.29**
Chalatenango	20	250	977	42	13	0.00
La Libertad	154	16,175	48,449	2,083	625	0.17
San Salvador	34	3,834	16,525	711	213	0.06
Cuscatlán	10	174	258	11	3	0.00
La Paz	17	509	871	37	11	0.00
San Vicente	23	804	3,545	152	46	0.01
Central Region Total	**258**	**21,746**	**70,625**	**3,037**	**911**	**0.25**
Usulután	80	3,392	8,527	367	110	0.03
San Miguel	43	2,052	6,415	276	83	0.02
Morazán	16	311	1,026	44	13	0.00
Eastern Region Total	**139**	**5,755**	**15,968**	**687**	**206**	**0.06**
TOTAL	**752**	**52,547**	**168,250**	**7,235**	**2,170**	**0.60**

*12 hours x 300 days

(Source: JICA Study Team)

4.7.1.3 Rice

Table 4.7.8 shows the possible potential power output from rice husk based on rice production (2009/2010) in each department. The potential of power generation from rice husk in the Central Region is highest among the three regions. The potential of 12-hour operations for 300 days in the region is around 141.0 kW. Also, the potential in the Western Region is around 24.2 kW, and that of the Eastern Region is the smallest at 12.6 kW.

Western Region: 87,006 (kWh/year) / 12 hours / 300 days =24.2 kW

Central Region: 507,641 (kWh/year) / 12 hours / 300 days =141.0 kW

Eastern Region: 45,261 (kWh/year) / 12 hours / 300 days =12.6 kW

Table 4.7.3 Rice Production and Potential for Power Generation in Each Department (2009/2010)

Department	Area (ha)	Production (ton)	Yield (ton/ha)	Rice Husk (ton)	Estimated Power Output (kWh/year)	Potential* (kW)
Ahuachapán	403.2	2,388.3	5.9	597.1	48,542.3	13.5
Santa Ana	119.7	670.9	5.6	167.7	13,636.2	3.8
Sonsonate	186.2	1,221.5	6.6	305.4	24,827.5	6.9
Western Region Total	**709.1**	**4,280.7**	**18.1**	**1,070.2**	**87,006.1**	**24.2**
Chalatenango	900.2	6,498.3	7.2	1,624.6	132,077.7	36.7
La Libertad	1,623.3	13,379.8	8.2	3,345.0	271,944.9	75.5
San Salvador	0.0	0.0	0.0	0.0	0.0	0.0
Cuscatlán	115.5	846.0	7.3	211.5	17,194.8	4.8
La Paz	677.6	3,409.5	5.0	852.4	69,297.5	19.2
Cabañas	21.0	93.6	4.5	23.4	1,903.0	0.5
San Vicente	156.8	749.0	4.8	187.3	15,223.8	4.2
Central Region Total	**3,494.4**	**24,976.2**	**37.1**	**6,244.1**	**507,641.7**	**141.0**
Usulután	177.8	702.1	3.9	175.5	14,270.5	4.0
San Miguel	304.5	1,524.8	5.0	381.2	30,991.4	8.6
Morazán	0.0	0.0	0.0	0.0	0.0	0.0
La Unión	0.0	0.0	0.0	0.0	0.0	0.0
Eastern Region Total	**482.3**	**2,226.9**	**9.0**	**556.7**	**45,261.9**	**12.6**
TOTAL	**4,685.8**	**31,483.9**	**64.1**	**7,871.0**	**639,909.7**	**177.8**
1st plant (winter) (dry)	3,364.2	21,588.3	6.4	5,397.1	438,782.9	121.9
2nd plant (summer) (irrigation)	1,321.6	9,895.5	7.5	2,473.9	201,126.9	55.9

*12hours x 300 days

(Source: Anuario de Estadísticas Agropecuarias 2009-2010)

4.7.2 Barriers to Introduction

4.7.2.1 Woody Biomass

El Salvador is the second most deforested country in Latin America. Almost 85% of its forest cover has disappeared since the 1960s, leaving only about 5% of the land area forested. Fuel wood as an energy source represents almost 50% of all the consumed energy. Around 60% of urban households and 85% of rural households use fuel wood for cooking activities, leading to the growing deforestation process of the country's scarce forest resources. From the situation above and the results of discussions with CNE, woody biomass is not considered as a resource for power generation in this study.

4.7.2.2 Agricultural Residue

If agricultural residue is available free-of-charge, it would be one of the most suitable resources for biomass power generation. In addition, it is necessary to consider preparation costs such as for transportation, drying and cutting for preprocessing. It is difficult to use valuable biomass resources for power generation in terms of economical sustainability.

4.7.2.3 Technology

Large-scale biomass power generation systems using boiler and steam turbine were already introduced in El Salvador. On the other hand, small-scale biomass power generation systems such as gasification systems have not yet been introduced.

4.7.3 Existing and Ongoing Related Studies and Projects

Biomass power generation systems have been introduced by the private sector, mainly at sugarcane factories. Therefore, such companies have been studying and making development plans by themselves.

4.7.4 Future Development Plan

Biomass power plants have been installed by private companies. In accordance with the results of the site survey of the sugarcane factories of La Cabaña and El Angel, both companies have a future development plan on installing power generation plants using bagasse. Moreover, CASSA has a plan to introduce an additional power generation system with capacity between 20 MW and 30 MW at Chaparrastique before the harvest season from 2013 through 2014.

Table 4.7.4 Future Development Plan

Description	La Cabaña	El Angel	CASSA
Capacity of Additional Installation (MW)	15	25	20 to 30
Planned Year	2015	December 2011	2013

(Source: JICA Study Team)

4.8 Biogas

There is a landfill biogas (LFG) power plant at Nejapa in San Salvador Metropolitan Area. The installed capacity of the said LFG plant is 6.3 MW. There are landfills in other departments; however, the capacity of solid waste collection is much smaller than that in San Salvador. The installed capacity of the LFG can be increased up to a maximum of 25 MW.

4.8.1 Current Status

4.8.1.1 LFG

Around 55% of the total solid waste in the country and around 80% of solid waste in landfills are disposed in San Salvador. El Salvador has a national population of 6.2 million. Out of this, 2.1 million belongs to the highly-urbanized San Salvador Metropolitan Area. The Nejapa landfill receives municipal solid waste (MSW) from the San Salvador Metropolitan Area.

The Nejapa landfill receives MSW from the San Salvador Metropolitan Area based on a 20-year agreement signed with Mides S.E.M. de CV (Mides), the owner of the landfill. The site has been receiving 408,000 t of waste per year from the San Salvador Metropolitan Area and has a total capacity of 12.5 million t in 15 independent cells. The operational lifetime of the LFG collection and flaring system is expected to be 21 years (until 2026) or as long as the project is economically viable.

Currently the total installed capacity is 6.3 MW, however, there is enough potential to increase up to 10 MW. The plant generates electricity around 40,000 MWh per year, and energy consumption in the plant is around 3,000 MWh per year. The number of permanent staff at the power station is 30 people.

For the development of LFG power plants in other locations, detailed study has to be conducted. Figure 4.8.1 shows the development and expansion plan of landfills.

(Source: MARN)

Figure 4.8.1 Development and Expansion Plan of Landfills

The following table shows the estimated capacities of LFG power plants based on the “National Program for the Integrated Management of Solid Waste in El Salvador”. Based on the information of the Nejapa landfill power station, the available amount of power from solid waste is 10 MW. Therefore, the power production rate can be estimated as follows:

$$10\ (MW) \div 2000\ (t/day) = 5.0\ (kW/t)$$

Based on the power production rate, the potential capacities have been estimated as shown in the table below.

Table 4.8.1 Potential Landfill Power Generation (Excluding Nejapa)

	Landfill location	t/day	MW
Proposed landfill	Ahuachapán	100	0.5
	Santa Ana	300	1.5
	Chalatenango	50	0.3
	San Vicente	200	1.0
	Morazán	50	0.3
	La Union	150	0.8
Existing landfill	Sonsonate	250	1.3
	Usulután	200	1.0
Expansion of existing landfill	Puerto de La Libertad	50	0.3
	San Miguel	150	0.8
	Santa Rosa de Lima	80	0.4
TOTAL		1580	7.9

(Source: JICA Study Team)

4.8.1.2 Animal Waste

A. Possible Capacity of Introduction

Biogas is produced during anaerobic digestion of organic substrates such as manure, sewage sludge, and organic fractions of household and industry waste. Biogas consists mainly of methane and carbon dioxide and it can be utilized as a renewable energy source in combined heat and power plants.

a. Biogas from cattle

The potential for power generation is around 84 MW in the country. Also, the department with the highest biogas potential from cattle is La Union at around 11.6 MW.

b. Biogas from pigs

The potential for power generation is around 2.4 MW in the country. Also, the department with the highest biogas potential from pig is Cabañas at around 570 kW.

c. Biogas from poultry

The largest number of poultry is in the Central Region. In many cases, manure of poultry is mixed with vegetable manure of cattle or pigs and food waste from households. The potential for power generation is around 96 MW in the country. Also, the department with the highest biogas potential from poultry is La Libertad at around 72 MW.

4.8.1.3 Industrial Waste

Coffee Factory

In the coffee factory, which is located at Quezaltepeque City in La Libertad Department, around 15 km from San Salvador, processes coffee beans at around 3,450 t per year. The UASB reactor produces biogas at an amount of around 600-700 m^3/day. Produced biogas (methane) is burned in the flare tower, and not used as an energy source for the processing cycle in the factory.

4.8.1.4 Wastewater

According to MARN, natural water reservoirs have been polluted by industrial water and this has led to the deterioration of water quality in the country.

Water quality was monitored at 124 sites. 60% of the monitored sites were categorized as having regular water quality. In addition, 31% of the monitored sites were categorized as bad water quality and the remaining 9% were categorized as having worst water quality. In the case of worst water quality, it is possible to produce methane and other gases due to the lack of oxygen.

4.8.2 Obstructions to Introduction

For the Nejapa LFG power plant, a feasibility study has been conducted by a Canadian company under the Industrial Cooperation Program of CIDA. It is necessary to conduct feasibility studies at other landfills for further introduction. Currently, there is no law that prohibits the development of new landfill sites in El Salvador. However, all landfills have to be covered according to the Environment Law, Article No. 52 and the "National Program for the Integrated Management of Solid Waste".

4.8.3 Existing and Ongoing Related Studies and Projects

There are no existing and ongoing studies and projects related to LFG power stations in El Salvador.

4.8.4 Future Development Plan

At the Nejapa LFG power plant, there is a plan to increase the installed capacity from 6 to 10 MW depending on the financial resources. The maximum installed capacity at the Nejapa landfill will reach 25 MW in the near future.

Table 4.8.2 Future Plans of Nejapa LFG Power Station

Short–term Plan	10 MW
Long–term Plan	25 MW

(Source: JICA Study Team)

Chapter 5 Review of Power Demand Supply Forecast

5.1 Review of Demand and Supply Forecast by the Government

The Electricity Market Division of Consejo Nacional de Energía (CNE) of the Government of El Salvador conducted a demand and supply forecast in August 2011. The demand forecast was conducted for the period of 15 years from 2012 to 2026 in order to estimate the demand of each year based on annual energy generation. CNE also prepared development scenarios to meet the forecasted demand. There are seven different scenarios in estimating marginal costs for operations of the said 15 years.

5.1.1 Demand Forecast

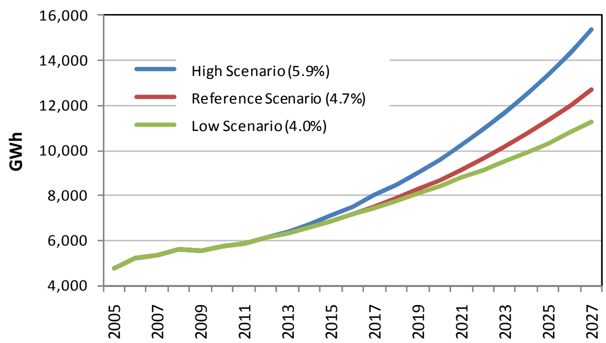
The method applied for the projection is multiple linear regression system, which applies parameters such as gross domestic product (GDP), crude oil price, electricity price and number of users.

The demand forecast is regarded as reference for three scenarios, namely “High”, “Reference”, and “Low”.

Demand forecast targeted from the years 2012 to 2026 to estimate the demand considering the following assumptions that are specific to the wholesale electricity market:

- Study Period: from 2012 to 2026 (15 years)
- Standard of constant price: 2010
- Discount Rate: 12%

By applying the above conditions, the results are as shown below.



Year	Demand Forecast Reference Scenario [GWh]	Peak Demand Reference Scenario [MW]
2005	4,744.80	829
2006	5,197.00	881
2007	5,352.60	906
2008	5,614.10	943
2009	5,574.80	906
2010	5,734.10	948
2011	5,906.10	976.2
2012	6,108.10	1,009.50
2013	6,346.30	1,048.90
2014	6,604.60	1,091.60
2015	6,877.10	1,136.60
2016	7,193.60	1,188.90
2017	7,536.60	1,245.60
2018	7,900.20	1,305.70
2019	8,283.10	1,369.00
2020	8,685.20	1,435.50
2021	9,146.30	1,511.70
2022	9,646.60	1,594.40
2023	10,179.70	1,682.50
2024	10,744.20	1,775.80
2025	11,340.80	1,874.40
2026	12,016.10	1,986.00

(Source: CNE)

Figure 5.1.1 Demand Forecast of the Three Scenarios and Values of the Reference Scenario

5.1.2 Generation Expansion Plan

5.1.2.1 Reference Scenario

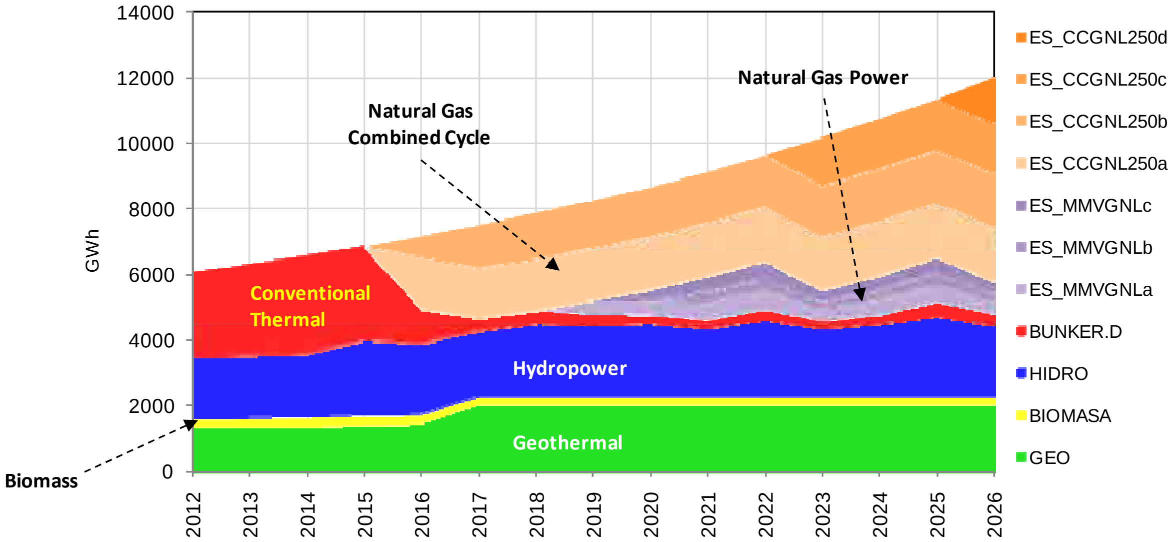
CNE conducted simulations using conditions as shown in the previous section and formulated the Indicative Generation Expansion Plan (Reference Scenario) shown in Table 5.1.1. As shown by the gray-colored cells of Table 5.1.1, the total power output of renewable energy project, including that from medium to large hydropower projects with capacities of more than 20 MW, is 289 MW, which is 18% of the total injection (1,589 MW).

Table 5.1.1 Indicative Generation Expansion Plan (Reference Scenario)

Year of Installation	Name of the Project	Power Output (MW)
2011	Expansión Ingenio El Ángel (Biomass)	15
2012	Contrato Xacbal (Hydropower)	30
2013	Expansión Ingenio La Cabaña (Biomass)	15
2015	Hidroeléctrica Chaparral (Hydropower)	66
	Optimización Geotérmica Ahuachapán (Geothermal)	5
2016	Expansión hidroeléctrica 5 de Noviembre (Hydropower)	80
	Geotérmica Berlín, Unidad 6 (Geothermal)	5
	Ciclo Combinado Gas Natural -a	250
	Ciclo combinado Gas Natural –b	107
2017	Central Geotérmica Chinameca (Geothermal)	47
	Geotérmica Berlín, Unidad 5 (Geothermal)	26
	Ciclo Combinado Gas Natural – b	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
Themal Power Subtotal		1,300
Renewable Energy Sources Subtotal		289
Total		1,589

(Source: CNE)

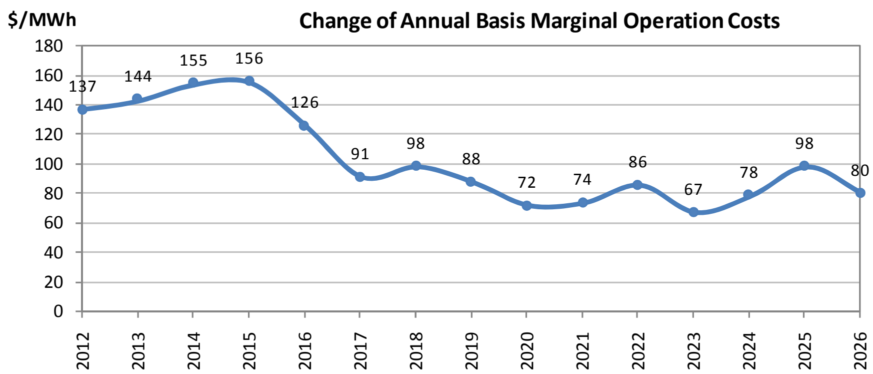
As presented in the table above, the Government of El Salvador intends to intensively promote renewable energy sources from 2011 to 2016, in order to greatly renovate the country’s energy matrix (Figure 5.1.2).



Source: CNE

Figure 5.1.2 Change of Power Generation Amount by Each Energy Source

In addition, the government intends to lower the level of power generation cost for the long-term through the aforementioned changes in power generation sources. Figure 5.1.3 presents a simulation result of annual marginal costs for operation. From the results of simulation result, it can be seen that the Government of El Salvador intends to lower the current level of generation cost of US$140-160/MWh (US¢14-16/kWh) to US$70-100/MWh (US¢7-10/kWh) by changing the energy matrix in the next five years.



Source: CNE

Figure 5.1.3 Simulation Results of Annual Marginal Operational Costs

5.1.2.2 Other Scenarios for the Generation Expansion Plan

CNE calculated marginal operational costs for six other scenarios based on the Reference Expansion Scenario (Table 5.1.2).

Table 5.1.2 List of Scenarios for Generation Expansion Plans and Marginal Cost for Operation

Scenario	Investment (US$ million)	Operational Cost (US$ million)	Total (US$ million)	Marginal Cost for Operation (US$ /MWh)
Reference	977.91	2280.2	3258.11	111
High Demand (Demanda Alta)	1062.02	2672.9	3734.92	120
Shifted Projects (Desfase Proyectos)	973.33	2302.8	3276.13	108
Cimarrón Hydropower (Cimarrón)	1028.65	2225.4	3254.05	116
Natural Gas High Input (Inversión Alta CCGNL)	1005.29	2298.5	3303.79	115
High Fuel Price (Combustibles Altos)	1002.17	2920.5	3922.67	148
Renewable Energy (Renovables)	1290.04	2138.4	3428.44	110

(Source: CNE)

Table 5.1.3 presents the power development plan of the Renewable Energy Scenario. The power output of renewable energy sources, including that of medium and large hydropower projects of more than 20 MW in capacity, are as shown in the gray-shaded cells of the table. The power output from renewable energy sources share 44% (680 MW) of the total development of 1,530 MW. This amount is more than double compared with the 289 MW presented in the Reference Expansion Plan.

Table 5.1.3 Development Plan for Renewable Energy Scenario

Year of Installation	Name of the Project	Power Output (MW)
2011	Expansión Ingenio El Ángel (Biomass)	15
2012	Contrato Xacbal (Hydropower)	30
2013	Expansión Ingenio La Cabaña (Biomass)	15
2015	Hidroeléctrica Chaparral (Hydropower)	66
	Optimización Geotérmica Ahuachapán. (Geothermal)	5
	Fotovoltaico - a	5
2016	Expansión hidroeléctrica 5 de Noviembre (Hydropower)	80
	Geotérmica Berlín, Unidad 6 (Geothermal)	5
	Ciclo Combinado Gas Natural –a	250
	Ciclo combinado Gas Natural –b	250
	Pequeña Central Hidroeléctrica – a	10
2017	Central Geotérmica Chinameca (Geothermal)	47
	Geotérmica Berlín, Unidad 5 (Geothermal)	26
	Pequeña Central Hidroeléctrica - b	10
	Fotovoltaico - b	3
	Parque Eólico	42
	Térmico Solar Concentrado	50
2018	Fotovoltaico – c	10
2021	Motores de media velocidad, gas natural	100
2022	Ciclo combinado Gas Natural – c	250
	Cimarrón	261
Themal Power Subtotal		850
Renewable Energy Sources Subtotal		680
Total		1,530

(Source: CNE)

5.1.2.3 350 MW Power Procurement Plan

The 350 MW Power Procurement Plan was prepared to achieve the "Long-term Contract through Bidding" which was announced in August 2011. Planned total procurement amount is 350 MW which consists of natural gas combined cycle, coal and renewable energy sources etc. Long-term contracts used to be concluded between generators and distributors through individual bilateral negotiations. It is intended to reduce the power procurement costs by applying bidding procedures into the long-term contract. Bidding process for "350 MW Power Procurement Plan" is coordinated by a distribution company DELSUR as a window. Bid was closed in December 2011 and the result will be announced in the first quarter of 2012. The power supply through the "350 MW Power Procurement Plan" will start from the year 2016.

5.2 Consistency of the Power Development Plan and Introduction of Renewable Energy

"Reference Scenario" consists of more than 80% of natural gas thermal power. Examinations were made by assuming the plant factor of the natural gas thermal power as 70%, it was confirmed that the power generation amount satisfied the demand for the next 15 years.

"Renewable Energy Scenario" consists of 44% of renewable energy sources (including medium to large hydro) and 56% of natural gas thermal power. At the moment, the scenario seems to have been prepared by putting maximum possible renewable energy sources and compensating the balance by natural gas thermal power. Therefore, the scenario can be regarded as consistent with the power development plan.

Chapter 6 Review of Regulations Related to Transmission and Distribution Networks

6.1 Outlines of Regulations Related to Transmission and Distribution Networks

Regarding the regulations on power transmission and distribution networks, it could be classified into four categories, i.e., laws and regulations of overall electric sector, standards for electrical interconnection, standards for operations, and specifications of electrical equipment.

Table 6.1 summarizes the laws, regulations and standards related to electric power transmission and distribution networks.

Table 6.1.1 Regulations on Electric Power Transmission and Distribution Networks

No.	Category	Documents	Objectives
1	Laws and Regulations of the Electric Sector	♦ General Electricity Law (Legislative Decree No. 843, 1996) ♦ Regulation of the GEL (Executive Decree No. 70, 1997)	**Regulates private or public activities related to the generation**, transmission, distribution, **and marketing of electric power in El Salvador.**
2	Technical Standards for Electrical Interconnection to the Transmission and Distribution Networks	♦ Technical Standards for Electrical Interconnection and End User Access to the Transmission Network (Agreement No. 30-E SIGET-2011, January 2011)	**Specifies the procedures**, requirements, **and responsibilities of electrical interconnections between operators, in order to guarantee the principle of open access to transmission and distribution facilities**, as well as **the quality and safety of the system.**
3	Technical Standards for the Operations of Transmission and Distribution Networks	♦ Regulation of Transmission System Operation and Wholesale Market based on Production Costs (SIGET Agreement No. 335-E-2011, July 2011) - Annex 10 (Operation in Real Time) - Annex 12 (Quality and Operational Safety Standards) ♦ Standards for the Quality of Service of Distribution Systems (SIGET Agreement No. 192-E-2004, December 2004) - The quality of the supply or service provided (interruptions) - The quality of the technical product being supplied (levels of voltage, disturbances in the voltage wave) - The commercial service quality (customer service, customer service channels, accuracy of measuring equipment)	Definition of technical standards, methods and/or procedures developed by the UT for operations of the transmission system, taking into account issues of quality and safety. Regulates the ratings and benchmarks used to assess the quality with which electricity distribution companies provide electricity services to the users of the distribution network.
4	Technical Specifications of Electrical Equipment	♦ National Electrical Code of the United States of America (NEC), Spanish edition, 2008 (NFPA 2008). ♦ Policy for the Construction of 46 kV, 23 kV, 13.2 kV, 4.16 kV and 120/240 V Networks (Agreement No. 66-E SIGET-2001, March 2001)	Contains the safety and quality requirements for all natural or legal persons that are involved in the design, construction, supervision, operation and maintenance of electrical installations.

(Source: JICA Study Team)

6.2 Issues of Current Regulations Related to Transmission and Distribution Networks when Introducing Renewable Energy into Networks

Following to the results on review of the laws, regulations and standards on power transmission and distribution networks, connection problems of power generation projects running on renewable energies are explained into the following three categories;

1) Issues of small hydropower introduction,
2) Issues of unstable power source introduction (such as solar PV and wind), and
3) Issues of other power sources (geothermal, biomass, etc.)

6.2.1 Issues of Small Hydropower Introduction

Small hydropower (SHP) has variation of generating energy due to river run-off condition, but it is possible to supply a stable energy to the networks in rainy season. The main issues for grid connection on the introduction of SHPs with capacity up to 20 MW are mentioned in Table 6.2.1.

Table 6.2.1 Issues of Small Hydropower Introduction

No.	Category		Description	Issues in current regulations
1	Permissions for grid-connection		SHP projects up to 20 MW are commonly connected to the transmission and distribution networks in the Medium Voltage (MV) (13.2 kV, 23 kV, 46 kV). In case small hydropower generation up to 20 MW connected to the distribution networks, the distribution company can modify and adapt their facilities (feeders, transformers, etc.)	None.
2	Normal operation	Voltage regulation	Synchronous generators have advantages of adequate voltage control through their excitation systems by injection and absorption of the reactive power. In case synchronous generators used in distributed generation, voltage control is not performed but only constant power factor control is performed (poor voltage control). On the other hand, induction generators need capacitors for starting operation because induction generators consume reactive power, and do not perform voltage regulation.	To comply with SIGET standard, it is necessary for small hydropower generators to actively regulate the voltage at the connection point (point of common coupling; PCC).
3		Electrical losses	In general, SHPs can reduce electrical losses in the neighboring transmission and distribution networks. The SHPs used as distributed generation could increase electrical losses depending on their location and size of generation.	Therefore it is necessary to define regulations on the size of SHPs to be connected to distribution networks to avoid electrical loss increase.
4	Abnormal operation	Islanding operation	Generation systems could possibly be operated as islanding operation in case of isolated systems in rural areas (off-grid). But in case of distributed generation operation, it is prohibited to adopt islanding operation (for example, after a failure) intentionally or unintentionally.	There are no regulations regarding the islanding operation of generators connected to distribution networks.
5		Protection schemes	SHPs have basic protection schemes related to minimum and maximum voltage, minimum and maximum frequency, over current, among others . The technical standard of interconnection of SIGET states that protection coordination studies must be made when generators are connected to distribution and transmission networks.	There are technical standards for protection schemes in the current regulations, but it is necessary to define unintentional islanding protection schemes for distributed generation
6		Voltage fluctuation	There have been no reported problems on voltage fluctuation caused by SHPs.	None.
7	Power Quality	Voltage flicker	There have been no reported problems on voltage flicker caused by SHPs.	None
8		Harmonic distortion	There have been no reported problems on o Harmonic distortion caused by SHPs.	None
9	Other issues	Mainte-nance	Synchronous generators require more complex control than induction generators, both for synchronization with the transmission and distribution systems, and for controlling excitation system.	The standard for interconnection of SIGET states that it is necessary to do the maintenance activities to meet the technical and safety standards.

(Source: JICA Study Team)

6.2.2 Issues of Unstable Power Source Introduction (such as Solar PV and Wind)

Solar PV and wind energies follow the availability of natural resources, like the sun and wind, which depend on weather factors. Such energies are classified as unstable power sources due to their intermittent energy generation. The main issues on the introduction of unstable power sources, such as solar PV and wind, are discussed below.

Table 6.2.2 Issues of Unstable Power Sources Introduction, such as solar PV or wind

<table>
<tr><th>No.</th><th colspan="2">Category</th><th>Description</th><th>Issues in current regulations</th></tr>
<tr><td>1</td><td colspan="2">Permissions for grid-connection</td><td>Small solar PV energy projects are commonly connected to the distribution networks in Low Voltage (LV) levels less than 600 V (NEC 2008). Most solar PV projects are connected to the distribution networks in MV levels of 13.2 kV and 23 kV.
There are currently no wind energy projects connected to the electric system, but it is expected the connection to the distribution networks in MV (13.2 kV, 23 kV, 46 kV).
The technical standard of interconnection of SIGET allows connection to any of the networks (transmission and distribution) and when solar PV or wind generators (up to 20 MW) connected to the distribution networks, the distributor can modify and adapt their facilities for connection.</td><td>None.</td></tr>
<tr><td>2</td><td rowspan="2">Normal operation</td><td>Voltage regulation</td><td>The technologies used in generating units of solar PV energy are based on static inverters. These technologies are programmed to produce only active power while interconnected and it results in a unity power factor. Inverter technology has evolved to IGBT switching schemes which are able to control power factor and limit harmonics.
The technologies of the generating units involved with wind energy are classified as static inverters, synchronous and asynchronous (or induction) generators.
Technical standard of quality of SIGET defines the maximum voltages deviations in MV as urban zone: ±6%, rural zone: ±7% and isolated system: ±8.5%, and in as urban zone: ±7%, rural zone: ±8% and isolated system: ±8.5%.</td><td>To comply with SIGET standard, it is necessary for solar PV and wind generators to actively regulate the voltage at the connection point (point of common coupling; PCC).</td></tr>
<tr><td>3</td><td>Electrical losses</td><td>In general, solar PV and wind energy generators can reduce electrical losses in the neighboring distribution networks.
The solar PV and wind generators used as distributed generation could increase electrical losses depending on their location and size of generation.</td><td>It is necessary to define regulations on the size of solar PV and wind generators to be connected to distribution to avoid electrical loss increase.</td></tr>
<tr><td>4</td><td rowspan="3">Abnormal operation</td><td>Islanding operation</td><td>In case of distributed generation operation, it is prohibited to adopt islanding operation (for example, after a failure) intentionally or unintentionally.</td><td>There are no regulations regarding the islanding operation of generators connected to distribution networks.</td></tr>
<tr><td>5</td><td>Protection schemes</td><td>Solar PV generators have basic protection schemes related to minimum and maximum voltage, minimum and maximum frequency, inverse power, among others . Wind generators have basic protection schemes similar to solar PV generators, but it could be necessary additional protection for asynchronous machines.
The technical standard of interconnection of SIGET states that protection coordination studies must be made when generators are connected to distribution and transmission networks.</td><td>There are technical standards for protection schemes in the current regulations, but it is necessary to define unintentional islanding protection schemes for solar PV and wind generators which are connected to the distribution networks.</td></tr>
<tr><td>6</td><td>Voltage fluctuation</td><td>In distribution networks, the effect of switching of a large load causes voltage fluctuation, which is similar to the effect that generation output power variation has.
The output power variations of solar PV and wind generators are subject to daily and seasonal variations.
On the other hand, the dynamic voltage restorer used in energy storage devices provides technically advanced solution to compensate voltage sag in distribution systems.</td><td>There are no regulations regarding the voltage fluctuation of generators connected to distribution networks.</td></tr>
<tr><td>7</td><td rowspan="2">Quality Power</td><td>Voltage flicker</td><td>In distribution networks the most common cause of voltage flicker is a rapid variation of load current in solar PV and wind generators.
In particular, wind generators have been seen as potential cause of voltage flicker due to wind turbine variations or power output variation. However, the design of modern wind turbines has been changed such that large variations of the output power within a short time period can be effectively avoided (variable speed).
Technical standard of quality of SIGET defines the maximum short time flicker perceptibility (Pst) as 1 for MV and buses or nodes.</td><td>There are technical standards for voltage flicker in the current regulations, but it is necessary to define responsibilities for flicker emission in LV connections.</td></tr>
<tr><td>8</td><td>Harmonic distortion</td><td>The harmonics of concern from classical static inverters were the low-order odd harmonics (third, fifth, seventh, etc.). Nowadays, the harmonics of concern from IGBT switching inverters are the high-order harmonics, for</td><td>There are technical standards for harmonic distortion in the current regulations, but it is necessary to review</td></tr>
</table>

			example 25th, 35th, and higher. Technical standard of quality of SIGET defines the maximum total harmonic distortion of voltage and current in buses or nodes as 8% and 20%, respectively.	current limits for connection due to avoid damage in equipments of the end-users facilities.
9	Other issues	Mainte nance	Low maintenance in solar PV panels and asynchronous (induction) machines of wind generators.	The technical standard for interconnection of SIGET states that it is necessary to do the maintenance activities to meet the technical and safety standards.

(Source: JICA Study Team)

6.2.3 Issues of Other Power Sources (Geothermal, Biomass, etc.)

Geothermal generation in El Salvador is classified as conventional generation since it has the most presence in the current power dispatch. Other renewable power sources such as biomass and biogas have been developed in El Salvador and are classified as alternative energy source against fossil fuel. E.g., bagasse for biomass energy is exploited in harvest season of sugarcane.

The main issues on the grid connection of geothermal, biomass and biogas are discussed below.

Table 6.2.3 Issues of other power sources (geothermal, biomass, etc.)

No.	Category		Description	Issues in current regulations
1	Permissions for grid-connection		Geothermal generation would mainly be connected to the transmission networks. Biomass generation can be developed from a few MW to high capacities (greater than 20 MW). Biogas generation can be developed up to 25 MW. Biomass and biogas generation could be connected to distribution networks in MV levels of 13.2 kV, 23 kV and 46 kV. The technical standard of interconnection of SIGET allows connection to any of the networks (transmission and distribution) and when small generators (up to 20 MW) connected to the distribution networks, the distributor can modify and adapt their facilities for connection.	None.
2	Normal operation	Voltage regulation	Geothermal generation uses synchronous generators which present an adequate tension control. Concerning the biomass or biogas systems they may use asynchronous and synchronous generators, depending on the capacity. Technical standard of quality of SIGET defines the maximum voltages deviations in MV as urban zone: ±6%, rural zone: ±7% and isolated system: ±8.5%.	To comply with SIGET standard, it is necessary for biomass and biogas generators to actively regulate the voltage at the connection.
3		Electrical losses	In general, geothermal generation can reduce electrical losses in the neighboring transmission and distribution networks. The biomass and biogas generation connected in distribution networks could increase electrical losses depending on their location and size of generation.	Therefore it is necessary to define regulations on the size of biomass and biogas to be connected to distribution networks to avoid electrical loss increase.
4	Abnormal operation	Islanding operation	Generation systems could possibly be operated as islanding operation in case of isolated systems in rural areas (off-grid). But in case of distributed generation operation in biomass and biogas projects, it is prohibited to adopt islanding operation (for example, after a failure) intentionally or unintentionally.	There are no regulations regarding the islanding operation of generators connected to distribution networks.
5		Protection schemes	The geothermal generation has very complex protection devices for the generators and other components. The biomass and biogas generation has basic protection schemes. The technical standard of interconnection of SIGET states that protection coordination studies must be made when generators are connected to distribution and transmission networks.	There are technical standards for protection schemes in the current regulations, but it is necessary to define unintentional islanding protection schemes for connections in distribution networks.
6		Voltage fluctuation	There have been no reported relevant problems on voltage fluctuation caused by geothermal, biomass and biogas.	None.
7	Power Quality	Voltage flicker	There have been no reported relevant problems on voltage flicker caused by geothermal, biomass and biogas.	None
8		Harmonic distortion	There have been no reported relevant problems on harmonic distortion caused by geothermal, biomass and biogas.	None
9	Other issues	Mainte-nance	In biomass and biogas generation, synchronous generators require more complex control than induction generators, both for synchronization with the transmission and distribution systems, and for controlling excitation system.	The standard for interconnection of SIGET states that it is necessary to do the maintenance activities to meet the technical and safety standards.

(Source: JICA Study Team)

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. 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.

7.1.1 Preparation of Wind Power Potential Map

7.1.1.1 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 (500m 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 (30m, 50m and 80m 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.

7.1.1.2 Weather Simulation Model for Evaluation of Wind Potential

A. Weather Research and Forecasting Model (WRF Model)

On the basis of WRF Model[1], annual wind power potential was simulated in this study. 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 8784 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

1 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.

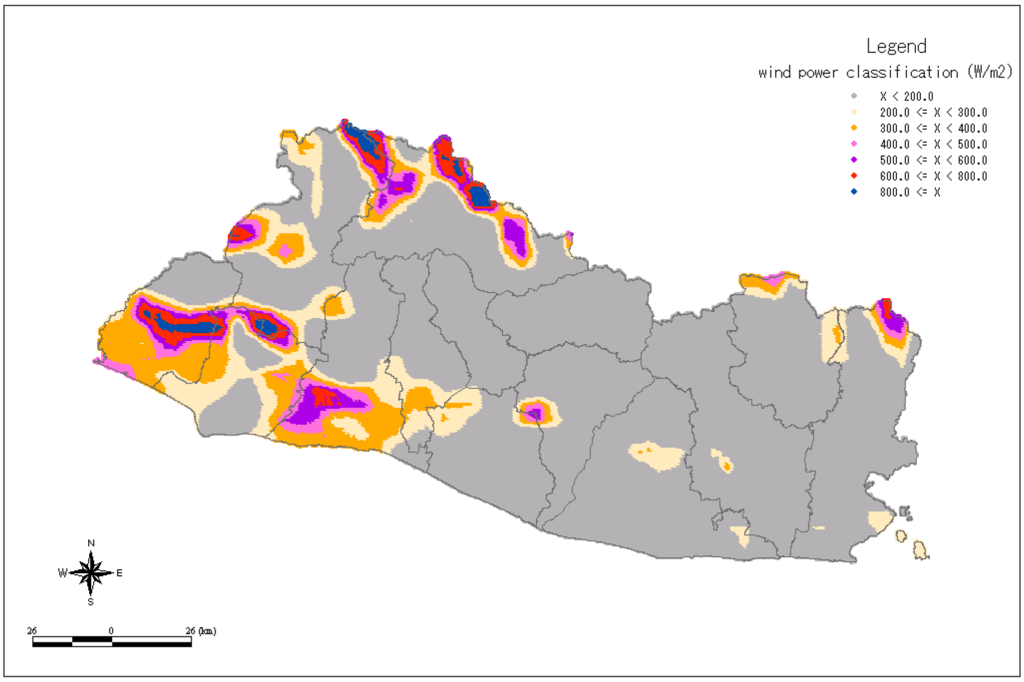
value and boundary value for weather simulation by WRF. Data of terrain and land-use are included in WRF Model which prepared by United States Geological Survey (USGS).

B. MASCON Model

On the basis of the results of calculation on wind speed in each 5km horizontal mesh by WRF Model, wind potential data which cover nationwide of the country area by 500m 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 500m which prepared by digital data of SRTM was used for the topography altitude level.

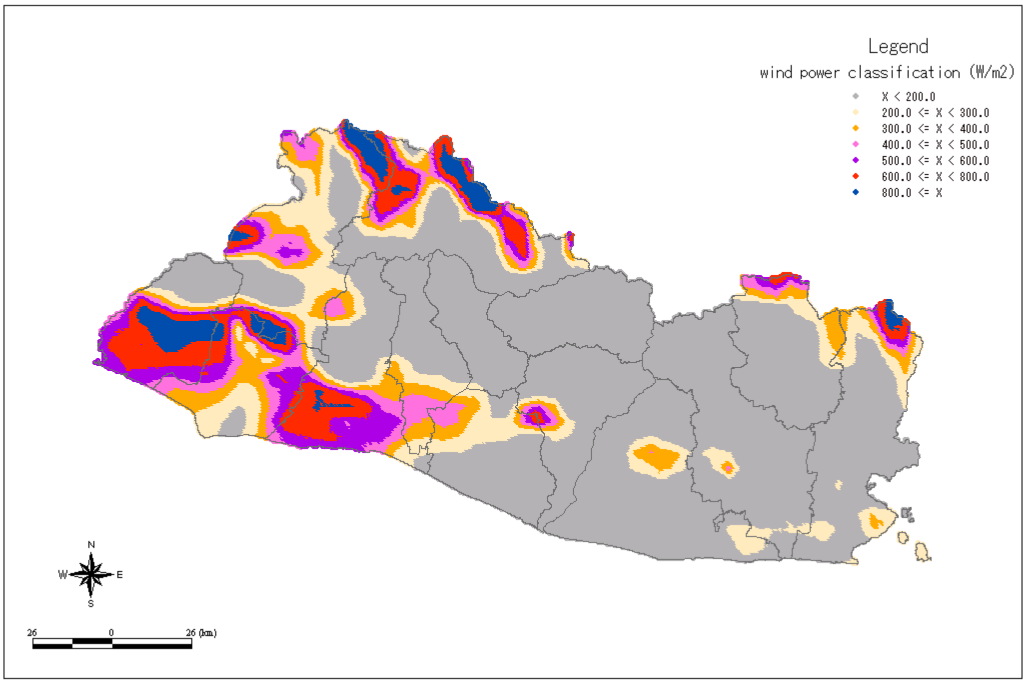
7.1.2 Wind Power Potential Map

The height of wind potential maps which prepared in the studies are 30m, 50m and 80m 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 50m 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. Nationwide wind potential maps of El Salvador are as shown in the below.



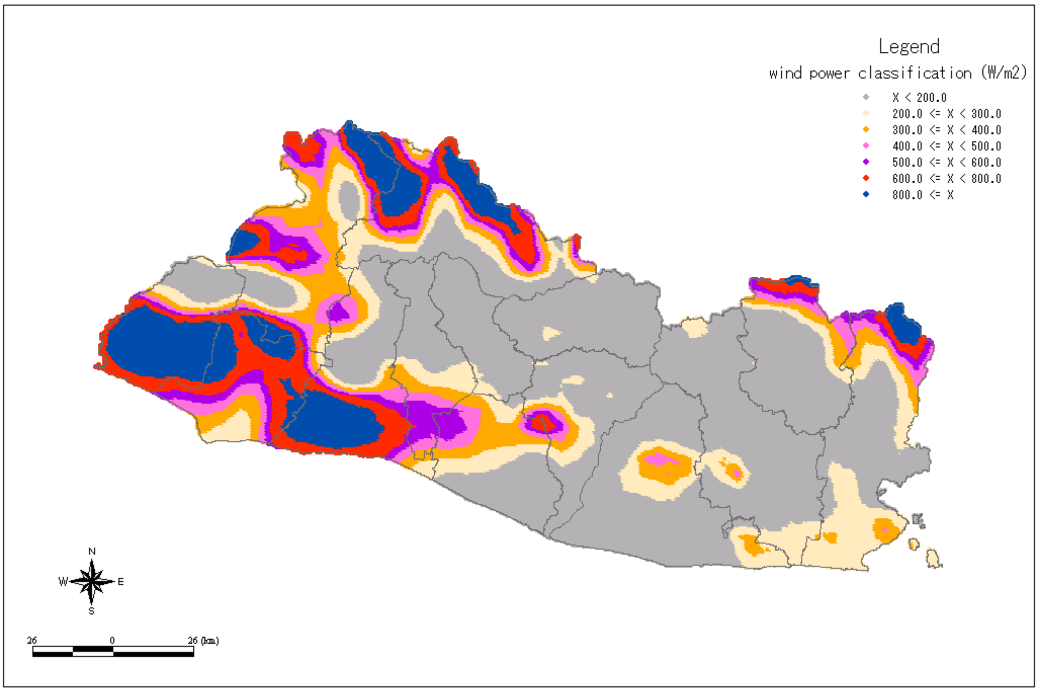
(Source: Japan Weather Association)

Figure 7.1.1 Wind Potential Map of El Salvador (30m above ground level)



(Source: Japan Weather Association)

Figure 7.1.2 Wind Potential Map of El Salvador (50m above ground level)



(Source: Japan Weather Association)

Figure 7.1.3 Wind Potential Map of El Salvador (80m above ground level)

7.1.3 Analysis Results

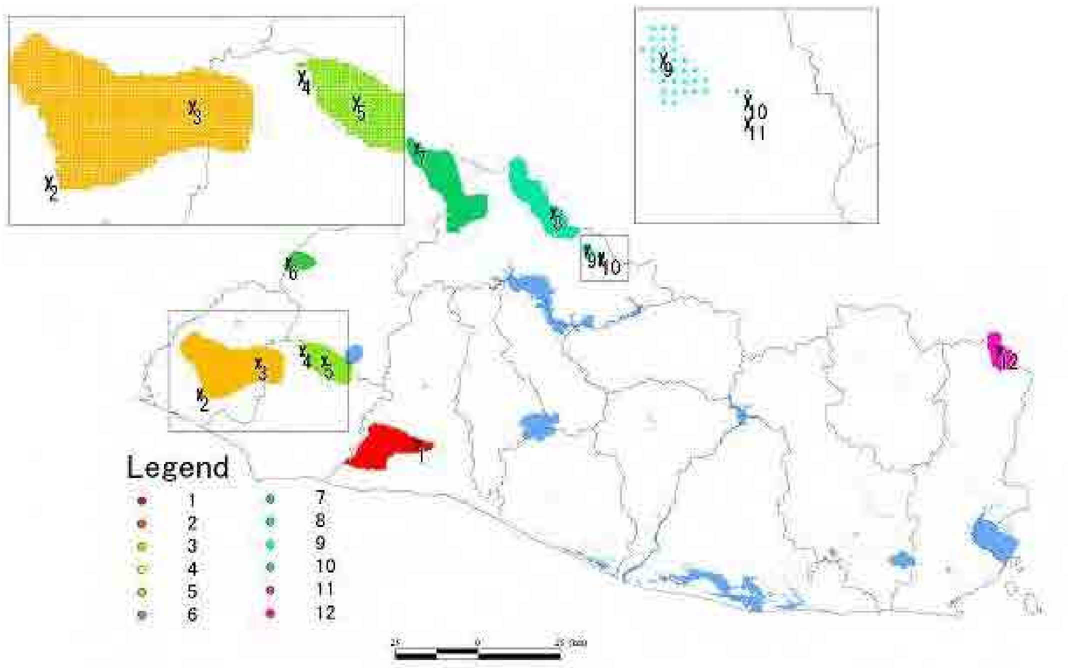
7.1.3.1 Wind Power Potential

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)

7.1.3.2 Wind Power Potential Sites

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 show 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 7.1.4 Wind Potential Sites

Wind speed and potentials at 30m, 50m and 80m above ground level are shown in Table 7.1.1.

Table 7.1.1 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	30m	50m	80m	30m	50m	80m
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)

7.1.3.3 Comparison to Monitoring Data

In area of existing weather stations, the example 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 7.1.2 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

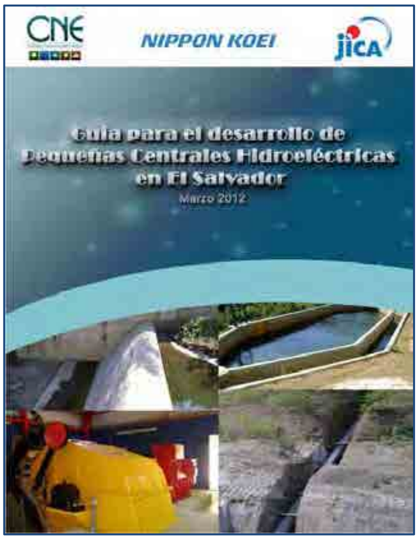
(Source: Japan Weather Association)

7.1.4 Consideration

- The installation of the wind monitoring system: It is necessary to install wind monitoring tower to monitor wind characteristics in the wind potential sites.
- Wind characteristics data analysis: It is necessary to analyze the data which monitored, and to select suitable area for introduction of wind generation system.
- 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 with a capacity of less than 20 MW were were prepared only in Spanish, separate from the main report.



7.2.1 Outline of the Guidelines to be Prepared

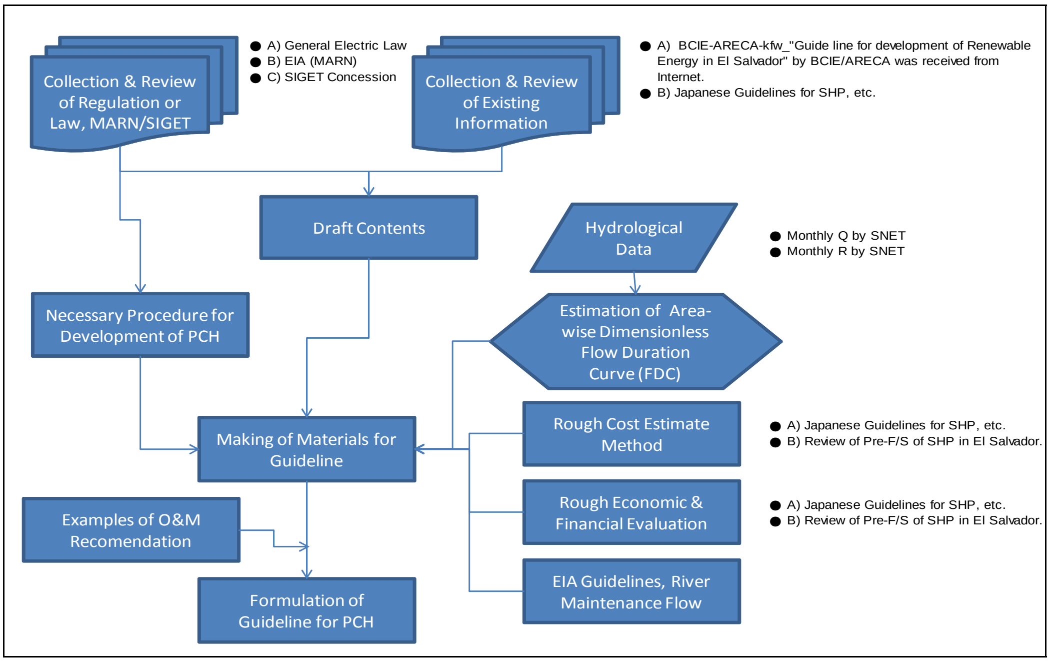
The guidelines include the following items:

a. Introduction
b. Necessary Procedure for Development of PCH
c. Plan Formulation & Evaluation of PCH Project
d. O&M of PCH Project
e. Recommendations
f. Attachments (Format of Procedure for SIGET, MARN)

7.2.2 Guidelines for the Promotion of Small Hydropower

7.2.2.1 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. 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.



(Source: JICA Study Team)

Figure 7.2.1 Flow of Guideline Formulation and Related Technical Aspects

7.2.2.2 Procedure on 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)

7.2.2.3 Contents of Guidelines

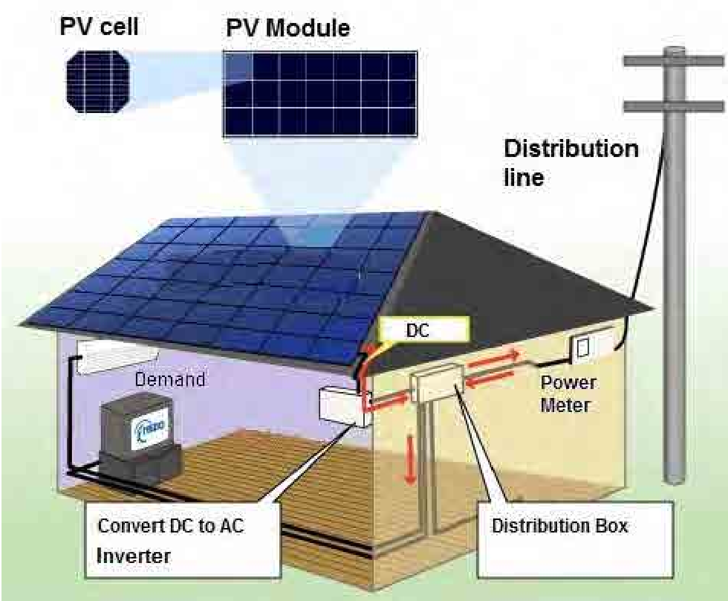
The contents of the guidelines are shown below:

Guidelines for the Development of Small Hydro Power in El Salvador

Table of Contents

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

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.

7.3.1.2 Estimated Price and Installed solar PV system

The current price of rooftop solar PV system with 2 kW capacity was 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 include 2kW PV modules, 2kW, AC120V, inverter, mounting structure, electrical accessories, labor, etc.)

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.

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 summarized below.

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.

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

The target of the roadmap of technology development on solar PV systems, which is prepared by the New Energy and Industrial Technology Development Organization (NEDO), Japan, is to decrease the power generation cost by improving the module conversion efficiency and production capability. 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.

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. The number of systems serves around 0.55% of the national population. Considering the price of rooftop solar PV systems, future installed capacity is estimated as shown in the table below.

Table 7.3.1 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

Following issues and countermeasures of electricity quality should be examined.

A. Over / Under Voltage

B. Harmonics

C. Unintended Islanding

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.

A. Strength Examination of Building Structure

B. Shading

C. Confirmation with Customer

7.3.4 Issues and Countermeasures on Institutional Aspects

El Salvador relies on tax incentives to support renewable. There is a “Tax Incentives Act to Promote Renewable Electricity Generation, Legislative Decree No.: 462,”which was issued in December 2007 in El Salvador. The exemption from payment of customs duties referred to in the preceding paragraph shall apply to projects of up to 20 MW, and must be requested from the Ministry of Finance 15 days prior to importation.

The following shows necessary regulations or laws for the dissemination of rooftop solar PV system.

A. FIT

B. Tradable Green Certificates (TGC)

C. Renewable Energy Portfolio Standard (RPS)

D. Loan Softening and Guarantees

E. Tendering Schemes

7.3.4.1 Human Resource Development

Further time is needed 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.

7.3.4.2 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.

A pilot project related to rooftop solar PV systems with a capacity of 540 kW has been prepared by CEL. In the project, rooftop solar PV system will be installed at public facilities such as schools, hospitals and government institutions. It is expected to accumulate necessary data and experiences on rooftop solar PV system. Moreover, it is good opportunity to raise awareness of environment and energy issues by appropriate informative activity in the country.

7.3.5 Roadmap for Introduction

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.

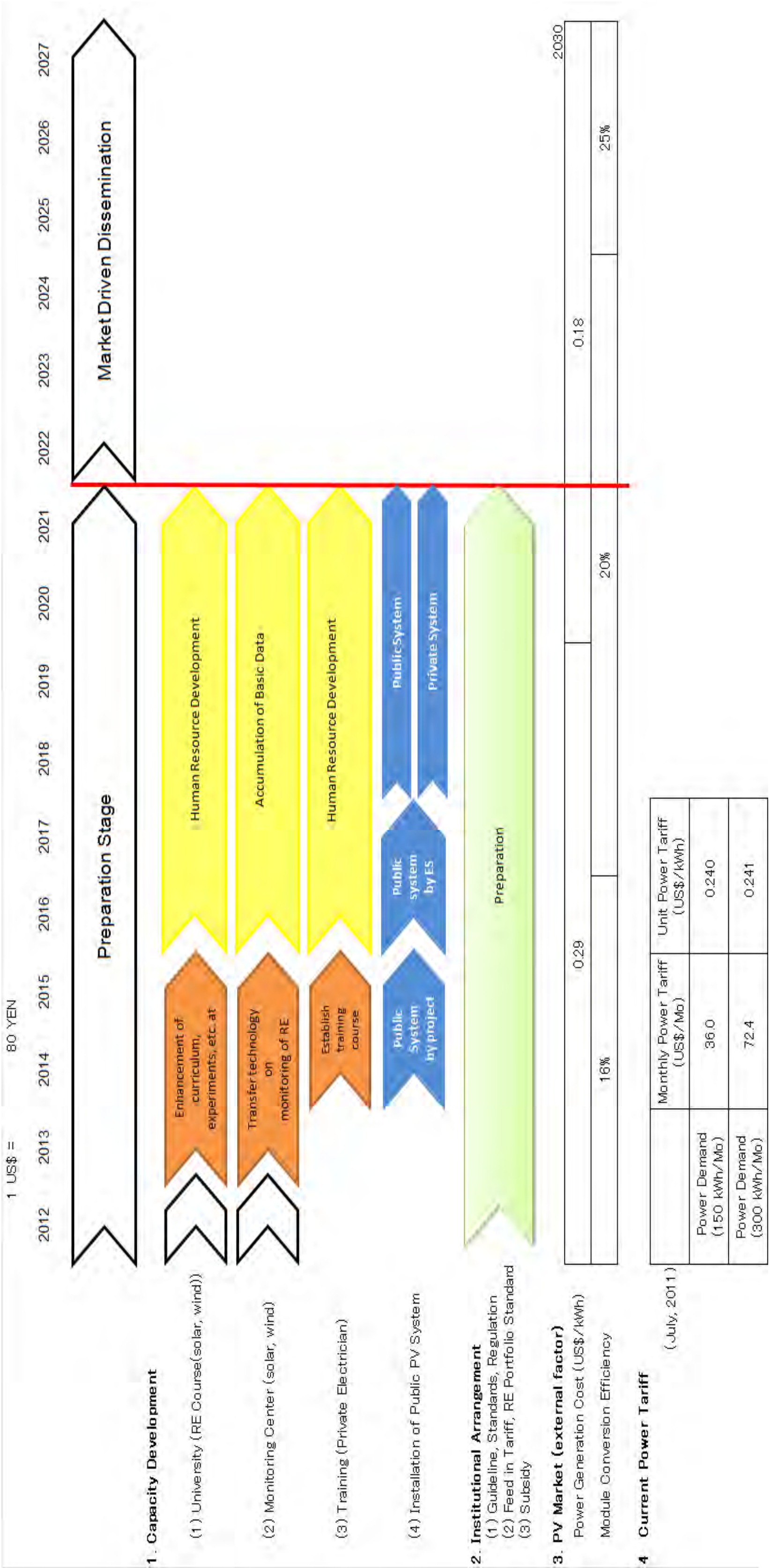
Institutional arrangement

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 roadmap for introduction of solar PV and other renewable technologies.



(Source: JICA Study Team)

Figure 7.3.2 Roadmap for Introduction of Solar PV

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

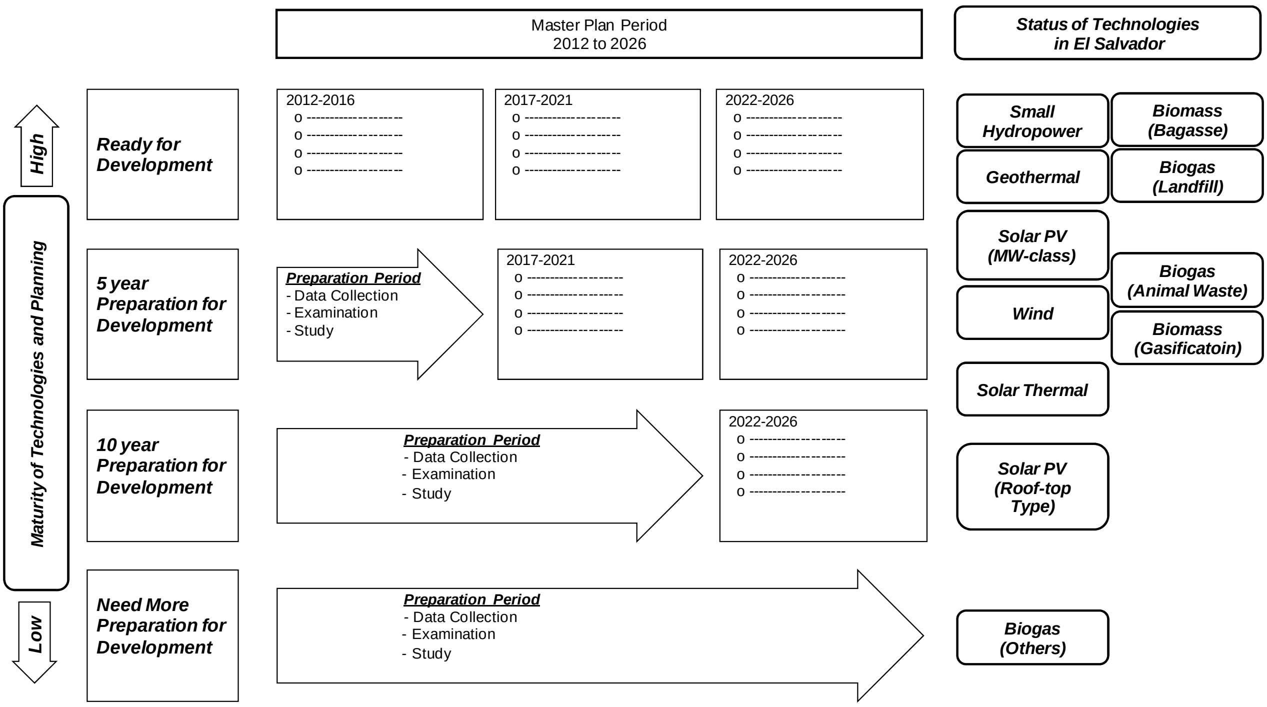
Based on the results of studies and examinations conducted, examinations will be made on the possibility of renewable energy introduction in El Salvador. Such examinations will be made on three aspects namely, “Technical,” “Economic and Financial,” and “Environmental.”

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 results of available materials, 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.



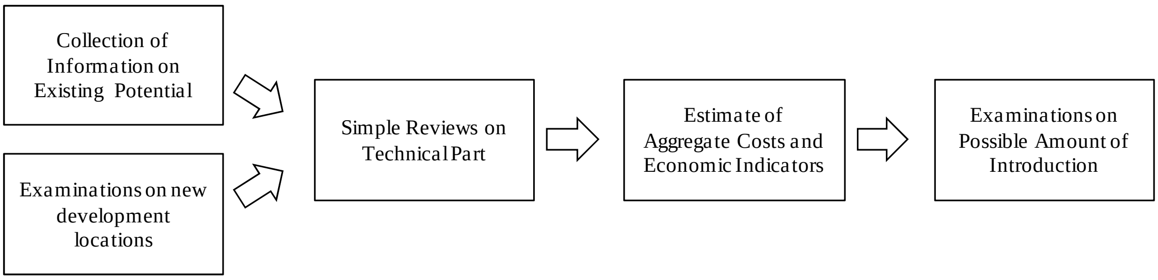
(Source: JICA Study Team)

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.



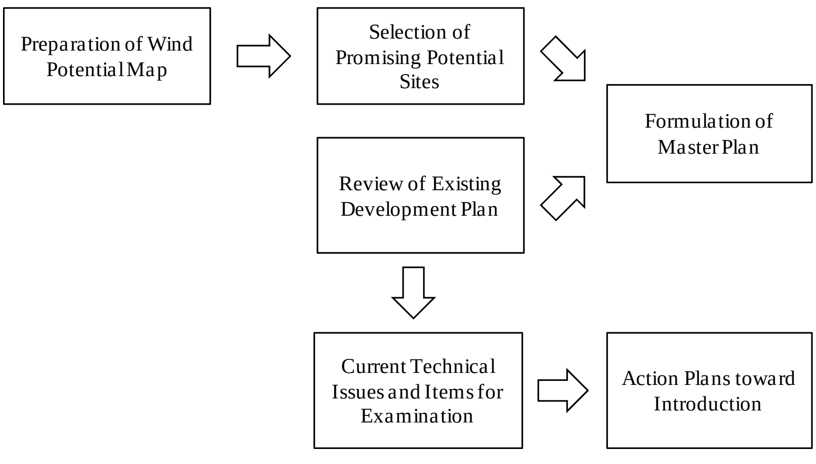
(Source: JICA Study Team)

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 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.



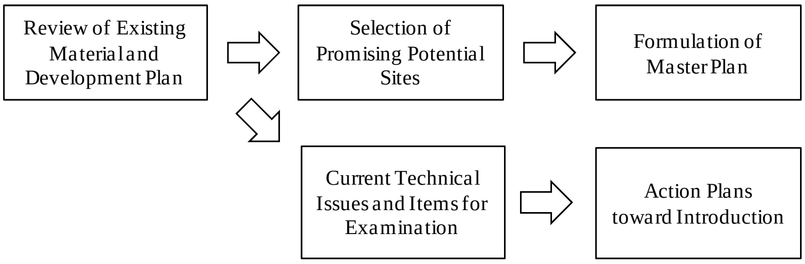
(Source: JICA Study Team)

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.

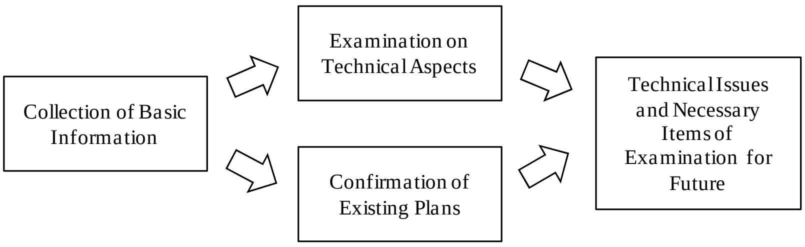


(Source: JICA Study Team)

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.

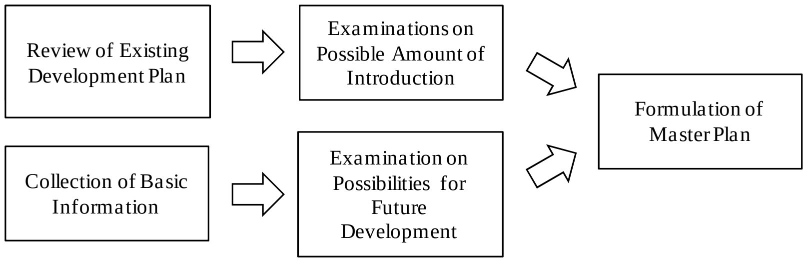


(Source: JICA Study Team)

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

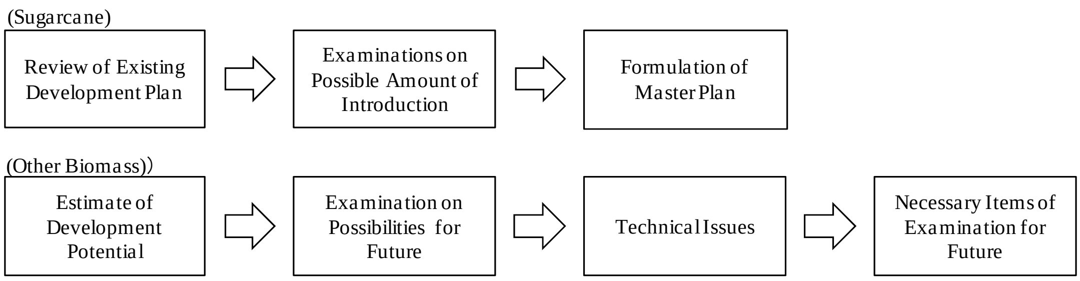
8.1.6 Biomass

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.

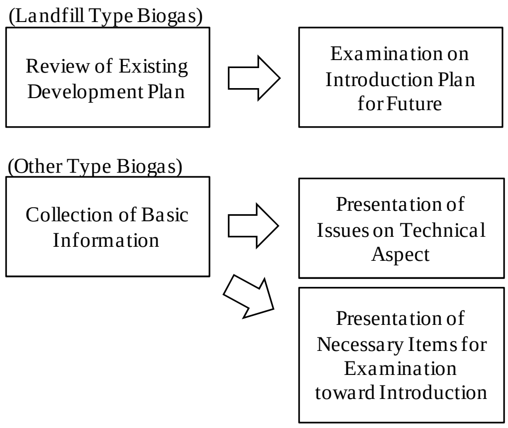


(Source: JICA Study Team)

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)

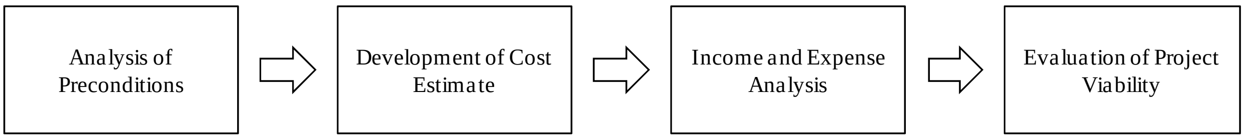
Figure 8.1.8 Flow of Technical Examination on Biogas Development

8.2 Economic and Financial Analysis

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

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

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

Table 8.2.1 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

The above typical analysis is carried out by the assumption of electricity sales price at the $ 140/MWh. In addition to this, 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)

Table 8.2.2 Evaluation Results by Case Study

Type of Energy	Case Study	Pre-conditions							Calculation Result						Overall Evaluation
									A.Unit Price ($140/MWh)			B.Unit Price ($100/MWh)			
		Plant Capacity (MW)	Capacity Factor (%)	Plant Cost ($000)	Inter-Connection Cost ($000)	O/M Cost		Tax Exemption (year)	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)

8.2.5 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.

8.3 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 the these, the Study Team has identified the following obstacles which must be breached in order to promote the said projects:

(1) Political Barriers

- Lack of a basic framework, which includes socio-environmental aspects within the national energy policies, 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), which focuses solely on renewable energies.

As a direct result of these obstacles, it is very difficult for any related institutions and even private sectors, to have a clear vision on how to promote the introduction of renewable energies.

(2) Institutional Barriers

- Lack of MARN experts on renewable energy.
- Lack of an environmental unit and a team of environmental experts at the National Energy Council (CNE), regardless of Articles 6 and 7 of the Environmental Act stating the need to create such unit in each of the related agency.
- Lack of an environmental unit and team of environmental experts at the General Superintendence

of Electricity and Telecommunications (SIGET), regardless of Articles 6 and 7 of the Environmental Act stating the need to create such unit in each of the related agency.

- 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.

As a consequence of these obstacles, it would be hardly possible for institutions directly involved with renewable energy to have the necessary or basic knowledge on socio-environmental matters pertaining to renewable energy.

(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 scoping and impacts that are expected to affect the socio-environment as a result of the development of renewable energy in El Salvador:

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 Act 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 here would be to optimize government resources and speed up the authorization processes for the ToR from projects regarding renewable energy sources.
- The State should be 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 geared towards the transfer of technologies from the renewable energy resources, aiming to enrich the abilities of technicians to develop these projects.
- The State 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 State should support the generation 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

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

Chapter 9 Recommendations on Further Promotion of Utilization of Renewable Energy

9.1 Recommendations on Future Directions of Development based on the Study Results

Based on the results derived from the study, recommendations on the future directions are compiled on (1) renewable energy development in general and (2) each renewable energy source. Recommendations are categorized into three aspects of (1) Technical, (2) Economic and Financial and (3) Environmental as shown in Table 9.1.1.

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

Master Plan (Draft) 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

There are energy sources that require further examinations or pilot projects prior to introduction because the technologies or conditions of the market are 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

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.

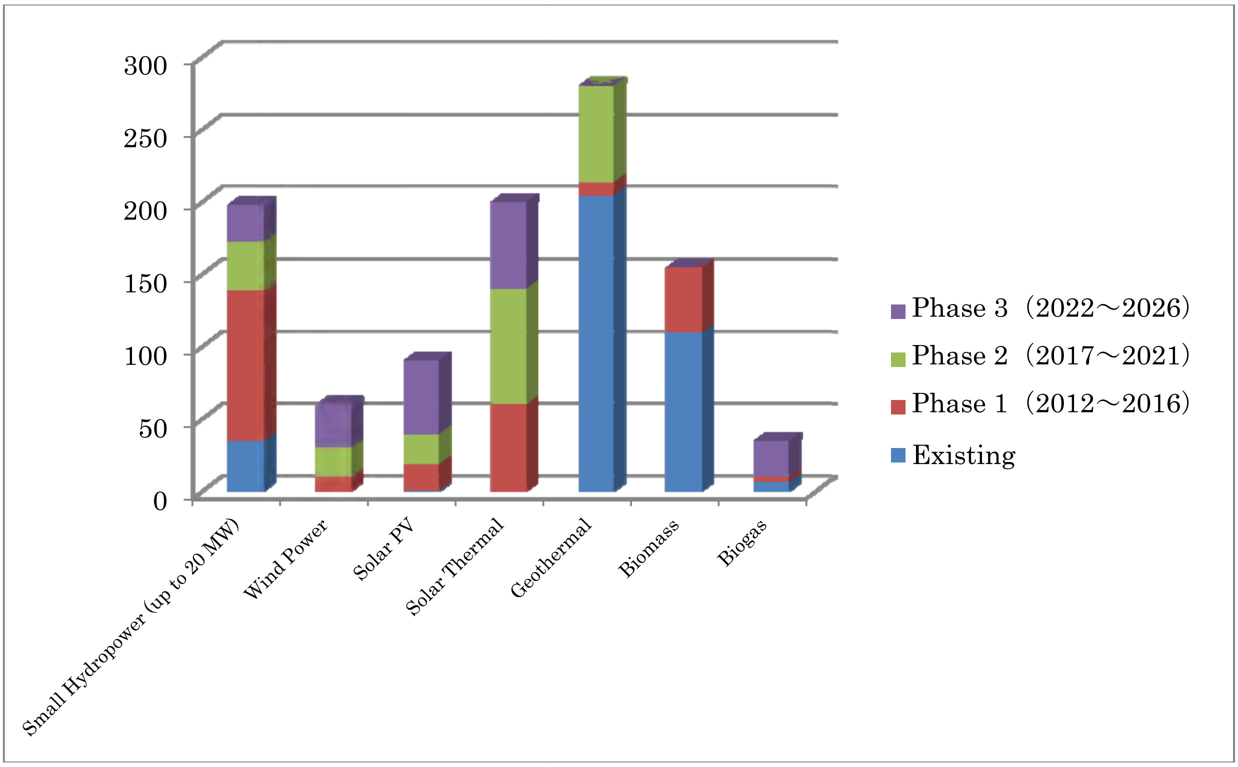
In this master plan study, renewable energy parts of the Indicative Development Plan for the next 15 years from 2012 to 2026 are presented. As the electricity supply system applies market mechanism, no prioritization were made for individual energy sources, but to present expected capacity of introduction 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 10.2.1.

Table 10.2.1 Indicative Development Plan (2012 to 2026)

Type of Energy	Existing	Phase			
		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 10.2.1 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.

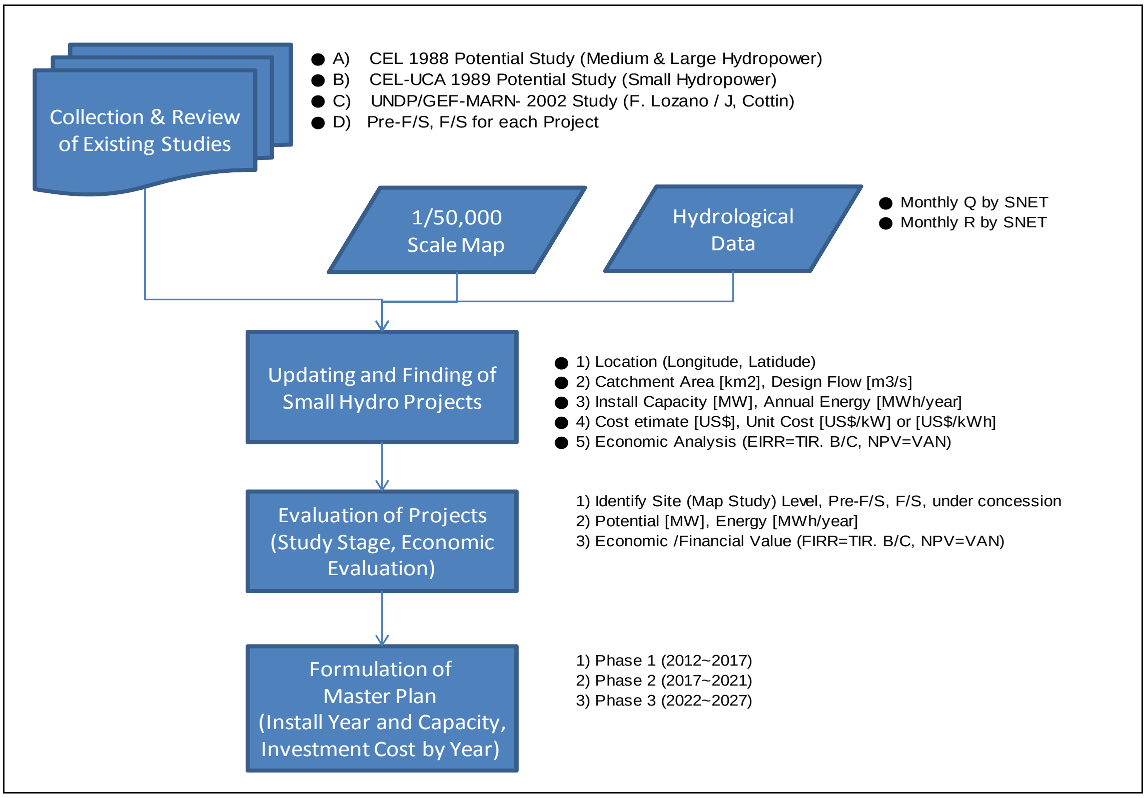
10.3 Master Plan for Each Renewable Energy Source

10.3.1 Small Hydropower

Based on information about the existing potential sites and the newly identified potential sites through desk studies, simple technical reviews were conducted. After estimation of the aggregate development costs, economic viabilities of development sites were examined at master plan study level. By using the result of the investigation, development plans were prepared for the target master plan periods (15 years from 2012 to 2027) of five years for each of the three phases.

10.3.1.1 Workflow of Master Plan Formulation for Small Hydropower Projects

The workflow of master plan formulation for small hydropower development is shown in Figure 10.3.1.



(Source: JICA Study Team)

Figure 10.3.1 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.

10.3.1.3 Findings and Evaluation of New Potential Sites

In this 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.

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.

10.3.1.5 Cost Estimate of Potential Sites

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, 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.

10.3.1.6 Financial Evaluation of Potential Sites

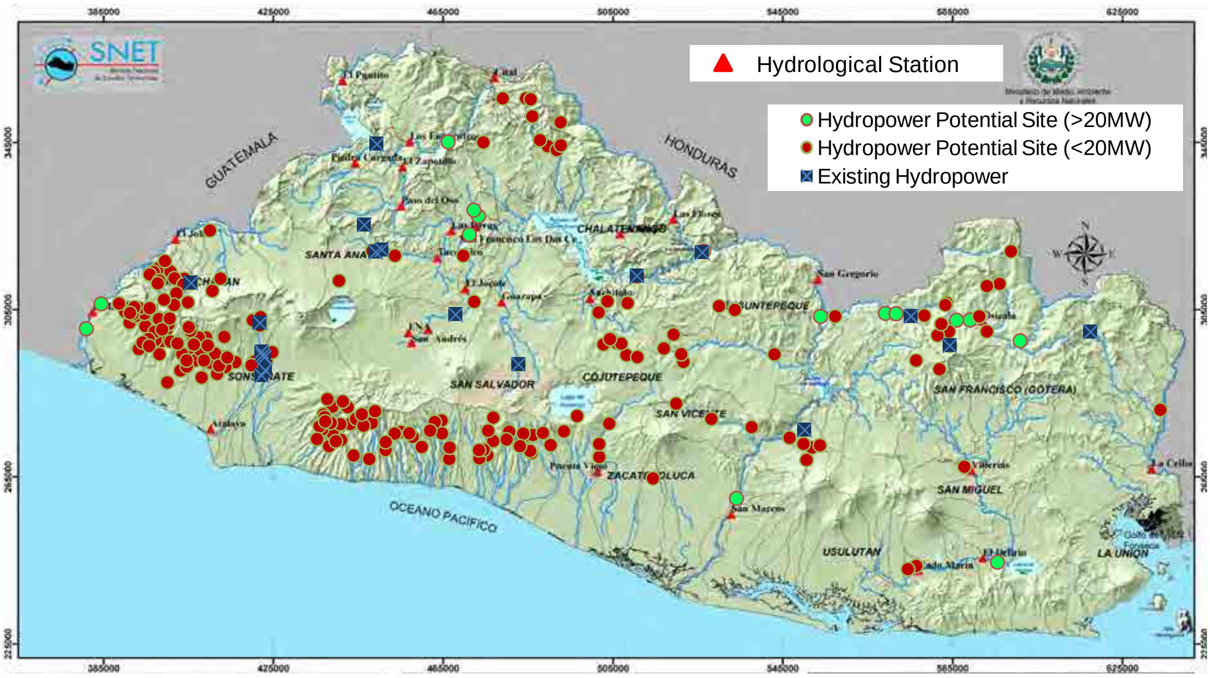
The project financial analysis “without” and “with” bank loan cases were carried out on the evaluation of the base case scenario of the project and on the more accurate financing cases using bank loan.

10.3.1.7 Optimization of Design Discharge for Potential Sites

Design discharge was selected based on the optimum B-C (or NPV) value resulting from the project financial analysis of the ’with bank loan’ case.

10.3.1.8 Potential Sites for Small Hydropower Plants

There are 209 sites in total that were identified. The total capacity is estimated at 180.8 MW 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 10.3.2 Location Map of Hydropower Potential Sites

10.3.1.9 Master Plan for Small Hydropower

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 are adopted.

Table 10.3.1 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.

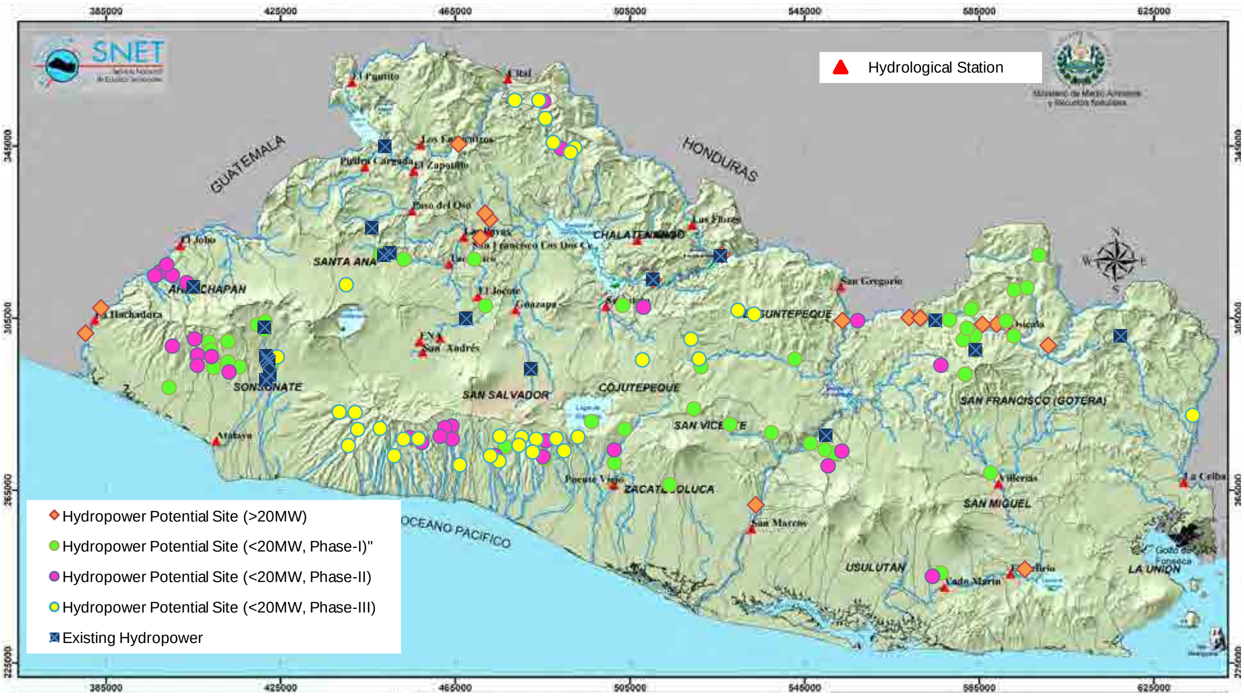
The formulated master plan for each phase is summarized in Table 10.3.2. The location map of selected potential sites for each phase is shown in Figure 10.3.3.

Table 10.3.2 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)	B/C (Average)
								(%)	(x1,000 US$)	
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)

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.



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

Figure 10.3.3 Location Map of Selected Small Hydropower Potential Sites for Master Plan 2012-2027

10.3.1.10 Recommendations for Realization of the Master Plan

A. Site Reconnaissance and Detailed Study for Next Step

For the realization of the master plan, the following field surveys and detailed studies are required.

The plan is reviewed based on the data acquired from the site reconnaissance, and a final plan during this stage of the study is produced. As a result of the review of the development plan, it is judged that the next step of the study, that is, pre-feasibility study and feasibility study should be conducted, and an investigation schedule prepared.

When 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 right away.

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

Government support for the feasibility study, detailed design or investment for development of small hydropower is strongly required.

C. Nationwide Hydrological Observation System

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 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 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

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

10.3.2 Wind Energy

In this study, wind power potential maps are prepared to clarify the wind potential area. There is no experience for implementation of wind power project in El Salvador. In this chapter, the permissible capacities of wind and solar energy in El Salvador are estimated.

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.

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

10.3.2.3 Consideration on Technical Aspects

A. Preparation Schedule

Technical issues on grid connected system and the selling price of generated power will also be discussed. 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. 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.

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.

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.

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.

Wind Speed

Wind speed data is the most important indicator of a site’s wind energy resource.

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 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. It is also used to calculate air density. Wind power density will be used to calculate the wind power output from the wind turbine.

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, wind speed has to be monitored in at least two different heights.

Barometric Pressure

Barometric pressure is used together with air temperature to determine air density.

b3. Monitoring Height

Typical wind monitoring heights for both wind speed and direction are 40 m, 25 m, and 10 m. 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. 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.

c. Evaluation

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.

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.

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.

Wind Energy Density

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

Capacity Factor of Wind Turbine

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

C. Basic Design

a. Determination of Exact Site for Installation

a1. Wind Potential

It is possible to identify the wind potential area by using the wind potential map.

a2. Natural Environment

Wind condition is heavily dependent on surrounding terrain and circumstances. It is necessary to study the local climatic features.

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.

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:

Estimation of power output

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.

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.

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.

b. Heavy-Duty Vehicle

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.

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.

F. Operation and 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. In anycontract agreement, it is necessary to consider the highly specialized nature of the works. The periodic inspections vary according to the manufacturer, but quarterly inspections are recommended by most manufacturers. The inspection costs for a 2,000 kW capacity wind turbine is around US$50,000.00 per year.

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

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 solar PV 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.

Table 10.3.3 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

There are no enough experiences of installation of solar PV system in El Salvador. 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 grid-connected solar photovoltaic (PV) systems and O&M work items are explained. In addition, general work schedules from bidding to power generation and cost are explained. A master plan until year 2026 is presented based on the information obtained from CNE.

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 result shows a 60-MW maximum allowable capacity for the grid-interconnected solar PV and wind systems. This value is approximately 7% of the assumed national power demand. 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

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.

B. Evaluation of Solar PV Potential

Nationwide solar irradiation map was created under the SWERA Pproject and solar irradiation is currently being monitored at several locations. Meteorological data are available at SNET (Servicio Nacional de Estudios Territoriales).

C. System Structure

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.

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.

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.

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

It is necessary to investigate corrosive damages from salt in coastal areas. Data of lightning has to be studied. It is also necessary to investigate the damage caused by hurricanes in the past.

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.

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.

F. 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.

An appropriate O&M system is necessary to secure sustainability of the project outcome. 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.

G. General Project Schedule

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.

H. 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 for a 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 10.3.4 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

In terms of energy, the average number of peak-sunshine hours is large as 5 hr/day in El Salvador. 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.

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.

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.

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.

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. 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

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. 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}.

B. Future Prospect

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.

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.

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.

d. Intermittent power output

Solar irradiation is available only during daytime. However, there are countermeasures to compensate the intermittent of power outpu.

e. Minimum warranted power for wholesale contract

Solar irradiation is an intermittent source of energy, which as expected, translates to power output of solar thermal plant that is also intermittent. 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.

C. 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.

10.3.4.3 Examination of Technical Aspects

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**.

10.3.4.4 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 10.3.5 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

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.

10.3.5.1 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 10.3.1 is a list of their new development plan which have specific development schedule.

Table 10.3.6 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.

10.3.5.2 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 in future is estimated to be 300 MW to 400 MW at the moment. Since this value is only tentative at the moment, it should be revised periodically.

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.

10.3.5.3 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 10.3.7. As seen in this table, a new 30 MW-class geothermal power development requires approximately eight years including permission procedures, with a total cost of US$150 to 200 million.

Table 10.3.7 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 abovementioned 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

Gasification is a thermo-chemical process that converts solid biomass to combustible producer gas. 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. There are two major methods (direct combustion and gasification) to generate electricity from solid biomass. 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. 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.

A. 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. Most of the small-scale gasifier electricity generation systems are downdraft-type. 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.

B. 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. 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. The power demand was overestimated and is one of the reasons for the current difficulties in management.

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. 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.

C. 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.

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.

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 and discussion with CNE in El Salvador. In this Chapter, information on animal waste, waste water and waste power generation are summarized. For each type of technology, outline, technology, sample project and cost information are described.

10.3.7.1 Animal Waste

A. General

Biogas is the gaseous product of anaerobic digestion of organic matter. The main difference in the composition between biogas and natural gas is on the carbon dioxide content. 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.

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.

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.

<u>pH value :</u>

The optimum biogas production is achieved when the pH value of input mixture in the digester is between 6 and 7.

<u>Temperature:</u>

The methanogens are inactive in extreme high and low temperatures. The optimum temperature is 35 °C.

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. 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.

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.

D. System Cost

Univercidad Centroamericana (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.

Construction cost:	US$41,000.66
Operational cost:	US$45.00
O&M cost:	US$55.00

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.

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).

C. Sample Project

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 result of the study shows that the power plant has capability to generate 30 thousand cubic miles of biogas in a year. The total cost of the project for a cogeneration of 4 MW in the beer breweries is around US$8 Million in total.

D. Future Requirements

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.
Water treatment plant input: The volume of organic materials in water has to be measured at each plant.
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.

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.

a. Specifications

Incineration capacity:	75 tons/day (ave. calorie content: 16,000 kJ/kg)
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

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.