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

March 2012

Japan International Cooperation Agency

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

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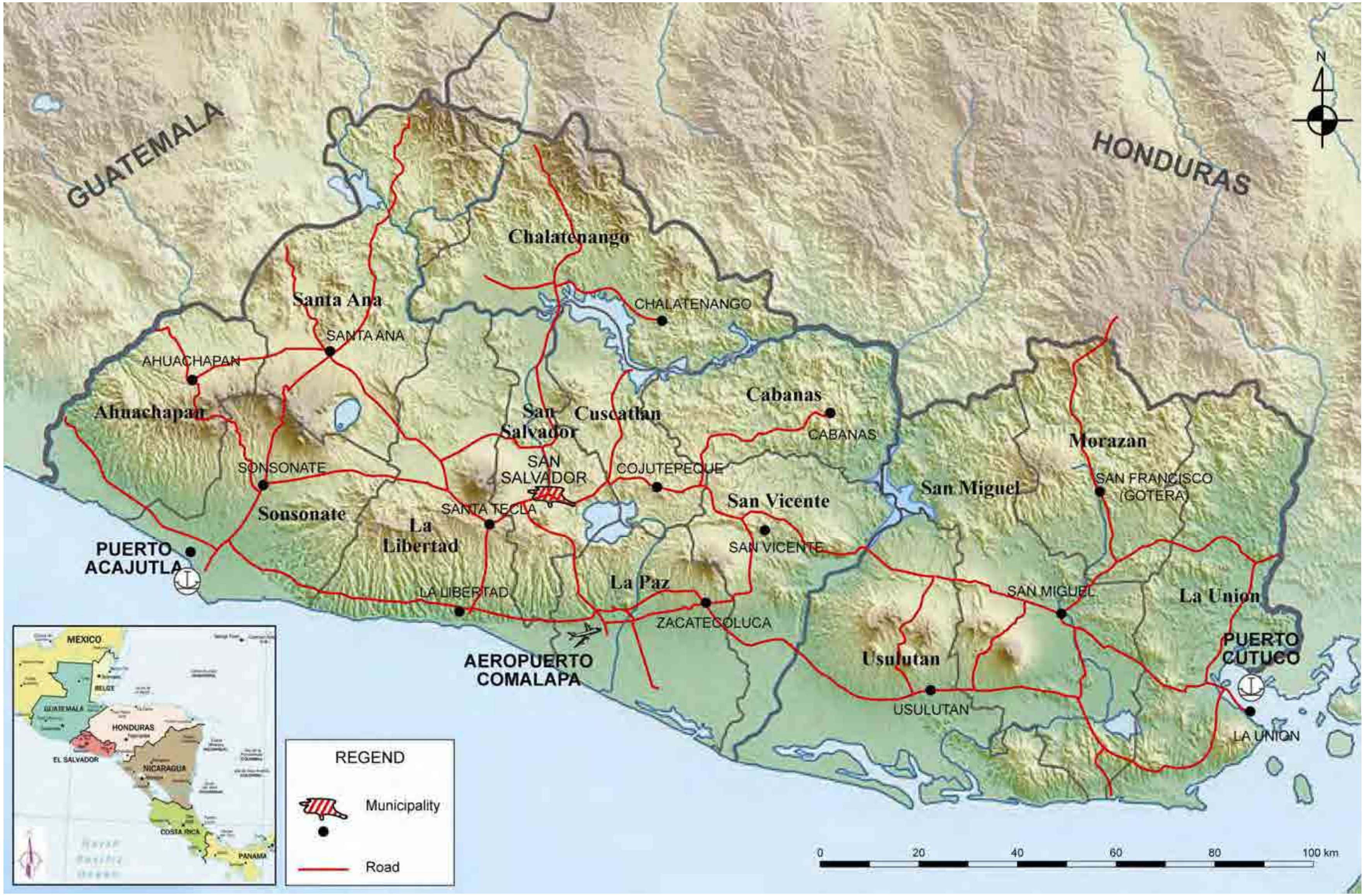
Currency conversion rate

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

Final Report

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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 Commissoin of Latin America and Carib
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
MINEC	Ministerio de Economía	Ministery of Economy

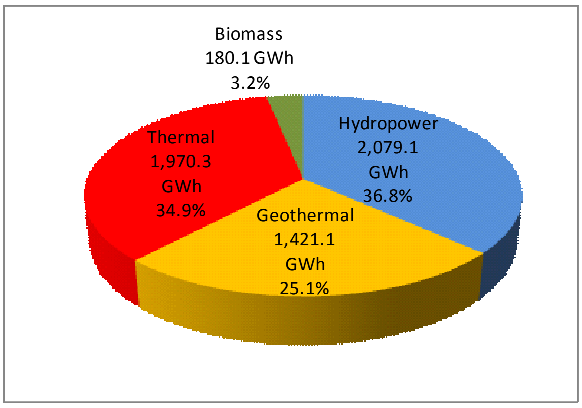
Abbreviation	Spanish	English
MRS	Mercado Regulador del Sistema	Market System Controller
MW	Megawatts (=1,000 kW)	megawatt (=1,000 kW)
MWh	Megawatts hora	megawatt hour
NEC	Código Eléctrico Nacional	National Electric Code
NFPA		National Fire Protection Association
NGO	Organización no gubernamental	Non-Governmental 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
SINAMA	Sistema Nacional de Gestión Ambiental	National Environmental Management System

Abbreviation	Spanish	English
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

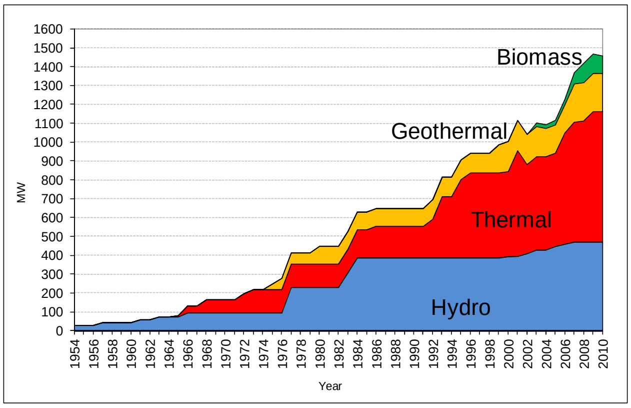
1.1 Background Information

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

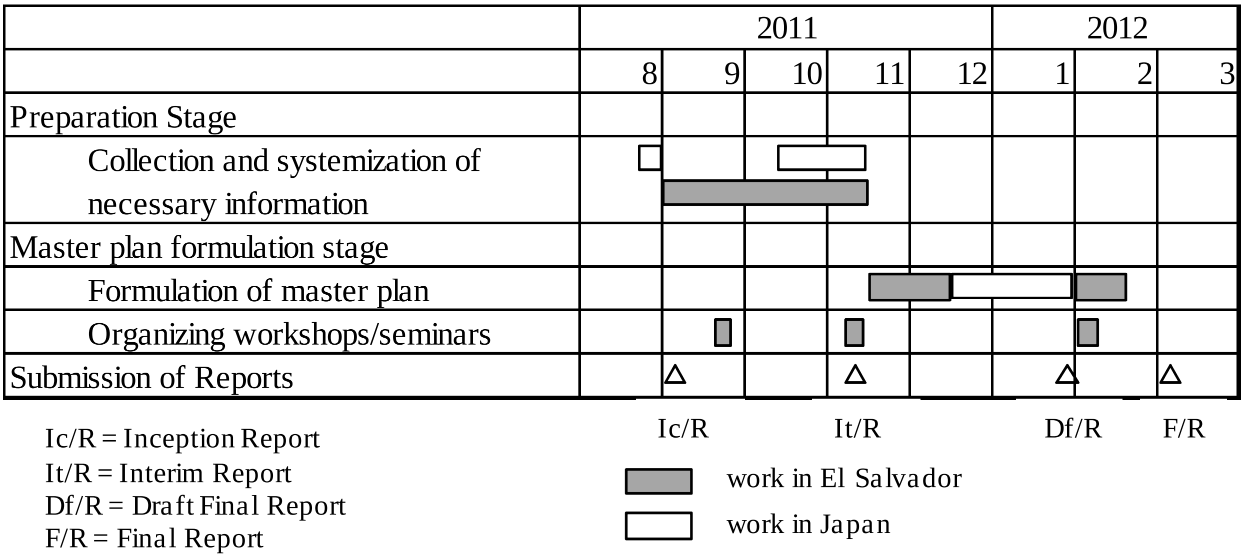
CNE shall act as the counterpart agency to the JICA Study Team.

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

1.6 Outputs of the Study

The reports listed in Table 1.6.1 will be prepared by the JICA Study Team. The reports will be submitted to JICA (Headquarters and El Salvador Office) and to the Government of El Salvador (CNE) for explanations and discussions. The number of copies to be submitted and the major contents of the relevant reports are also given in Table 1.6.1.

Table 1.6.1 Reports To Be Prepared

Study Report	Issue					Major Contents
	JICA			CNE		
	JPN	ESP	ENG	ESP	ENG	
1 Inception	5 (2)	1 (1)	-	4	-	Basic concepts, methodology, time schedule, work items and tasks of the study.
2 Interim	5 (2)	1 (1)	-	4	-	Describes the study concept on the possibility of renewable energy introduction in view of economical and financial, and technical and environmental aspects based on the study results by the first home works.
3 Draft Final						Describe all study results and the proposed master plan.
(Sum.)	5 (2)	1 (1)	2 (1)	4	1	
(Main)	5 (2)	1 (1)	2 (1)	4	1	
4 Final					1	The final output compiled with CNE comments for the draft final report.
(Summary)	10 (2)	8 (8)	2 (1)	2	1	
(Main)	10 (2)	8 (8)	2 (1)	2	1	
Electronic Data	3 (2) sets			-		In Spanish, English, and Japanese languages.

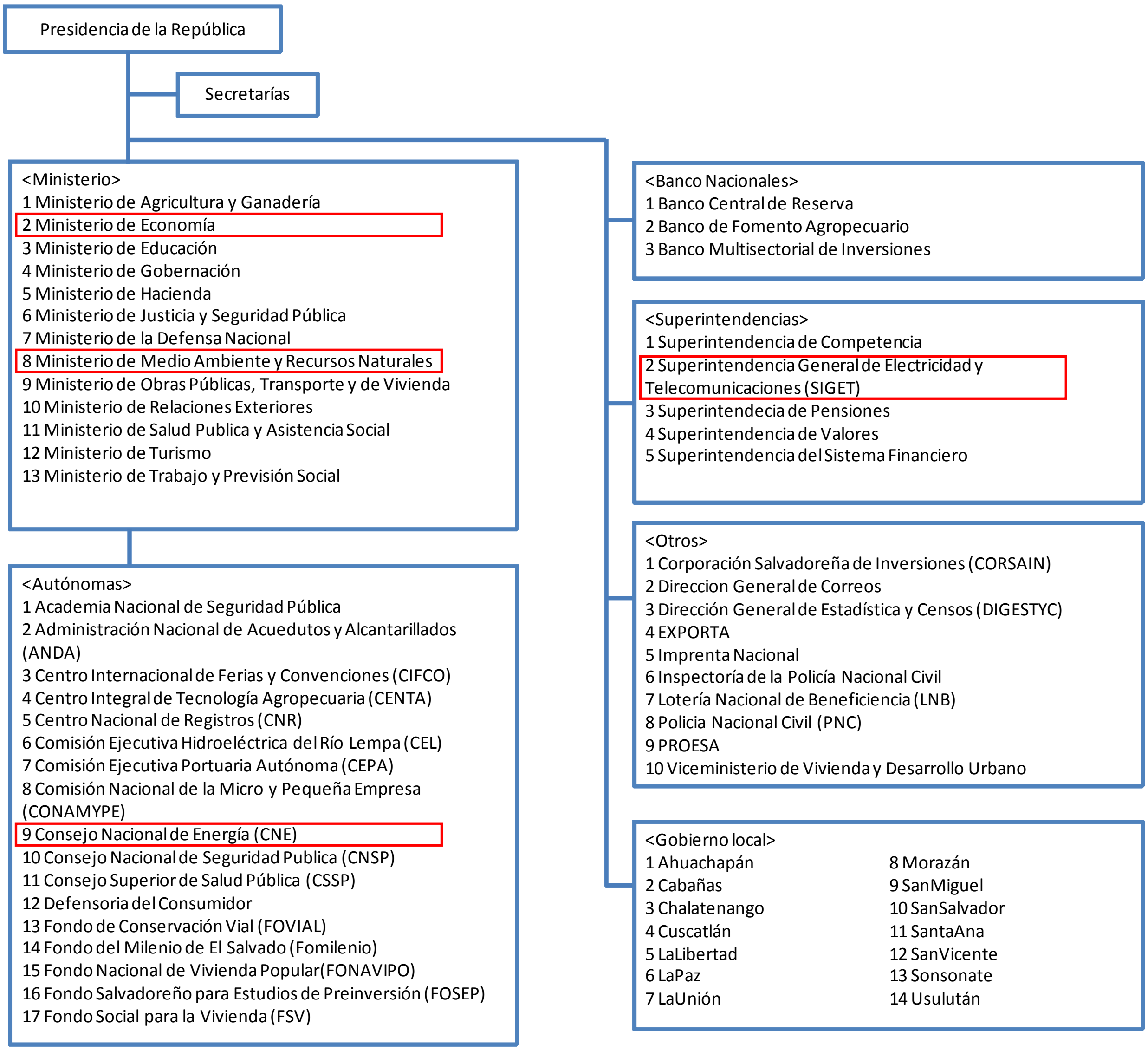
Note: The number in parenthesis is number distributed to JICA El Salvador Office.
Languages: Japanese (JPN), Spanish (ESP), English (ENG).
Sum.: Summary
(Source: JICA Study Team)

Chapter 2 Power Sector Overview and Roles of Renewable Energy

2.1 Power Sector Overview

2.1.1 Government Organization and Roles for Power Sector

According to the Constitution of the Republic, in El Salvador there are three main organizations, which are the Legislative, Executive and Judicial. The Executive Branch is composed of the president and vice president of the Republic, ministers and vice ministers with their subordinate officials. For its political administration, the territory is divided into departments, and in each there is a governor appointed by the executive branch, those officials execute administrative duties.



(Source: Prepared by JICA Study Team based on information from http://www.presidencia.gob.sv/)

Figure 2.1.1 El Salvador's Executive Organism Organizational Chart

For the territorial organization El Salvador is divided into 14 departments, each department is subdivided into municipalities, a total of 262, which have autonomy in economic, technical and administrative areas. And are governed by a council presided by the mayor.

The executive branch is composed of thirteen (13) ministries. In order to guarantee citizens the provision of essential services to the community in the best conditions several state institutions have been created under public law and autonomous in different ways, among them the General Superintendency of Electricity and Telecommunications (SIGET) and the National Energy Council (CNE) are included.

Of the aforementioned organizations of the government, the following ministries and agencies are in charge of the power sector, especially on the promotion of renewable energy introduction:

Major Ministries

- Ministry of Economy (Ministerio de Economía)
- Ministry of Environment and Natuaral Resources (Ministerio de Medio Ambiente y Recursos Naturales: MARN)

Related Agencies

- National Energy Council (Consejo Nacional de Enería: CNE)
- General Superintendency of Electricity and Telecommunication (Superintendencia General de Electricidad y Telecomunicaciones: SIGET)

The missions and tasks of the ministries and administrative departments focusing on the power sector activities are summarized in Table 2.1.1

Table 2.1.1 Missions and Tasks of the Ministry/Department in Charge of the Power Sector

Ministry/ Institution	Missions and Tasks
Ministry of Economy (MINEC)	• Promote economic and social development by increasing production, productivity and rational use of resources. • Contribute to the development of competition and competitiveness of productive activities for both the domestic and international market through the promotion of investment and export growth through a clear and transparent action to prevent the existence of discretionary barriers for economic operators.
Ministry of Environment and Natural Resources (MARN)	• Guide and decide on the development of the environment; • Develop policies and regulations for the conservation and restoration of ecosystems; and • Prepare plans and projects on the environment, or in connection with renewable natural resources.
National Energy Commission (CNE)	• Establish the policy and strategy to promote the efficient development of the energy sector; • Develop short-, medium- and long-term planning on energy, as well as the corresponding country's energy policy; • Promote the existence of regulatory frameworks that support investment. The competitive development of the energy sector also allows to monitor the functioning of energy markets by relevant institutions; • Promote the rational use of energy and all actions necessary for the development and expansion of renewable energy resources, considering the policies of environmental protection, issued by the competent organization; and • Promote the integration of regional energy markets, on the basis of free competition and fair, equitable and different nondiscriminatory actors and market actors.
General Superintendency of Electricity and Telecommunication (SIGET)	• Entity responsible for enforcing the rules contained in international treaties on existing electricity and telecommunications in El Salvador in the laws governing the electricity and telecommunications sectors, and its regulations, as well as to hear the breach of them; and • Apply and enforce the legal framework governing the electricity and telecommunications sectors, guaranteeing the rights of users and operators to create legal certainty that encourages investment and development of a competitive market.

(Source: JICA Study Team)

Of the above organizations, in terms of renewable energy development, CNE is in charge of policy formulation; SIGET for regulation and supervision; and MARN for required procedures for environmental aspects.

CNE was established by Decree No. 404 issued in November 2007. It started its acitivities in full swing from 2009, taking charge of policy formulation such as the national energy policy and the demand and supply forecast. The formulation of a renewable energy master plan, which is also the aim of the study, is also one of the important roles of CNE.

2.1.2 Power Supply System

2.1.2.1 Organizations for Power Sector

The power supply system of El Salvador was drastically changed through the power sector reform, which started in 1996. The power supply system 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 operations of the wholesale electricity market is handled by a private company called Unit of Transaction (Unidad de Transacciones: UT). The wholesale electicity market mainly consist of two types of transactions, i.e., one is a contract market and other one is a regulating market system.

A contract market (Mercade de Contratos) is a bilateral contract on electric power selling between generators and distributors/marketers. Distributors exchange a long term contract for 15 years in maximum on power selling with generators of small hydropower, geothermal, thermal, biomass etc., and executing energy trading. On the other hand, a regulating market system is supplying electric power based on a short-term trading in order to fullfill an demand of overall power market.

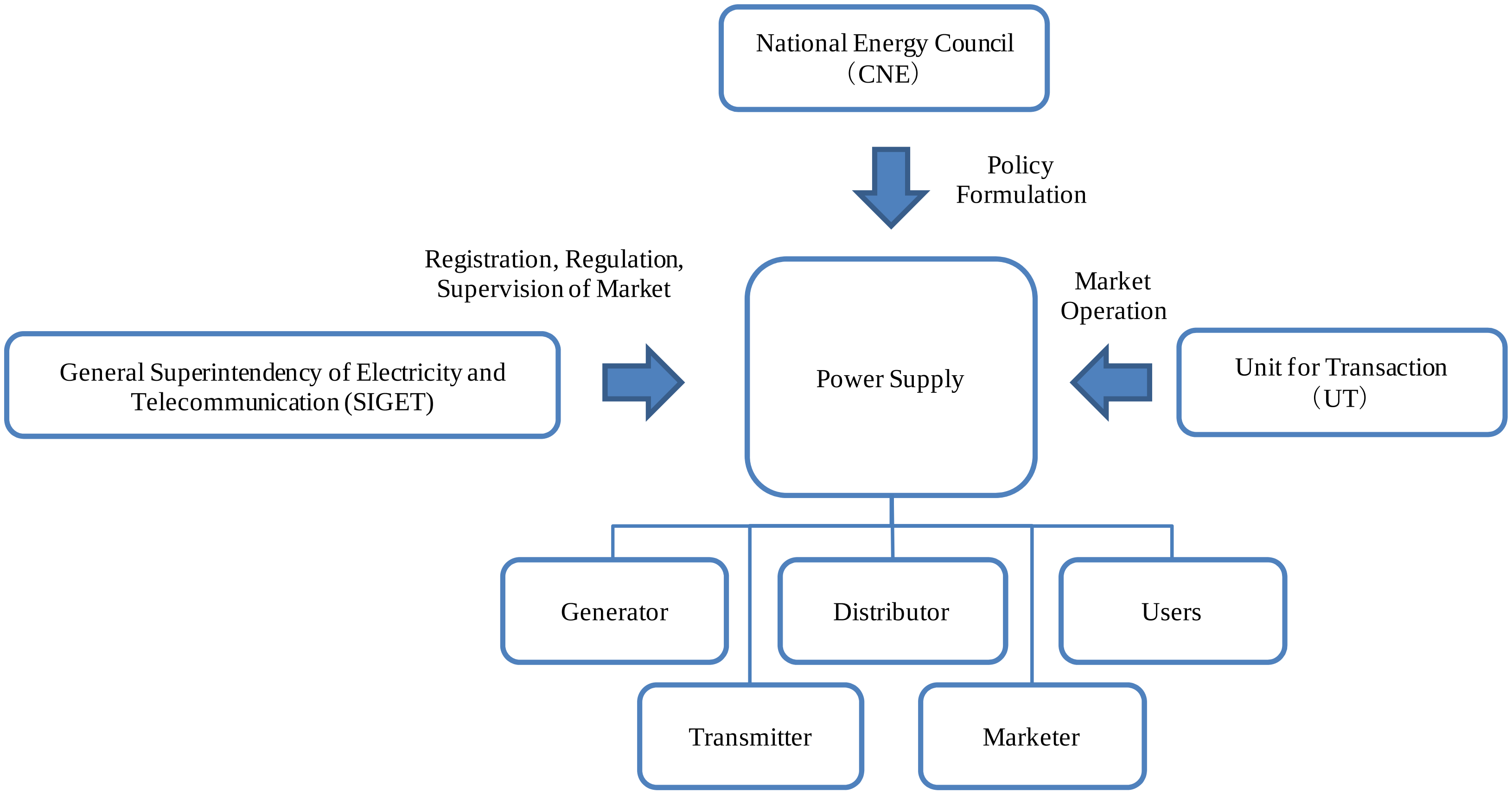
According to the UT statistics as of 2011, about 30 % of whole electric power is supplied from a contract market and other 70% is from a regulating merket system. Electric power is injected into the power system in ascending order of unit cost of power generation from hydropower, geothermal, thermal and so on, and the power demand fullfills by the system.

The roles of the government and private sectors in terms of the wholesale market are as shown in Table 2.1.2 and Figure 2.1.2.

Table 2.1.2 Roles of the Government and Private Sectors in the Wholesale Market

Roles	Organization in charge
Policy Formulation, Demand and Supply Forecast and Planning	National Energy Council (CNE)
Registration, Regulation, Supervision of the Market	General Superintendency of Electricity and Telecommunication (SIGET)
Operations of the Market	Unit of Transaction (UT)
Generation, Transmission, Distribution and Marketing	Private Companies

(Source: JICA Study Team)



(Source: JICA Study Team)

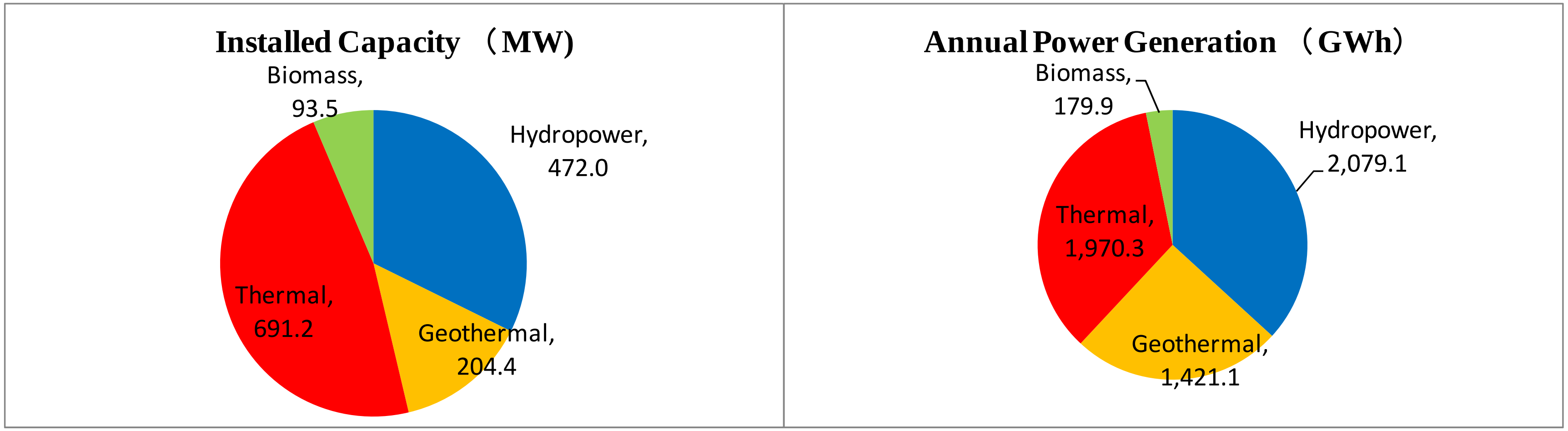
Figure 2.1.2 Roles of the Government and Private Sectors in the Wholesale Market

In addition to the above, there are several contracts between distributors and small-scale power generators (basically involving less than 5 MW generation capacity) where bilateral contracts will be concluded using medium or low voltage distribution lines, which is called as the retail market. Most small hydropower generators apply such type of contracts; however, the amount of transactions is not significant compared with the wholesale market, which is operated by UT.

2.1.2.2 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:

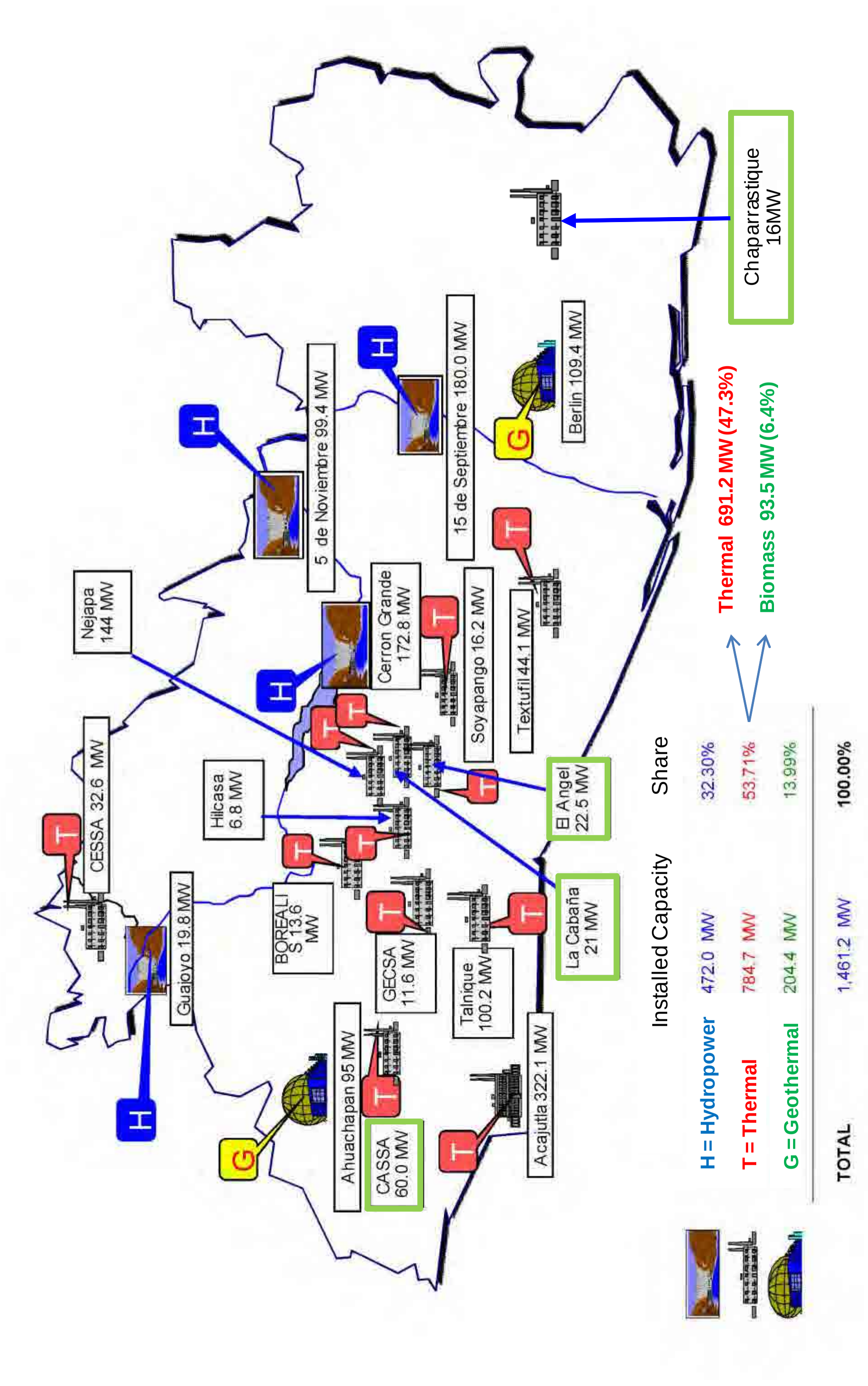
- Hydropower: four locations, installed capacity of 472.0 MW (32.3%), generation of 2,079.1 GWh (36.8%)
- Geothermal: two locations, installed capacity of 204.4 MW (14.0%), generation of 1,421.1 GWh (25.1%)
- Thermal: nine locations, installed capacity of 691.2 MW (47.3%), generation of 1,970.3 GWh (34.9%)
- Biomass: three locations, installed capacity of 93.5 MW (6.4%), generation of 179.9 GWh (3.2%)



(Source: SIGET Statistical Bulletin 2010)

Figure 2.1.3 Installed Capacity and Annual Power Generation (2010)

Figure 2.1.4 shows the approximate locations of power stations presented in the statistical bulletin of SIGET (2010), and their respective installed capacity (MW).



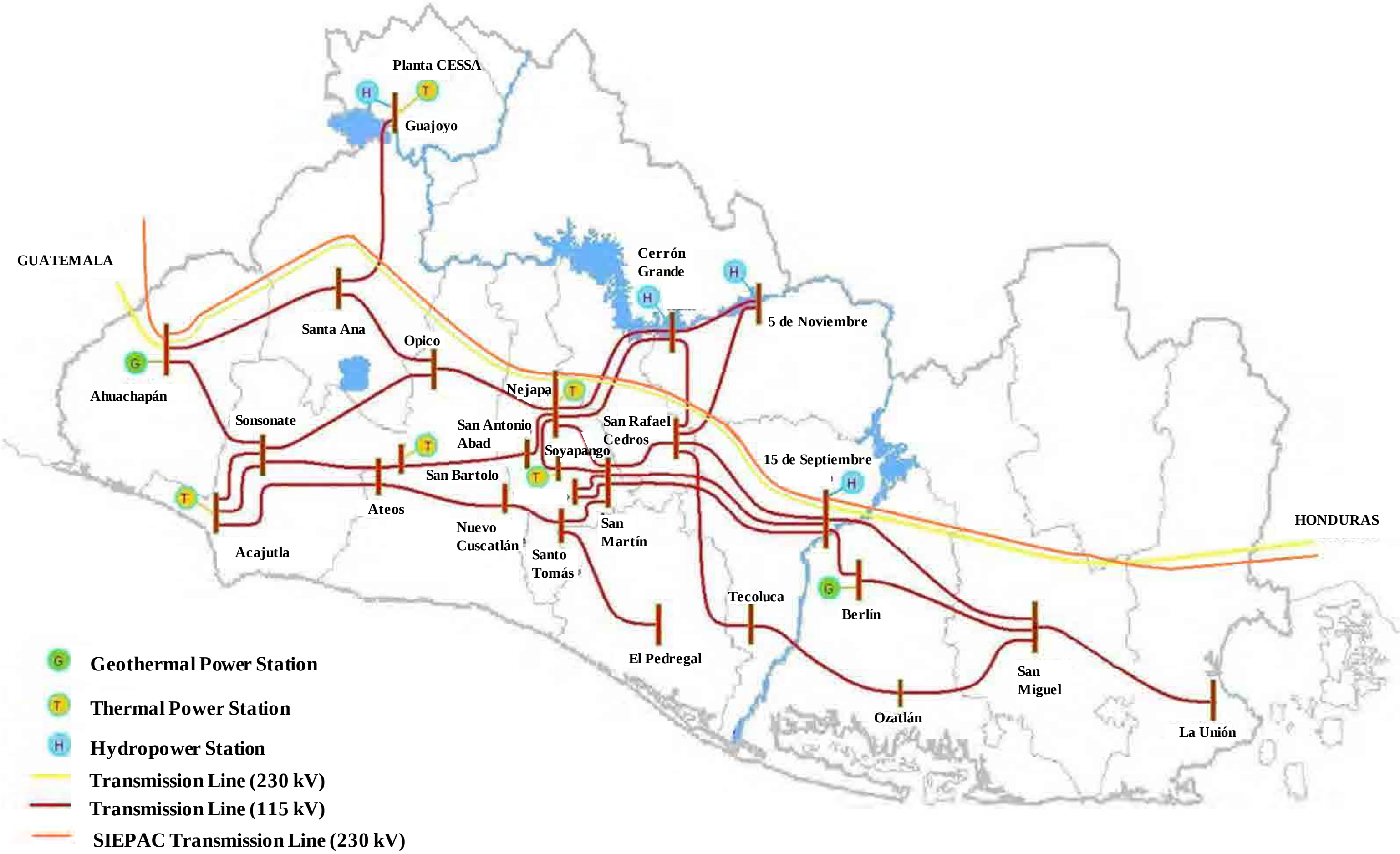
(Source: SIGET Statistical Bulletin N0 12, 2010)

Figure 2.1.4 Locations of Power Stations in El Salvador and Their Installed Capacity

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. In Figure 2.1.4, there are four power stations with names enclosed in bold green boxes. These power stations, though caetgorized as thermal power stations, are biomass power stations (CASSA, La Cabaña, El Angel and Chaparrastique). These power stations are directly burning bagasse (residue of sugarcane), and established as an annex to sugar factories. It was confirmed that Chaparrastique power station commenced its power generation in 2011, therefore, it was indicated in the map.

2.1.2.3 Transmission and Distribution Facilities

Figure 2.1.5 shows the transmission networks of El Salvador. The transmission networks 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. UT is in charge of operating the transmission networks of both 115 kV domestic high voltage and 230 kV international (interregional) transmission networks.



(Source: ETESAL)

Figure 2.1.5 Locations of Power Stations and Layout of Transmission Lines

A. Categorization of the transmission lines and distribution

The transmission and distribution lines of El Salvador are categorized as follows:

a. High voltage transmission line:

230 kV: ETESAL transmission networks for international connection with Guatemala and Honduras

- International connection with Guatemala: Ahuachapán – Eastern Guatemala (total length: 112.6 km)
- International connection with Honduras: 15 de Septiembre – Agua Caliente (total length: 147 km)

115 kV: ETESAL transmission networks for domestic connection (total length: 1,072 km)

b. Medium voltage distribution line (46 kV, 34.5 kV, 23 kV, 13.2 kV, 4.16 kV, 2.4 kV): for distributors.

c. Low voltage distribution line (120/240V): for domestic users.

B. Cost levels for Transmission and Distribution Facilities

References were collected regarding to construction cost of transmission and distribution facilities which is required for installation of renewable energy. Since there are no statistical sources about these costs, information has been collected from officials and experts involved in recent projects development. This section contains information related to transmission facilities costs in 115 kV[1], and distribution in 46 kV, 23 kV y 13.2 kV.

a. Transmission and Distribution Lines Costs

Collected costs here related to transmission and distribution lines projects include materials, equipment and labor for erection and assembly, but not the right of way cost.

Table 2.1.3 shows the costs of transmission lines in El Salvador. The average cost of a transmission line of 115 kV reaches the value of 173.700 US $/km, a value close to what was reported by IASA. Also, this cost is half the cost of transmission line 115 kV in the United States (325,000 US $/km). The cost of the 15 de Septiembre – San Miguel line is equivalent to 46% of the average cost, this is because the line was badly budgeted and there were losses for the builder.

The cost of the San Miguel – La Unión line equivalent to 153% of the average cost, this is because of several technical factors as adaptation to mountainous regions with difficult access that increased the size of the equipments (towers, arresters, among others).

[1] The power transmission in El Salvador includes all electrical installations in 115 kV and 230 kV. The facilities in 230 kV are used for regional international connection, that is, they form part of the Electrical Interconnection System for Central American Countries (SIEPAC). There is no cost information for transmission lines in 230 kV.

Table 2.1.3 Cost of Transmission Lines in El Salvador

Name of Project	Type of Structure	Year	Company	Power (MVA)	Voltage (kV)	Length (km)	Total Cost (Millions of US $)	Unit Cost (US $/km)
Several Projects[1]	Lattice Tower	Several	IASA	100	115	----	---	175,000
15 de Septiembre – San Miguel[2]	Steel Post	2005	ETESAL	100	115	44	3.50	79,545
San Miguel – La Unión[2]	Lattice Tower	2008	ETESAL	100	115	45	12.00	266,667

Source:

1 – Eng. Nelson Hidalgo, IASA´S General Manager (Ingeniería Asociada S.A., construction company for high voltage installations).

2 – Eng. Julio Posada, Projects Supervisor for ETESAL.

Table 2.1.4 shows the typical distribution line costs in El Salvador for the voltage levels of 13.2 kV, 23 kV and 46 kV. The unit costs of a distribution line (US $/km) increases with increasing voltage level, this due to the adoption of bigger size of conductors, as well as incresing of height and strength of tower and cost of attachment such as anchor, ring support, etc.

Table 2.1.4 Costs of Distribution Lines in El Salvador

Technical specifications	Type of Structure	Year	Company	Voltage (kV)	Unit Cost (US $/km)
3 phases, 477 MCM, 70 m. span	Concrete pole 40 feet	2011	EDESAL	46	61,300
3 phases, 4/0 AWG, 70 m. span	Concrete pole 40 feet	2011	EDESAL	23	55,300
3 phases, 1/0 AWG, 70 m. span	Concrete pole 40 feet	2011	EDESAL	13.2	37,000

(Source: Eng. Leonel Bolaños, technical manager of EDESAL (Salvadorian distribution company))

b. Power Transformers Cost

The costs of power transformers described here do not include installation costs, oil treatment and suggested replacements, only costs for equipment supply. Also, the landing of power transformers is carried out up to date by the port of Acajutla, therefore, the path to the installation location must be the least complicated when it comes to cities pass, bridges, etc. This can increase costs in transformers.

Table 2.1.5 shows the costs of power transformers in El Salvador for different types of transmission, distribution and generation projects. The average cost of transformers for transmission is approximately 18,500 US $/MVA, less than the costs for distribution and generation projects. The table shows examples of power transformers that would be used in small generation projects, these can be connected to the grid at 13.2 kV or higher voltage levels, depending on the generation capacity, and have an average cost of 26,667 US $/MVA. The prices shown are approximate, since they depend on the voltage, capacity and quantity of transformers.

Table 2.1.5 Costs of Power Transformers in El Salvador

Electrical Substation	Type	Year	Company	Rated Capacity (MVA) P/S/T	Voltage (kV) P/S/T	Total Cost (Millions of US $)	Unit Cost (US $/MVA)
La Unión[1]	transmission	2008	ETESAL	45/60/75	115/46/23	1.20	16,000
Nejapa[1]	transmission	2010	ETESAL	75/115/155	230/115/46-23	3.25	20,968
S/E EEO[2]	distribution	2010	EEO	10/12	46/13.2	0.356	29,667
San Luis II[3]	generation	2010	CECSA	1.2	2.3/13.2	0.032	26,667

Source:
1 – Eng. Julio Posada, ETESAL projects supervisor.
2 – Eng. Erasmo Hércules del Cid, Contractor for EEO (Empresa Eléctrica de Oriente, distributing company in El Salvador).
3 – Eng. José Hermes Landaverde for INGENDEHSA (consulting firm for small hydro projects)
Abbreviations: P / S / T - Primary / Secondary / Tertiary, S/E – Electric Substation

2.1.3 Electricity Tariff

The electricity tariff is revised by SIGET every three months based on the average of the previous quarterly 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. Depending on the amount of usage, the total rates for the three steps are summed up and charged. The base tariff, usage charge and distribution charge are tabulated for distribution companies by SIGET. Table 2.1.6 shows an example of electricity tariff.

An example, in case the monthly usage is 120 kWh in the distribution area of DEL SUR, the tariff is calculated to be some 31 US$ per month.

In the case of small-scale users, if the monthly usage is less than 200 kWh, a constant subsidy is provided by the government. The category for subsidy is used for users of less than 300 kWh. However, this was revised to “less than 200 kWh”, as announced on October 12, 2011 through Ministrial Decree No. 149. The Payment of subsidy is responsibility of the Government, however, resource of subsidy is borne by CEL at present. Subsidy is paid through the National Investment Fund for Electricity and Telephone (FINET). The budget size of the subsidy resources are not known because the financial data of CEL was not disclosed.

Table 2.1.6 Example of Electricity Tariff of each Distributor

No.	Tariff Category		Tariff by Distribution Company							
1	**Tariff for Residential (Monthly usage up to 99 kWh)**		Name of Distribution Company							
	Base Charge		CAESS	DEL SUR	CLESA	EEO	DEUSEM	EDESAL	B&D	ABRUZZO
	Fixed Charge	US$/user	0.813531	0.967705	0.879995	0.86499	1.021556	0.756047	0.754195	0.799957
2	**Block 1 (Up to 99 kWh)**		CAESS	DEL SUR	CLESA	EEO	DEUSEM	EDESAL	B&D	ABRUZZO
	Energy Charge	US$/kWh	0.183679	0.178227	0.182361	0.183895	0.181902	0.191045	0.173273	0.189102
	Distribution Charge	US$/kWh	0.023168	0.044442	0.043942	0.055315	0.059613	0.049321	0.02238	0.035486
3	**Block 2 (100 to 199 kWh)**		CAESS	DEL SUR	CLESA	EEO	DEUSEM	EDESAL	B&D	ABRUZZO
	Energy Charge	US$/kWh	0.182791	0.177599	0.181461	0.182245	0.181168	0.191225	0.175644	0.187513
	Distribution Charge	US$/kWh	0.040409	0.053178	0.059401	0.061387	0.064555	0.05071	0.024009	0.038841
4	**Block 2 (More than or equal to 200 kWh)**		CAESS	DEL SUR	CLESA	EEO	DEUSEM	EDESAL	B&D	ABRUZZO
	Energy Charge	US$/kWh	0.182141	0.177426	0.18077	0.180696	0.180283	0.191407	0.178761	0.186885
	Distribution Charge	US$/kWh	0.046854	0.059186	0.064141	0.065951	0.066662	0.052101	0.025928	0.040434

(Source: SIGET)

2.1.4 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 Status of State-Owned Company

Due to the power sector reform initiated in 1996, the power supply system was changed from that supplied by the government, to separated generation, transmission, distribution and marketing. Operations of the wholesale electricity market started in 1999. According to the statistic bulletin of SIGET, CEL is the only state-owned company.

The current status of CEL is described below.

2.2.1 Current Status of CEL

2.2.1.1 Activities Since its Establishment up to 1980

CEL was established in 1945 to start the first power development project by the government. From 1951 to 1954, the first hydropower station was constructed. The hydropower station, Central Hidroeléctrica 5 de Noviembre, was named in honor of El Salvador's independence day.

For the first 20 years, from 1951 to 1970, the following power development projects were actively promoted:

- Central Hidroeléctrica 5 de Noviembre: 82 MW (completed in 1954)
- Central Hidroeléctrica de Guajoyo: 15 MW (completed in 1963)
- Centrales Térmicas de Acajutla: 70 MW
- Construction of 115 kV and 69 kV transmission systems, which interconnect major generating plants and major centers of consumption of the country.
- Subtransmission systems, which transmit electric power to major cities and agricultural centers
- Rural distribution systems that serve small populations, industrial, agricultural estates, farms and rural communities

(Source: http://www.cel.gob.sv/)

Figure 2.2.1 5 de Noviembre Hydropower Station

CEL continued its steady pace of expansion and growth in 1970s, and constructed two major projects, i.e., Ahuachapán geothermal plant (Planta Geotérmica de Ahuachapán) and Cerrón Grande hydropower station (Central Hidroélectrica Cerrón Grande) (172.8 MW) by 1976 in order to resort to energy production from fossil fuel.

In 1978, a difficult period for the country life began; an armed conflict was developed from 1980 to 1992. As a result, CEL suffered property damage, especially the transmission and distribution lines. Despite the situation, CEL continued to work and studies in the power plant in San Lorenzo.

2.2.1.2 Activities from 1996 up to date

Due to the large-scale restructuring of the electricity sector in 1996, the main activities of CEL were divided into generation, transmission, distribution and marketing. Subsequently, three companies were formed to accomplish some of these activities: the geothermal company LaGeo (established in 1999), the transmission company ETESAL (established in 1999), and the wholesale market operator company, UT.

From this process of modernization, the functions of CEL are reduced to: 1) The operation of four hydropower stations in the country, 2) Manage subsidiary companies and 3) studies and projects to expand the installed capacity of such an important energy source. CEL is currently expanding its activies considering the quality and social responsibility to the development of new schemes and alternative energy sources such as solar photovoltaic (PV) and wind power.

Having generation and marketing of electricity as its main acitivities, CEL is in charge of the overall management of the Lempa River, and development of new projects and alternative energy sources.

2.3 Private Power Company

As mentioned in the status of state-owned company, structure of electric power sector was reformed to be separated in each sub sector of generation, transmission, distribution and marketing, and private companies shoulder each sector.

According to statistical data of SIGET (2010), private companies in the power sector of El Salvador and operators in the electricity wholesale market, are composed of, 12 generation companies, one transmission company, eight distribution companies, and 13 marketing companies.

The status of each subsector is described hereunder.

2.3.1 Genearation Company

Of the 12 generation companies, the following four are in charge of power generation using renewable energy sources:

- CEL
- LaGeo: owns two geothermal power stations (Ahuachapán and Berlín)
- CASSA: Compañía Azucarera Salvadoreña S.A.
- El Angel
- La Cabaña

La Geo is a company specialized in geothermal energy development and before 1999 it was part of CEL. It owns two power stations, Ahuachapán (95 MW) and Berlín (109 MW), and has 14% share in installed capacity and 25% share in generation amount.

CASSA, El Angel and La Cabaña apply direct combustion of bagasse (residue of sugarcane) from sugar factories in order to generate power using rotating steam turbines. They generate power only during the sugarcane harvest period, which is from November to April.

For energy sources other than renewable energy, eight companies are in charge, namely, Duke Energy International, Nejapa Power Company, Cement El Salvador, Textufil, Energy Investment, Energy Borealis, Central Electricity Generating, and HILCASA Energy.

2.3.2 Transmission Company

The only existing transmission company in the country is Empresa Transmisora de El Salvador, S.A. de C.V.; ETESAL. It is not only in charge of transmission of electricity and maintenance of transmission line networks. The expansion, extension and reinforcement of transmission line networks are among its major activities. ETESAL was separated from CEL in 1999.

ETESAL owns two international transmission lines (230 kV) connected with Guatemala and Honduras through two substations namely, Ahuachapán and 15 de Septiembre. ETESAL also owns 37 of 115 kV domestic transmission lines and 22 substations at various locations. The total length of its domestic transmission lines is 1,204 km.

2.3.3 Distribution Company

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

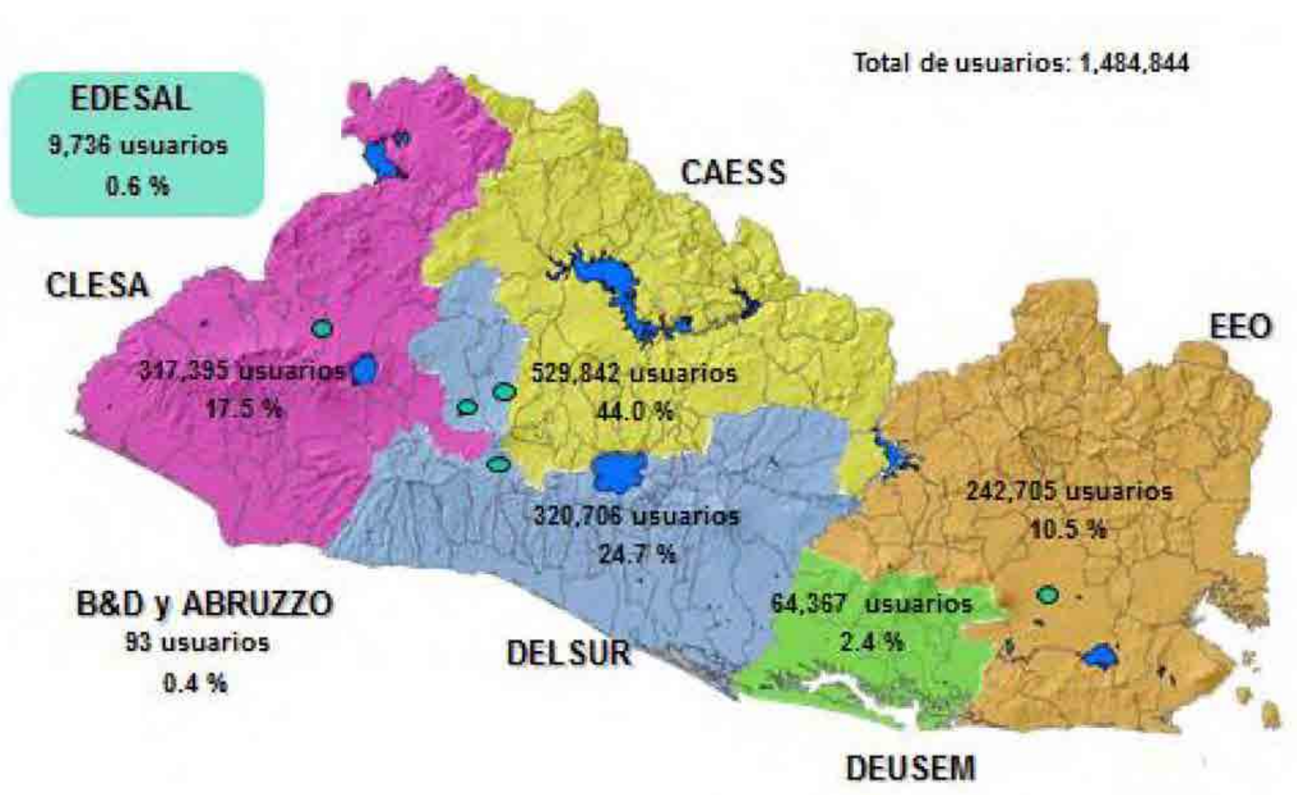
(1) CAESS, (2) AES-CLESSA, (3) AES-EEO, (4) AES-DEUSEM, (5) DELSUR, (6) EDESAL,
(7) B&D, and (8) Abruzzo.

Of the above, (1) to (4) are group companies of AES, which is renowned worldwide. Table 2.3.1 shows the list of companies along with their respective number of customers, and share of sales. Figure 2.3.1 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.

Table 2.3.1 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 2.3.1 Areas of Service for Distribution Companies, Number of Customers and Share

2.3.4 Marketing Company

According to the statistic bulletin of SIGET in 2010, some marketing companies are registered. Main activities of these companies is electric power trading with neighboring countries according to the same bulletin. Following eight companies shouldered electric power trading as records in 2010. Actual record of the trading: the import was 174.2 GWh and export was 89.0 GWh, and ratio toward whole injected energy of 5,650.6 GWh in wholesale market is 1 to 3 %.

Table 2.3.2 Electricity Trading Companies during 2010

No.	Company Name	Trading Energy（GWh）	
		Import	Export
1	CLESA	3.1	-
2	EXCELERGY	21.1	13.4
3	Cenérgica	16.9	7.4
4	Merceléc	44.0	40.0
5	ORIGEM	11.7	2.3
6	CECAM	63.7	25.7
7	CENER	2.8	-
8	INE-COM	10.9	0.2
	Total	174.2	89.0

(Source: statistic bulletin of SIGET in 2010)

2.4 Activities of Donors

The projects related with renewable energy sources development in El Salvador are described in Chapter 4 of this report. Among them, the project related with the current master plan study is discussed below. In The Estudio y Propuesta de Marco Regulatorio para la promoción de Energías Renovables en El Salvador (hereinafter called the Marco Regulatorio Study; AEA-CNE, 2011).

The consultant in charge of the Marco Regulatorio briefed the JICA Study Team in September 2011 regarding the outlines and interim results of the study. Below are the results of the presentation.

The Marco Regulatorio Study started on January 2011. It was conducted through the following four steps:

A. Diagnosis

B. Design

C. Standards Development

D. Implementation

Of the above, the first three stages were already conducted as of August 2011, with financial assistance by AEA.

At present, the implementation stage just started in October 2011, is now in progress with financial assistance from the Inter-American Development Bank (IDB).

The implementation stage is scheduled to be continued up to September 2012. In the master plan study, the recommendation will be prepared in view of three aspects, i.e., techinical, economical and financial and environmental aspects regarding to the injuction of renewable energy. For the preparation, the Study Team will also pay attention that the recommendation will be usefull for the pararelly on-going Marco Regulatorio. The detailes are described in Chapter 9.

2.5 Roles of Renewable Energy in the Power Sector

In this section, the roles of renewable energy in the power sector of El Salvador are examined in terms of installed capacity and power generation amount. The examination is made by referring to statistical data from SIGET and UT.

2.5.1 Roles in Terms of Installed Capacity

According to statistical data from SIGET, the power stations in El Salvador as of December 31, 2010 are as shown in Table 2.5.1.

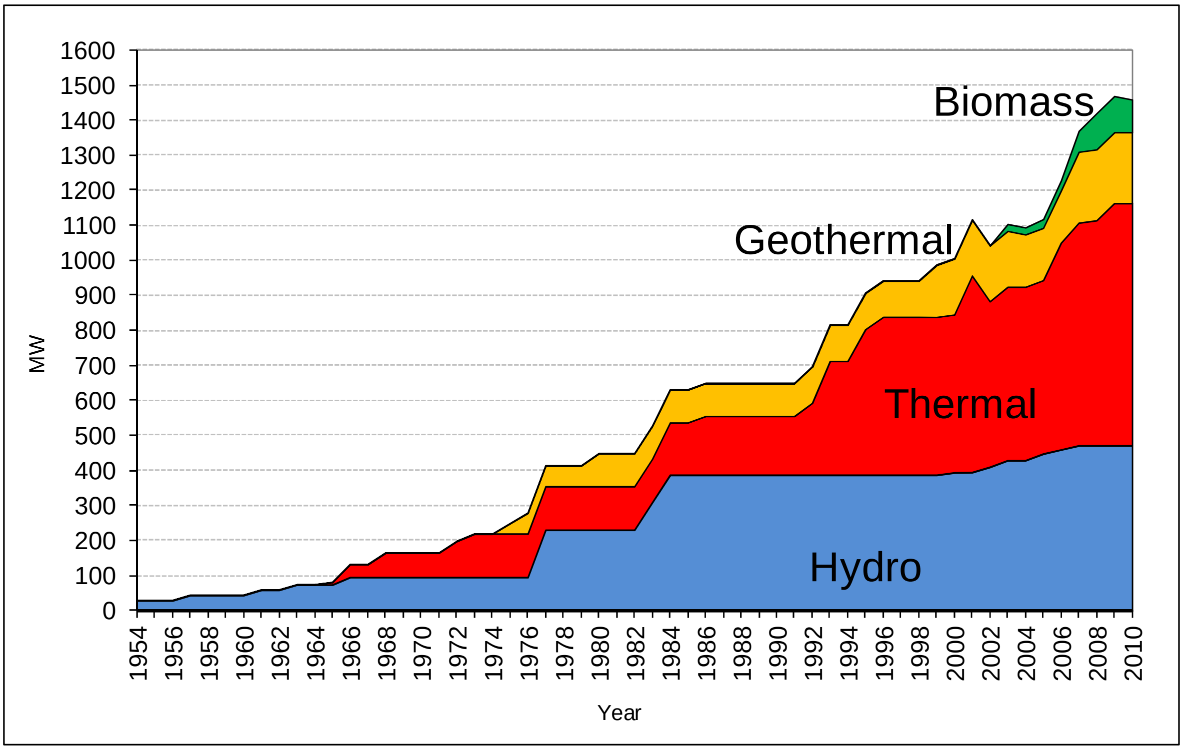
Table 2.5.1 Type of Resources, Installed Capacity and Effective Capacity of Power Stations in El Salvador

No.	Name of Power Station	Number of Units	Installed Capacity		Effective Capacity	
			(MW)	%	(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	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)

In terms of effective capacity, the shares of energy sources are as follows: hydropower with 34.0%; geothermal with 13.2%, thermal with 47.3%, and biomass with 5.5%. The ratio of renewable energy sources (including hydropower with installed capacity of more than 20 MW) is 52.7% against the total effective capacity. However, as shown in Figure 2.5.2 (same as Figure 1.1.2 in Chapter 1), the recent trend shows that the introduction of a thermal power station was accelerated after the liberalization of the electricity market in the 1990s in order to cope with the rapid growth of demand. The introduction of thermal power stations seems to have been accelerated by private power companies due to its relatively low initial installation cost and low risks.

The roles of renewable energy in terms of installed capacity can be positioned as to reduce the ratio of thermal power stations, which relies 100% of fuel sources on import. Due to the steep rise of fossil fuel prices, the reduction of thermal ratio in order to contribute in lowering the electricity tariff levels are essential in the power sector.



(Source: Electricity Statistics Bulletin No. 12 (SIGET, June 2010))

Figure 2.5.1 Change of Installed Capacity by Type

2.5.2 Roles in Terms of Power Generation Amount

2.5.2.1 Roles in Annual Power Generation

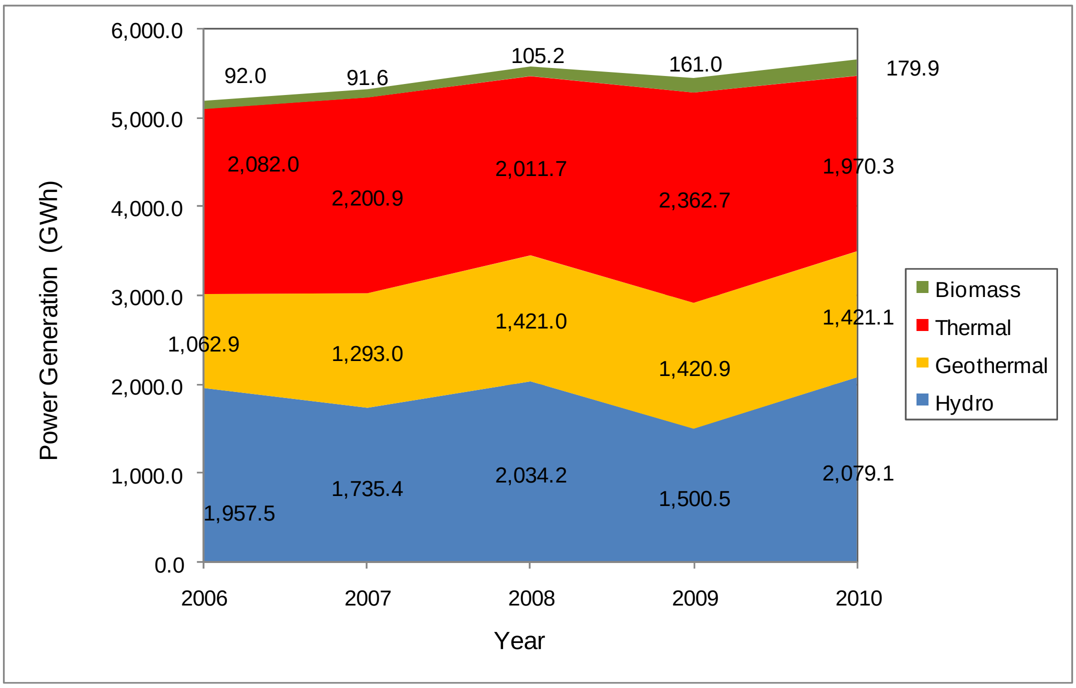
Figure 2.5.2 and Table 2.5.2 show the transition of annual power generation by energy source, which was injected into the wholesale market during the period from 2006 to 2010. Annual power generation increased at about 1.7% per annum for the past five years. Energy sources consist of the following: hydropower and thermal (30 to 40% each), geothermal (about 25%) and biomass (the rest).

This was an increase in generation observed in geothermal power output from 2006 to 2008. The reasons are as follows: due to the power output recovery of Ahuachapán Geothermal Power Station; and extensions of the third unit (44 MW) and fourth unit (9.4 MW) of Berlín Geothermal Power Plant. Since 2008, geothermal plants continuously produce stable power of 1,421 GWh per annum.

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 2.5.2 Annual Power Generation Amount by Energy Source 2006 - 2010

Table 2.5.2 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)

2.5.2.2 Roles in Monthly Power Generation

Tables 2.5.3 and 2.5.4 show the monthly power generation status in 2009 and 2010, respectively. Graphs for the same are as presented in Figures 2.5.3 and 2.5.4.

Table 2.5.3 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

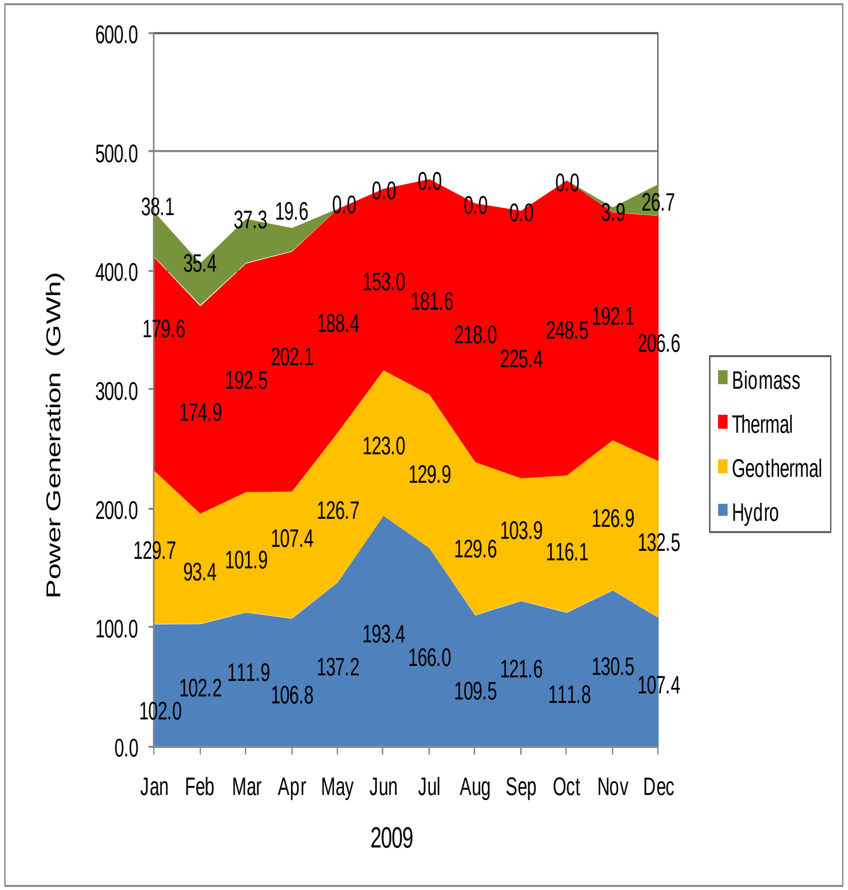
(Source: UT Annual Report 2009)

Table 2.5.4 Monthly Power Generation in 2010

(Unit: GWh)

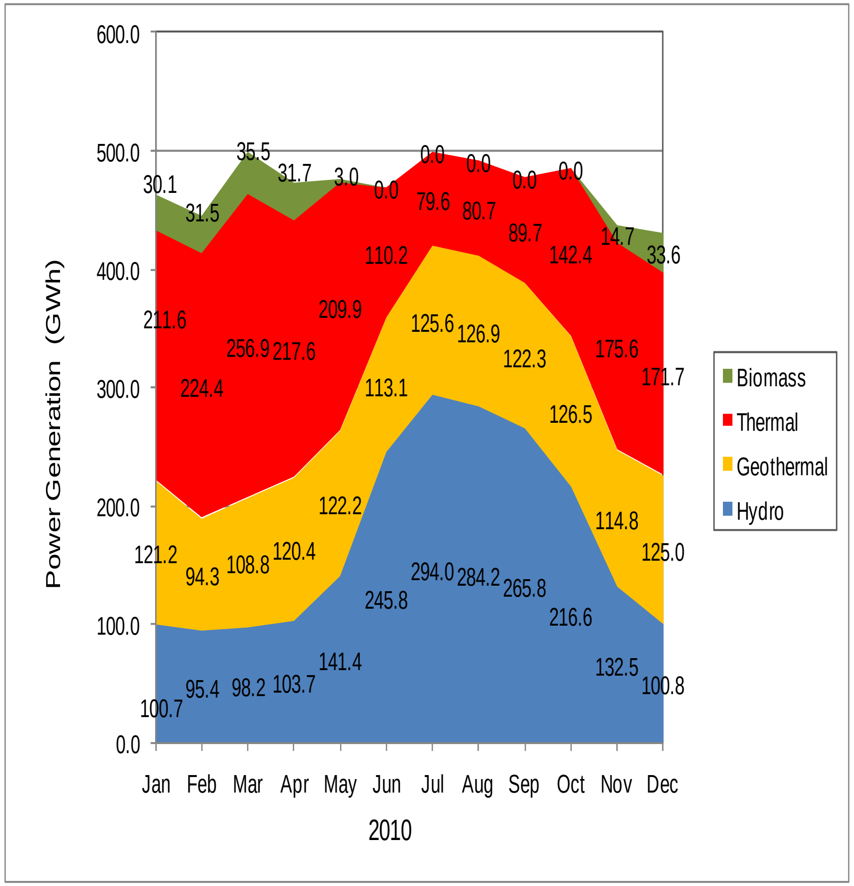
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Hydro	100.7	95.4	98.2	103.7	141.4	245.8	294.0	284.2	265.8	216.6	132.5	100.8	2,079.1
Geothermal	121.2	94.3	108.8	120.4	122.2	113.1	125.6	126.9	122.3	126.5	114.8	125.0	1,421.1
Thermal	211.6	224.4	256.9	217.6	209.9	110.2	79.6	80.7	89.7	142.4	175.6	171.7	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 2.5.3 Monthly Power Generation in 2009 (GWh)



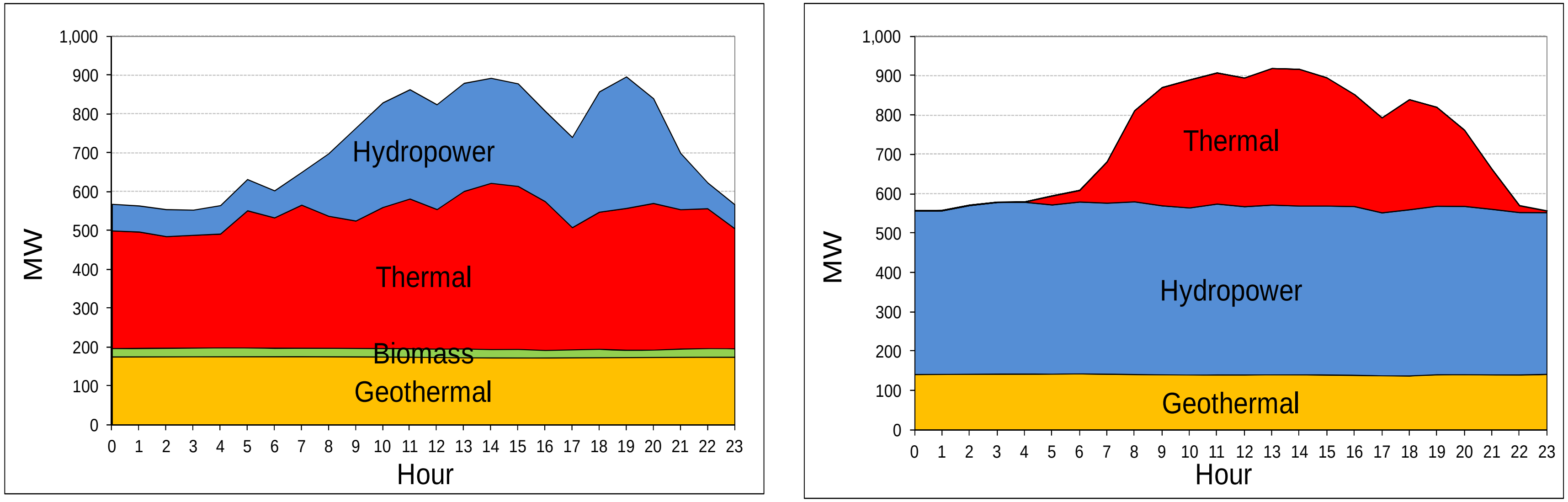
(Source: UT Annual Report 2010)

Figure 2.5.4 Monthly Power Generation in 2010 (GWh)

As described in the preceding section “Annual Power Generation”, power generation by hydropower in 2009 was at 1,500.5 GWh, which was about 25% lesser than that in 2010 (2,079.1 GWh). The deficit was therefore covered by thermal power. 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. Such period is in the dry season in El Salvador when the output of hydropower tends to decline. Biomass can play a role for covering the deficit of hydropower although its amount is not that significant.

2.5.2.3 Daily Load Curves

Figure 2.5.5 shows the typical daily load curves (on a week day-Tuesday) in the dry and rainy seasons of 2011. The shape of daily load curves is 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.



(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 2.5.5 Daily Load Curves and Ratio of Injection by Source

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

The daily load curves above show the amount of energy injected into the wholesale market, which does not include injections from distribution lines.

2.5.2.4 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 Energy 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.

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.

Legislation	Function
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. Atmospheric Emissions	- 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)
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.

Legislation	Function
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.
<Power and Electricity>	
General Law of Electricity,	- Prescribes the fundamental issues related to electricity. This law prescribes the

Legislation	Function
SIGET	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

The Ministry of the Environment and Natural Resources (MARN) is the responsible institution in the central government for socio-environmental aspects. Table 3.1.2 lists several institutions that are related to renewable energy development in El Salvador.

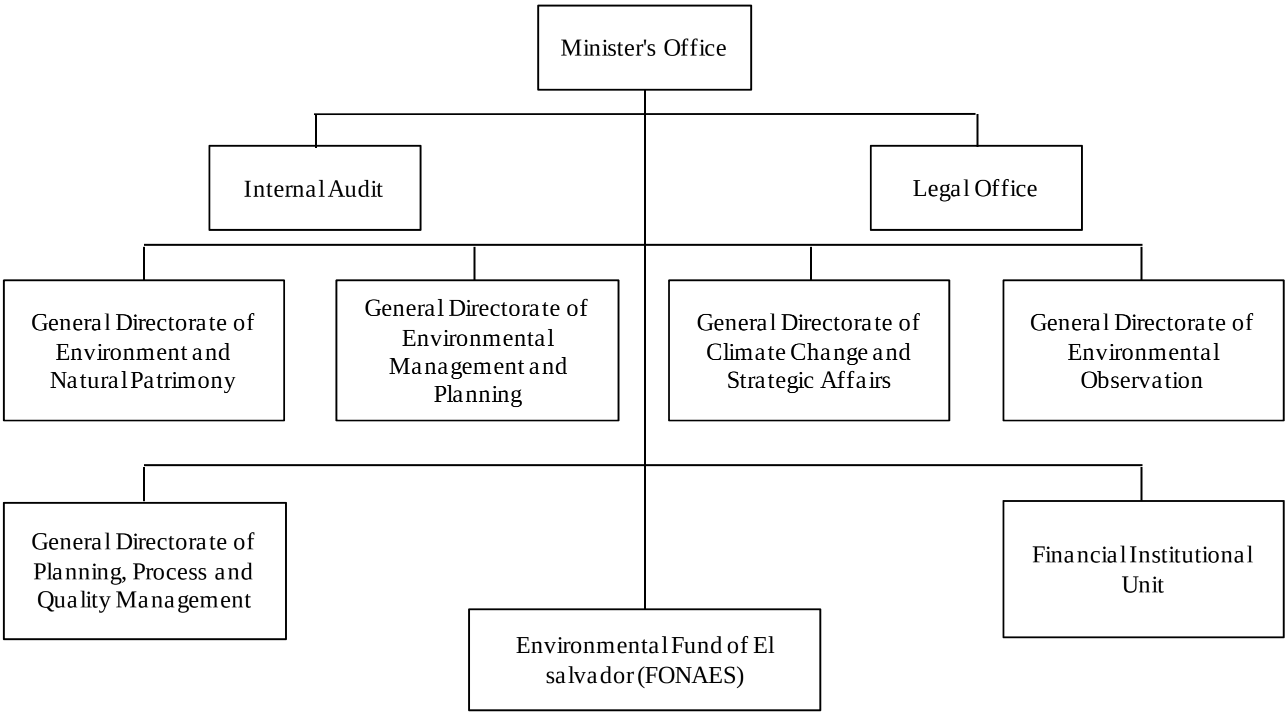
Table 3.1.2 Institutions Responsible for Socio-environmental Aspects in the Development of Renewable Energies

Entity	Responsibilities
Department of Public Assets Control in the Republic's Attorney General Office	- Participate in the approval process of notarization. - Inscription of real estate acquired in the respective Real Estate Property Registry.
Civil Unit of the Attorney General Office	- Participation in titling procedures for real estate that have no duly registered property titles. - Participation in expropriation trials if necessary.
Courts with Territorial Jurisdiction	- Participation to solve cases of dispute or conflict, when owners do not reach an agreement on the terms of indemnification of the real estate to be occupied. - Participation in the processes of solving legal problems on real estate
National Registry Center	- The institution responsible for cadaster registry provides documentation regarding updated status of real estate, approval of plans of simple segregation, registration and disencumberment, and transference of real estate.
VMVDU	- Construction permits and work acceptance.
National Energy Council (CNE)	- The institution responsible for establishing and promoting the energy policy and strategy on promoting renewable energy development.
General Superintendence of Electricity and Telecommunications (SIGET)	- The institution responsible in applying the regulations on electricity and telecommunications. - Implementation of the actions, contracts and operations that are necessary to comply with the objectives established by laws, regulations and other provisions that rule the sectors of electricity and telecommunications.
Municipal Governments	- Regulations and development of plans and programs destined to the preservation, restoration, rational use and improvement of natural resources, according to the law. - Issuance of local ordinances and regulations. - Prepare tax rates and reforms, and propose them as laws to the Legislative Assembly. - Construction permits.

(Source: JICA Study Team)

3.1.2.1 Structure of MARN

The structure of MARN is composed of five director offices: 1) the General Directorate of Environment and Natural Patrimony, which organizes public consultations; 2) the General Directorate of Environmental Management and Planning, which reviews the Environmental Form and establishes the TOR for the preparation of the EIA; 3) the General Directorate of Climatic Change and Strategic Affairs; 4) the General Directorate of Environmental Observation; and 5) the General Directorate of Planning, Processes and Quality Management.



(Source: MARN)

Figure 3.1.1 MARN Organizational Structure

MARN implements capacity buildings programs to public institutions to strengthen their capabilities on environmental protection and conservation under the Strategic Vision 2009-2014 of MARN, as listed below.

- Extension and strengthening of data and information related to the environment
- Strategic implementation of environmental evaluations
- Implementation of the System of National Environmental Management (SINAMA)
- Preparation of the National Environment Report
- Preparation of the National Environment Policy
- Preparation of the National Environment Prevention Plan
- Arrangement of the environment law for development and land use planning

Based on the vision of MARN, some recommendations to the National Energy Council (CNE) regarding the energy sector are as follows:

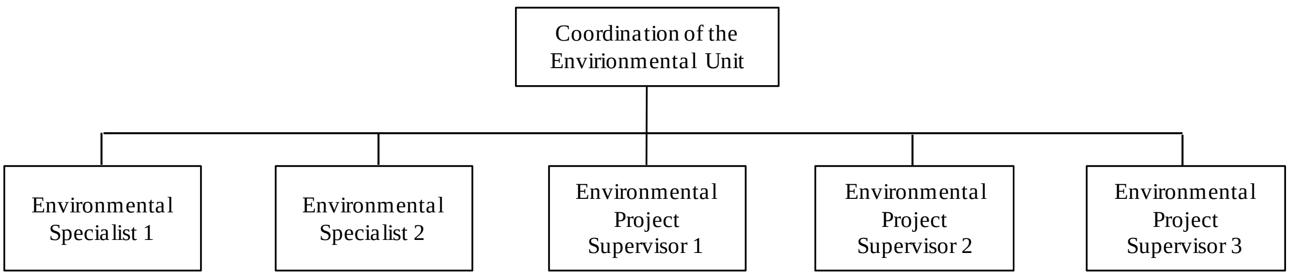
- Deal with environmental issues strategically in case CNE prepares an energy policy
- Coordinate and cooperate with MARN on environmental assessment and evaluation in the energy sector
- Promote assistance on the environmental conservation program and efficient use of energy
- Promote renewable energies to avoid unnecessary impacts to the environment

3.1.2.2 Institutions Related to Renewable Energies and Environmental Issues

The environmental units of LaGeo and CEL have played an important role in environmental and social considerations of renewable energy projects in El Salvador. The organizational structure and functions are presented below.

A. LaGeo Environmental Unit

LaGeo organizes an environmental unit as presented in the organizational chart shown in Figure 3.1.2, and has the following functions as six axes of action in the strategic plan 2011-2013, considering socio-environmental aspects:



(Source: LaGeo)

Figure 3.1.2 LaGeo's Organizational Structure

a. Environmental evaluation process

- Ensure compliance with environmental legislation applicable to project development.
- Prepare environmental assessments and environmental management programs for each activity or project, and carry out of the procedures required by MARN.

b. Project follow-up and control

- Follow-up and control environmental management, and safety and occupational health programs for the projects under execution.
- Detect nonconformities and carry out corresponding preventive and/or corrective actions.

c. Environmental_management_systematization

- Carry out standardization and systematization of environmental management of geothermal projects.

d. Research and development

- Develop research focused on the management or control of environmental aspects identified in the development of geothermal projects.

e. Communications and diffusion

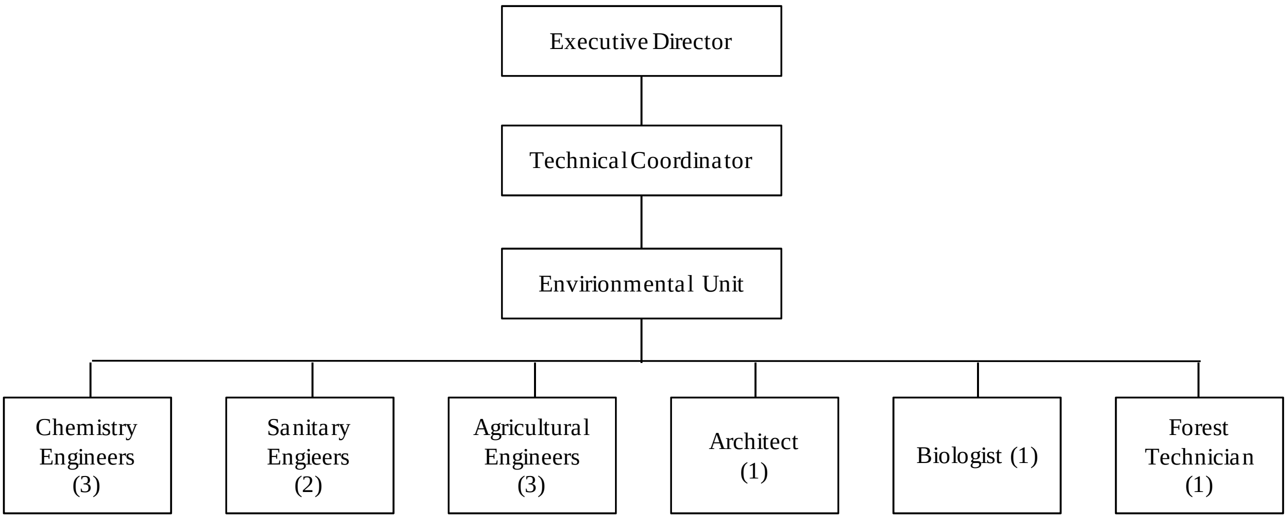
- Inform environmental management on geothermal projects such as awareness of local people about the environmental benefits of geothermal development.

f. Attention to unforeseen circumstances

- Provide support to other activities or requirements of the company related to the environment.

B. CEL Environmental Unit

CEL organizes an environmental unit as presented in the organizational chart shown in Figure 3.1.3, and has the following functions to implement CEL's environmental management:



(Source: CEL)

Figure 3.1.3 CEL's Organizational Structure

- Implement adaptation programs and monitoring plans resulting from environmental diagnoses.
- Ensure an adequate incorporation of environmental component.
- In charge of EIA of CEL's projects and request the respective approvals from MARN.
- Participate in public consultation activities that are required in the approval process of EIAs of CEL's projects.
- Assist and participate in external meetings and activities on environmental issues
- Contribute in the development of regulatory and sustainable management activities of the Río Lempa Basin as a function of reservoirs and future projects of CEL.
- Organize and update the environmental information system (EIS) referring to documentation

related to CEL's environmental management.

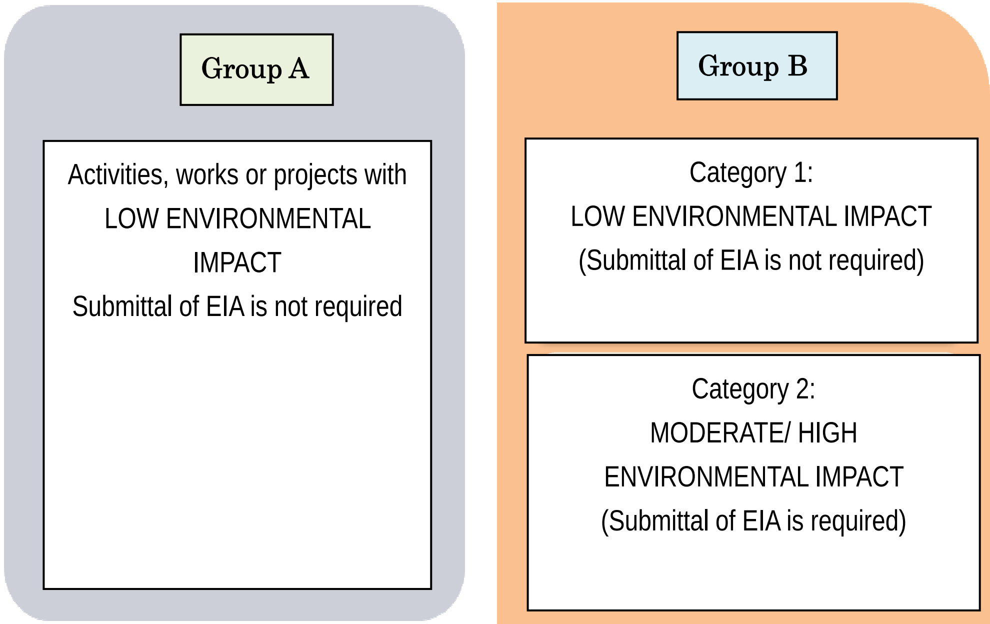
- Coordinate with the renewable energy management office on environmental impact.
- Apply continuous improvement to the activities carried out by the unit.

3.2 Procedures on EIA

Articles 19, 20, 21, 22 and 23 of the Environmental Law states that prior to the beginning and operations of the activities defined in this law, there must be an environmental permit. Renewable energy projects require the carrying out of an EIA and obtaining of environmental permit issued by MARN. However, based on Article 22 of the Environmental Law, MARN classifies projects according to its magnitude and to the nature of the potential impact. Article 23 of the law states that an EIA will also be carried out at the expense of the executing institutions.

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)

3.2.3 Preservation of Cultural Heritage

Paragraph 3 of Article 1 of the Constitution of the Republic of El Salvador provides that “it is the State’s duty to ensure to the people their enjoyment of culture”, and Article 63 states that “The artistic, anthropological, historical and archaeological wealth of the country forms part of the Salvadorian cultural treasure, which is safeguarded by the State and is subject to special laws for its preservation”.

Therefore, it is important that the executive corporation of the project acquires a work permit from the Secretariat of Culture before starting the construction stage of renewable energy projects. Table 3.2.2 shows the steps to be followed in order to obtain the work permit.

Table 3.2.2 Steps to Obtain Work Permits from the Secretariat of Culture

	Step Description	Responsible
1	Delivery of the inspection request for the project zone to the Secretariat of Culture, after defining the project zone	Executive Corporation
2	Inspection and preparation of TOR	Secretariat of Culture
3	Publication of resolution	Secretariat of Culture
4	Preparation of work plan	Executive Corporation
5	Approval of work plan	Secretariat of Culture
6	Carrying out of cultural heritage assessment	Executive Corporation / Secretariat of Culture
7	Publication of modifying resolution	Secretariat of Culture

(Source: JICA Study Team)

3.2.4 Environmental Management in Renewable Energy Projects

Based on the information collected in the areas of renewable energy projects and on information supplied by those responsible for following up the socio-environmental component of such projects, a description of the environmental management for each energy type follows, which is carried out during the execution and operation of such projects,

3.2.4.1 Small Hydropower

An environmental impact assessment (EIA) is realized for construction and operations. On the basis of the environmental format by MARN, MARN decides to establish the EIA as well as environmental management program and environmental monitoring plan (EMP), which is to a certain extent guarantees the environmental feasibility of the project and environmental protection. There is a commitment of environmental character of the executive corporation of the projects, which is subject to audits or to complaints from local people. Adequate management is implemented for solid and liquid wastes, air pollution, soil and water contamination, soil erosion, dumping of hazardous substances, waterproofing of areas, combustible gases, hazardous substances, resettlement of affected people, skill improvement programs for local people, environmental education to workers and neighboring people, and so on.

3.2.4.2 Wind Power / Solar Panels / Thermal Solar

The follow-up to the environmental component in wind and solar power projects is carried out based on the EMP prepared by environmental specialists in the planning and design stages. Such measures are mandatory for the executive corporations of the project to maintain the project in compliance with socio-environmental conditions.

3.2.4.3 Geothermal Power

During construction of such, management is carried out through an Environmental Management and Industrial Safety and Occupational Health Program (PMASYSO), which consists of the following:

- Identification of activities that will be carried out during the construction stage
- Environmental analysis to determine the potential impacts that each activity would generate

- Assessment of the potential impacts in consideration of their sensitivity
- Preparation of an EMP which comprises the control of all environmental aspects of the activity as well as the mitigation and/or compensation measures of the significant impacts
- Proposal of supervision and monitoring program in the EMP to guarantee the measures

Under the EMP, the executing corporation is to conduct environmental management in/around the project site, and to control environmental conditions continuously through the supervision of the environmental specialist.

Some of the environmental measures proposed for the construction of a geothermal well perforation platform are the following:

- Elimination of trees: to prepare an inventory of affected trees and to compensate by planting ten trees for each tree eliminated is proposed, including maintenance of the planted trees for a 2-year period.
- Dust emissions: to carry out an irrigation plan to humidify the soil
- Loss of organic soil: to stock up organic soil for later use in the creation of forest nursery
- Modification of superficial drainage: to conduct protection and drainage works
- Soil waterproofing: to construct systems for infiltration ditches and rainwater absorption wells
- Generation of erosive processes: to plant *vetiver* grass in slopes
- Water consumption: to construct roof and water systems donated to families in the project area
- Increase in noise levels due to perforation: to construct soundproofing screens
- Contamination of air from gases and smells: to absorb H_2S by water injection
- Landscape modification: to plant live fences and windbreaker curtains
- Occupational and/or public accidents: to train on road and occupational safety, and on risks
- Generation of common and special solid residues: to implement final disposal plan for common and special solid wastes
- Generation of common and special liquid residues: to implement final disposal plan for common and special liquid wastes

The following actions are carried out during operations of the geothermal plant:

- Monitoring programs for water and air quality such as monitoring of H_2S, CO_2 and noise in/around the project sites
- Monitoring of residual water management
- Common and special solid residues management plan
- Common and special liquid residues management plan
- Reforestation and forest maintenance plans

- Environmental protection measures

3.2.4.4 Biomass

Environmental management during the installation and operation stages is carried out based on the EMP and monitoring plan of the EMP, which ensures the environmental feasibility of the project and environmental protection, in consideration of the local people and their livelihood conditions. Comprehensive management is carried out for solid and liquid wastes, air pollution, soil and water contamination, soil erosion, dumping of hazardous substances, waterproofing of areas, combustion gases, hazardous substances, environmental education to workers and surrounding people, and so on.

3.3 Regulations Related to Land Use

In implementing territorial development in El Salvador, it is indispensable to observe the regulations on land use and obtain an environmental permit discussed in the following sections.

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.

Land Use Decree 855 is applied to the construction of any structure and any type of project using land. Applicants should submit relevant application forms with required documents to the offices in charge in order to obtain permits and licenses in a way of either through procurement of the land or rent.

Currently, Land Use Decree 855 is under revision in the office of the President by the Undersecretary of Territorial Development.

3.3.2 Protected Natural Areas

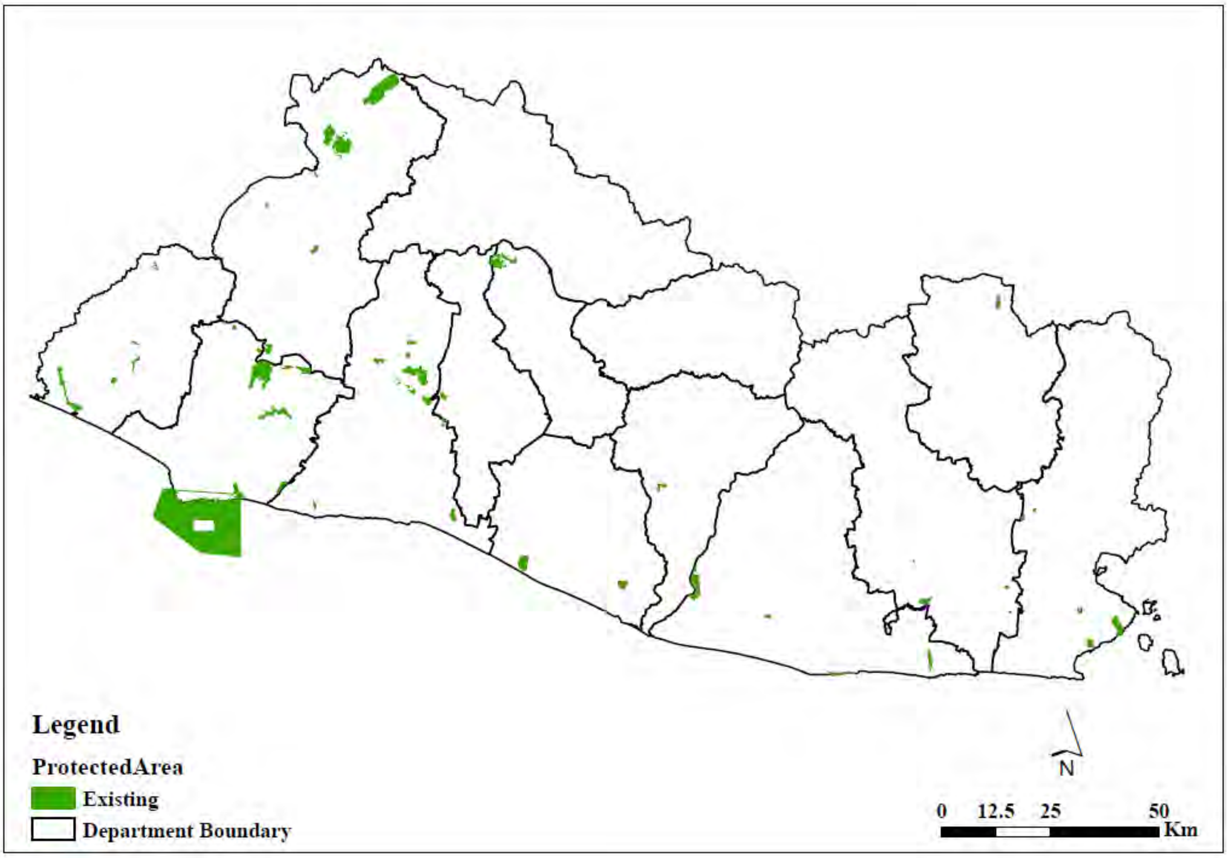
Environmental Law, which was established by Legislative Decree No. 579 on 15 February 2006, in Articles from 78 to 81 and from 85 to 95 refers to the protected natural areas. The following three points are emphasized in particular.

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

- to establish legal system, management system and specification for all 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.

Under the Environmental Law and the related regulations, any development project in the protected natural areas is seriously restricted by MARN. In case of renewable energy development in the protected natural areas, the procedures of Environmental Impact Assessment (EIA), which is mentioned in the Section 3.2 of this report, are conducted under the supervision of MARN to get an environmental permission in the same way as development in other sectors and as development in non-protected natural areas.

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

3.3.3 Environmental Permit

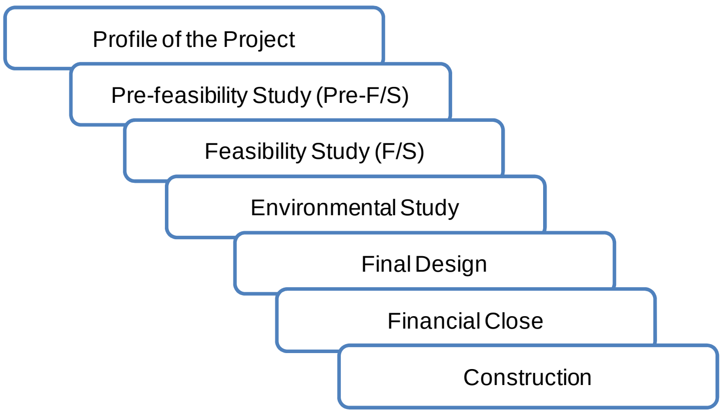
Aside from the permits and licenses required under Land Use Decree 855, those who want to implement any projects should obtain an environmental permit[2] from MARN. Relevant descriptions were previously given in Section 3.2. For renewable energy in particular, Section 2.1, subparagraphs f, g and h, provide the required procedures for wind, hydropower and geothermal power developments.

3.4 Regulations Related to Participation of Private Power Developers

In this section, descriptions will be given on procedures and rules required for private power developers to participate in the electricity market in the power sector of El Salvador. The electricity market has been liberalized since 1999 and applied wholesale market mechanism. Therefore, any private developer can participate in the electricity market by following procedures and rules. The existing procedures required for planning until participation into the electricity market are given in this section, derived from information through interviews with SIGET, CEL, LaGeo, and through review of existing reports and relevant materials.

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

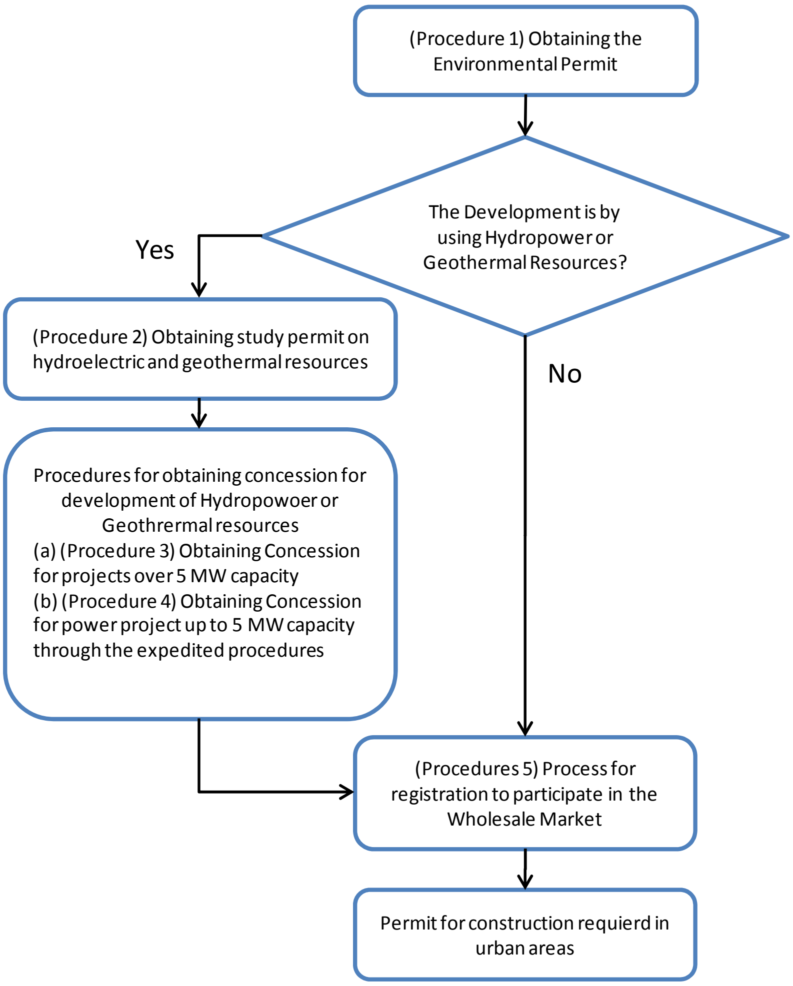
The required procedures to realize the abovementioned power development by renewable energy can be categorized into five major procedures as follows:

(Procedure 1) Obtaining the environmental permit

[2] Official Gazette No. 79, Volume 339, published on April 05, 1998, Decree 233

(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 above procedures were confirmed through interviews with SIGET and other organizations. The same descriptions are given in the guidelines prepared by ARECA project assisted by BCIE and KfW entitled, “Guide to developing renewable energy projects in El Salvador, Central America”. 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

The above procedures are independent. Before advancing to the next step, the preceding procedures should have been completed.

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

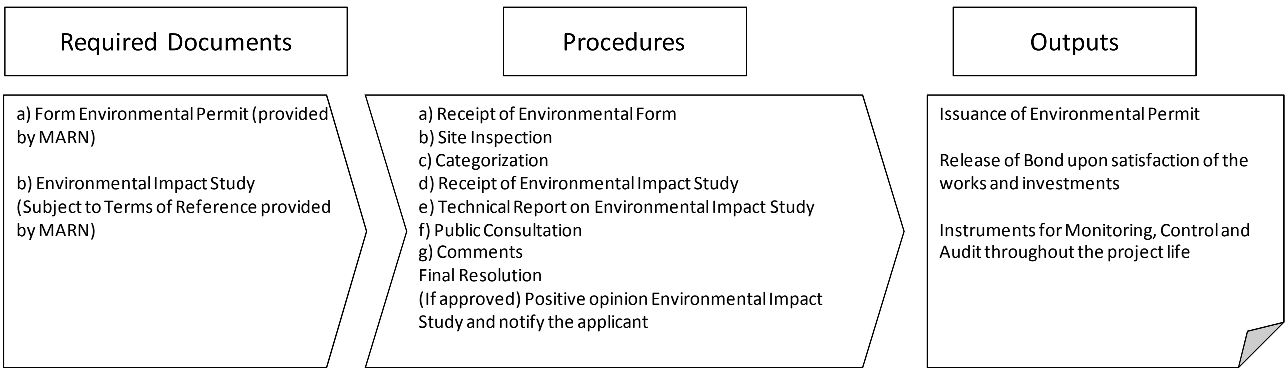
(Procedure 1) Obtaining the environmental permit

The procedures are shown in Figure 3.4.3 and described as follows:

(Required Document) Applicants should submit forms for environmental permit provided by MARN.

(Procedures) MARN should conduct site inspection and categorize the project to determine whether an environmental impact study (EIS) is needed or not. If needed, the study is conducted by the applicant and submitted to MARN. MARN will then give technical report to the applicant. After which public consultation will be held. All costs generated by such studies must be borne by the applicant. MARN will have 60 days to evaluate the EIS including public consultation (this period can be extended exceptionally subject to justified reasons). MARN will give their comments on the EIS and requests the applicant to modify the EIS report.

(Output) A resolution will be issued by MARN after approval of the EIS, and favorable technical opinion will be given to the applicant. The applicant must pay the environmental compliance deposit prior obtaining the environmental permit. This deposit should be equivalent to the total cost of the works and investment required in order to comply with environmental management and adaptation. This deposit will be kept until these works and investments are completed.

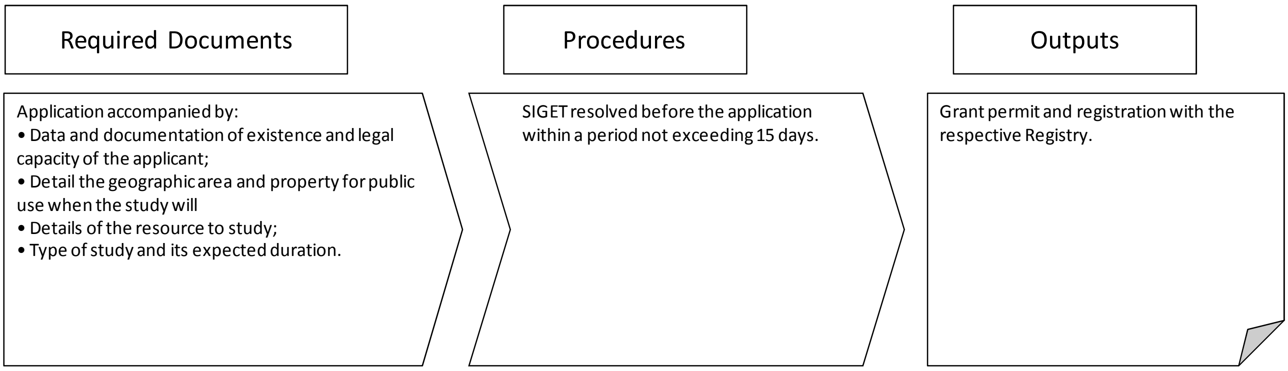


(Source: SIGET, ARECA Report)

Figure 3.4.3 Procedures to Obtain an Environmental Permit

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

The procedures are as shown in Figure 3.4.4 and described as follows:



(Source: SIGET, ARECA Report)

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

(Required Documents) The permit should be requested from SIGET. The application should be accompanied by the applicant’s data and documentation of existence and legal capacity, detailed geographic area and public use of property where the study will be done, details of the resource to study, type of study and its expected duration.

(Procedures) SIGET has 15 days to grant the permit after the application is received. The permit cannot be granted for more than two years (applicant can request for an extension of this period for one time only. Applicant should request 90 days prior to its expiration).

(Output) If the request is approved, SIGET will record the application in an appropriate institution. Inscription will state the authorized entity to do the study, the geographical area where the study will be done and the permits’ validity period.

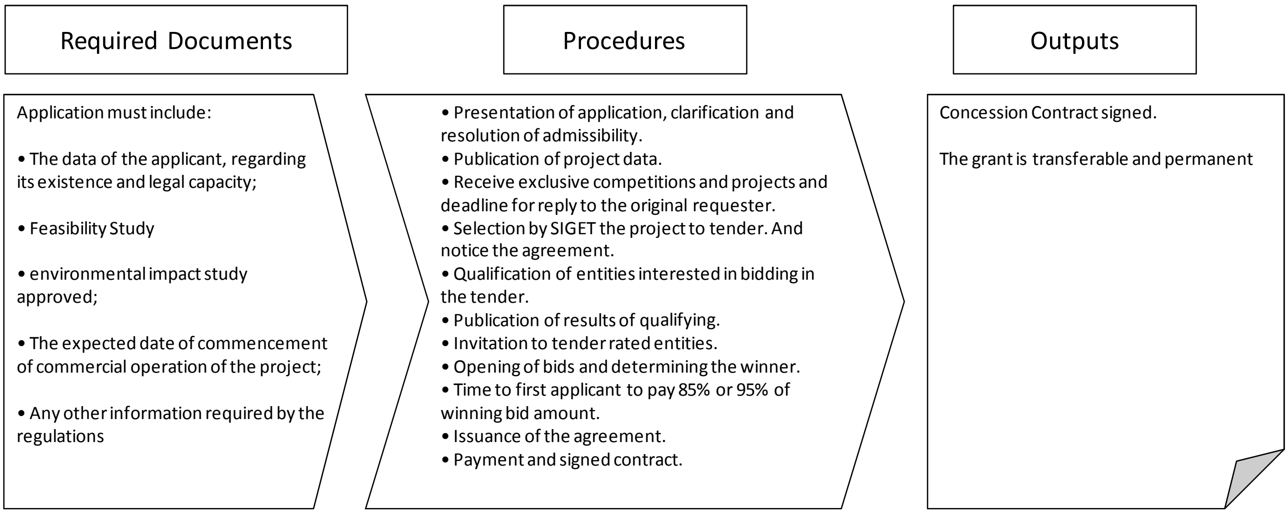
After the study, the applicant should obtain a concession for exploitation. The procedures are described below.

Concession Procedures for Hydropower and Geothermal Resources Exploitation

The permit should be requested from SIGET. The application should be accompanied by the applicant’s data and documentation of existence and legal capacity, feasibility study, previously approved EIS, expected start date of the project’s commercial operation, and any other information requested. The concession is granted through a bidding process, and if there is nobody interested in developing the same concession, this could be granted to the applicant without any cost. The procedure varies depending on the project's dimensions.

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

The procedures are as shown in Figure 3.4.5 and described as follows:



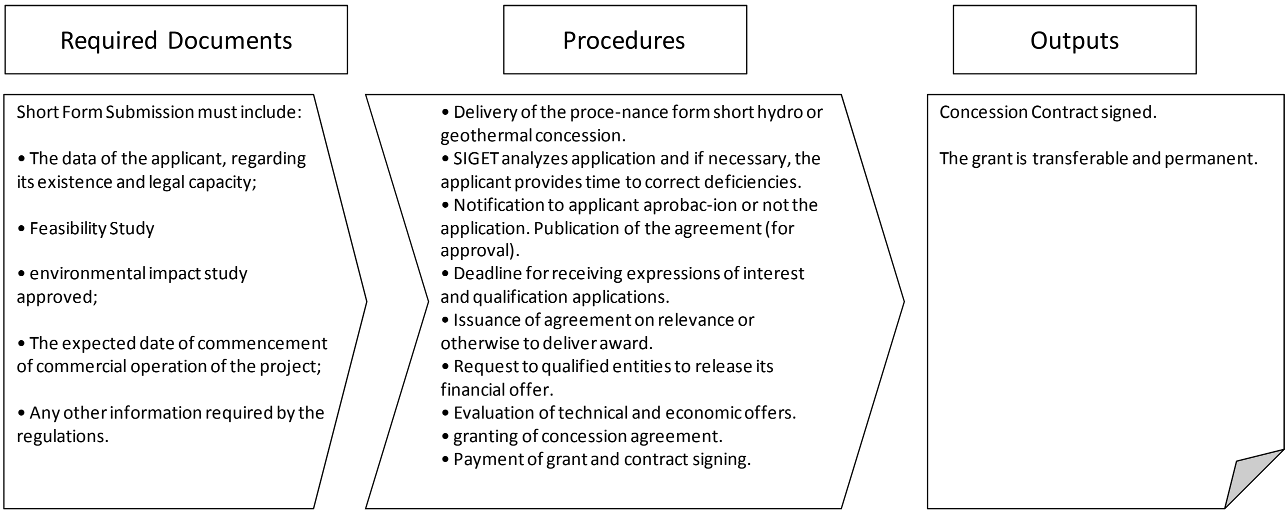
(Source: SIGET, ARECA Report)

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

SIGET estimates that at least 246 working days is necessary in order to complete the request. After the applicant submits the application, SIGET must determine if it will be received or if there are any clarifications needed. Consequently, the project data will be published for comments. A certain period of time is given to see if anyone else is interested in developing the same project or if there are any objections. If such, the applicant must answer corresponding comments. SIGET selects the project to be tendered and notifies the acceptance agreement, followed by the names of entities' that wish to participate in the bidding process (SIGET will notify entities the date in which they can purchase the prequalification document). Prequalification results will be published, and an invitation is sent to qualified entities requesting them to submit their offers in a sealed envelope. A guarantee of no less than 10% of the offer's total amount should be included. Bid opening will be held and the winning offer is determined. In case the first applicant is not successful with the bid, a time period is allotted for the applicant to express its intention to pay 85% for geothermal or 90% for hydropower out of the winning offer. After that, the agreement will be made and the necessary amount will be paid.

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

The procedures are as shown in Figure 3.4.6 and described as follows:



(Source: SIGET, ARECA Report)

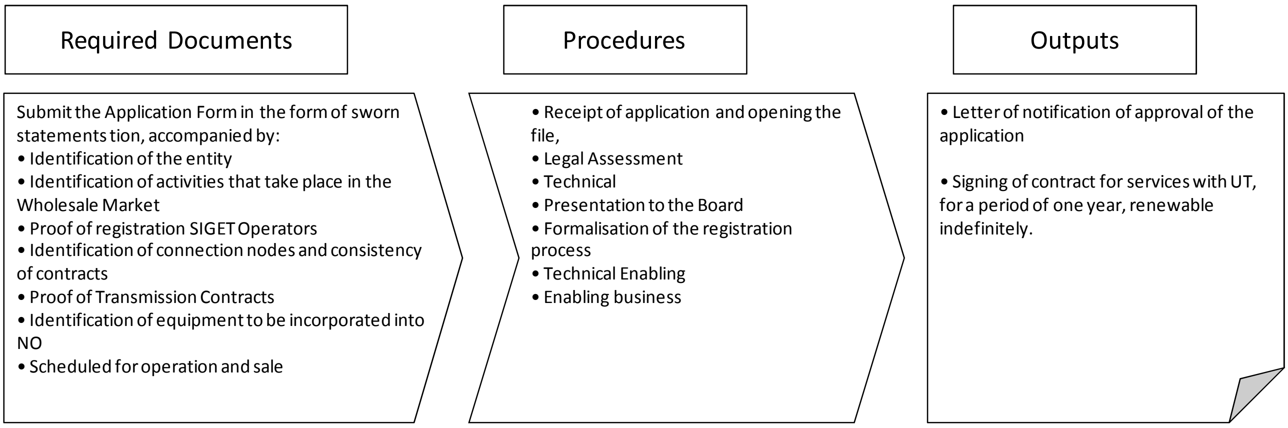
Figure 3.4.6 Procedures to Obtain Concession for Projects of up to 5 MW Capacity Through Expedited Procedures

SIGET estimates that this expedited process could take at least 75 working days in case when all requirements are met, and if there are no oppositions to the proposed project by the applicant. The applicant submits the application and a period for the application to be analyzed and corrected, is set. The applicant is notified if the application is accepted or not. If accepted, the acceptance agreement is published, and a period of time is given for others interested in developing the same project. In case there are others interested, they must submit their application. The applications are received and evaluated, and consequently, a decision is given stating if the application is accepted or not. All entities interested in the concession and have been accepted must submit their offers. All offers are evaluated and the winning offer is determined. The agreement is then signed and the concession is paid.

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

The procedures are as shown in Figure 3.4.7 and described as follows:

The applicant must submit an application from UT as a sworn statement, which includes identification and activities of the applicant, certificate of inscription given by SIGET stating the activity to be developed, promising that they will submit any information or guarantees requested by UT, and bank account information that they will use for transactions in the market. Certain time is given for the contract to be signed with UT. The date that the applicant intends to start operations in the market should also be stated. Additionally, the application must be accompanied by the applicant's identification, certification of activities that will be developed in the wholesale market, certification of inscription as operators by SIGET, identification of nodes for connection and copy of contracts, certificates of transmissions contracts, identification of equipment to be incorporated into the electricity system if there will be any, and schedule for operations and sales. The inscription process takes about a month. In case that no inconvenience arises, the application is received and a file is opened. It is then legally and technically evaluated and presented to the UT board of directors. Once the registration process is formalized, it is technically and commercially enabled. This process has no cost but the applicant has to pay a guarantee fee. After an approval notification letter is issued by UT, a contract for a period of one year is signed with UT. The contract is automatically extended, except if the applicant wants to terminate the contract or if UT decides that obligations are not complied with.



(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 Decree was prepared to realize the objectives advocated by the Ministry of Economy and CNE such as: rational use of resources; to reduce dependence on fossil fuels; to reduce environmental pollution in the country and to significantly improve the national balance of payments; to reduce greenhouse gas emission; to encourage the use of renewable energy sources in electricity generation; to promote investments that enable sustainable development projects; and so forth. In view of the above objectives, it was judged necessary to make legal provisions for promoting investment in power generation projects based on the renewable energy sources in the country such as hydropower, geothermal, wind power, solar PV, biomass etc. encouraging research, exploration and development projects.

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

In this chapter, the following information on renewable energy were examined: (i) current status, (ii) obstacles to introduction, (iii) related existing and ongoing studies and projects, and (iv) future development plans. Herewith, descriptions are generally given on renewable energy, small hydropower, wind, solar photovoltaic (PV), solar thermal, geothermal, biomass and biogas. Considering the information on (i) to (iv) above, their description will be given on the basic approach for master plan formulation, i.e., how to formulate the master plan by taking into account the available information. Due to technical and economic issues, it might be necessary to prepare the required environment for some of the renewable energy sources prior to introduction such as implementing pilot projects, research and development, and human resources development in enterprises and universities, or to bring up related industries. For such energy sources, the main works would be to review existing materials in order to give recommendations toward future introduction.

4.1 Renewable Energy in General

Prior to the introduction of each renewable energy source, general information on renewable energy will be examined.

4.1.1 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.

4.1.2 Obstructions to Introduction

The obstacles to the introduction of renewable energy sources in general, i.e., common challenges that can be observed when introducing renewable energy sources, are the following:

- Complicated procedures to get permits and licenses from SIGET and MARN take a long time to complete.
- Lack of data and information (observation data and studies) for the introduction of renewable energy.
- No sufficient regulatory frameworks to promote the introduction of renewable energy sources that require relatively high initial investment costs.

4.1.3 Existing and Ongoing Related Studies and Projects

The studies and projects carried out for renewable energy sources are described in the next sections. In this section, the studies and projects related to renewable energy in general such as on regulatory frameworks to promote the introduction of renewable energy, general guidelines, comprehensive studies, etc. will be examined in chronological order.

4.1.3.1 UNDP/GEF Electrification Project Based on Renewable Energy Sources (October 2002)

In order to attain energy development while maintaining a clean environment, the Government of El Salvador initiated a project for the development of renewable energy. The project was aimed at reducing emissions of greenhouse gases (GHGs) by promoting small-scale renewable energy sources (0 to 5 MW), which can be integrated into the existing urban and rural distribution networks. The project was supported by the United Nations Development Program (UNDP) in order to formulate projects that are to be financed later using the Global Environment Facility (GEF). The Ministry of Environment and Natural Resources (MARN in Spanish abbreviation) acted as the counterpart agency for the implementation of the project. The goal of the project is to reinforce the competitiveness of small-scale renewable energy sources to be sold to distribution companies, thereby reducing GHG emissions.

4.1.3.2 Analysis for the Salvadoran Market of Renewable Energy (ARECA/BCIE, 2009)

Analysis was made and presented to the renewable energy market of El Salvador through a project titled “Accelerating Renewable Energy Investment in Central America and Panama” (ARECA). The ARECA was implemented by the Central American Bank for Economic Integration (BCIE), with the support of UNDP through its GEF.

The ARECA is a project focused on Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica and Panama, for promoting renewable energy introduction aimed at the reduction of GHG emissions for sustainable development of the region. The main focus is to realize medium- to small-scale renewable energy power development projects with equal to or smaller than 10 MW capacities, which can be funded by BCIE. The project includes the identification and removal of obstacles toward introduction, and mitigating the risks to financial institutions through a mechanism of partial credit guarantees.

The major contents of the report are as follows:

A. Background Information: Relevant development indicators, an overview of the government system, geography, climate, natural resources, etc.

B. The Electricity Market and Renewable Energy: Mechanism of the electricity market, regulatory frameworks, market operations, permitting and licensing, etc.

C. Generation Costs and Energy prices: Generation costs of each renewable energy source up to 10 MW, and pricing schemes of the electricity market.

D. Renewable Energy Projects and Carbon Markets: General elements of the status of the Clean Development Mechanism (CDM) at international, regional and country levels, and the application of CDM to renewable energy projects.

E. Renewable Energy Projects up to 10 MW: Several examples of renewable energy projects of relevant scale at different stages of development identified in the country.

F. Financing to Renewable Energy: Summarizes the results of interviews with representatives of major banks in the country in order to help understand the trends and positions of such banks on financing small-scale renewable energy projects up to 10 MW.

G. Conclusions and Recommendations: Through the use of diagrams, such as the "Spider", general conclusions about the development climate of renewable energy projects are shown.

4.1.3.3 Study and Proposal of the Regulatory Framework for the Promotion of Renewable Energy in El Salvador (December 2009, Ec**onomic Commission for Latin America and the Caribbean **(CEPAL))**

The Central America Sustainable Energy Strategy 2020 (Strategy 20/20) was approved in 2007, presenting the directions and indicators towards achieving sustainable development of the region. Based on the strategy, activities related to renewable energy development are reported by each country in the region.

The report is presented with the following chapters:

Chapter I provides a background on subregional energy initiatives and their current status as well as a brief overview of the energy sector of the subregion.

Chapter II discusses the possibilities for renewable energy, particularly on hydropower and wind power markets in the six five countries in Central America and Panama.

Chapter III discusses the situation of biofuels that are produced mainly from sugarcane and African palm.

Chapter IV presents the status of the main actions taken by each country in the priority areas of Strategy 20/20, especially those related to energy efficiency and diversification of the energy matrix.

Chapter V presents the conclusions and recommendations.

4.1.3.4 Guide to Developing Renewable Energy Projects in El Salvador, Central America (January 2010 by BCIE and KfW)

Countries in Central America are strongly working on the promotion of renewable generation projects. However, there are a considerable number of small- and medium-scale developers who do not have an agile and practical source of information.

This guide was prepared with the objective of introducing necessary procedures toward the development of renewable energy sources. It includes a brief overview of the mechanism of the electricity market in each country. The guide consists of the following: (1) Issuance of permits and licensing, (2) Financing, and (3) Registration to CDM, etc. The guide also briefly describes the characteristics of major renewable energy sources such as hydropower, wind, geothermal, biomass and solar PV.

4.1.3.5 Consultation to Collect Studies and Information on Renewable Energy Development for Validation and Estimation of Potential Projects on Electricity Generation up to 20 MW in El Salvador (March 2011, CNE/GIZ)

The project was aimed at the collection and compilation of existing studies and information on renewable energy development for use in future projects or activities promoting renewable energy utilization up to 20 MW. The report reviews the existing studies, technical and financial potential, and selection criteria of projects to be implemented. The target energy sources are the following: (i) hydropower, (ii) geothermal, (iii) solar PV, (iv) biomass, (v) wind, and (vi) ocean energy.

4.1.3.6 Study and Proposed Regulatory Framework to Promote Renewable Energy in El Salvador (March 2011, CNE/AEA)

As part of the national strategy of promoting renewable energy sources and diversification of the energy matrix, the National Energy Council (CNE) proposed to develop a regulatory framework that would encourage the development of renewable energy generation projects.

In this context, the captioned study was conducted with the main objective of carrying out the diagnosis, design and development of incentives and instruments to promote the implementation of renewable energy development projects up to 20 MW for introduction into the distribution networks.

The report is the result of the execution of the three phases indicated below. The objective of each phase is as follows:

- Diagnosis: to conduct an analysis of the regulatory framework in the electricity sector with special emphasis on the instruments for renewable energy projects on a small scale.
- Design: to develop strategic recommendations and guidelines aimed at understanding the barriers and key issues identified in the diagnosis.
- Policy development: to write the reforms at the level of rules and regulations in order to implement the regulatory design developed in the next phase of the project.

In each chapter of the report, the following descriptions and analysis were given:

General overview (Chapter 1); diagnosis results on the policy and regulatory frameworks on renewable energy development in the country (Chapter 2); analyze how the proposed design seeks to remove the priority barriers (Chapter 3); how to reform the rules in the existing General Electricity Law (Chapter 4); and how the barriers can be eliminated or mitigated through the implementation of the proposed solutions such as a regulatory approach (Chapter 5).

4.1.4 Future Development Plan

There is no development plan covering all the renewable energy resources (master plan). There is a study on regulatory framework that was introduced in Section 2.4 of Chapter 2. The study is under implementation by CNE with financial support from IDB. The JICA Study Team will watch the progress of the regulatory framework study and will refer to relevant information or recommendations from that study.

4.2 Small Hydropower Plants

A total of 20 hydropower plants with a total capacity of 487 MW was installed in 2011. Small hydropower plants of less than 20 MW each are currentlty operating in 17 sites with a total capacity of 35 MW.

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.

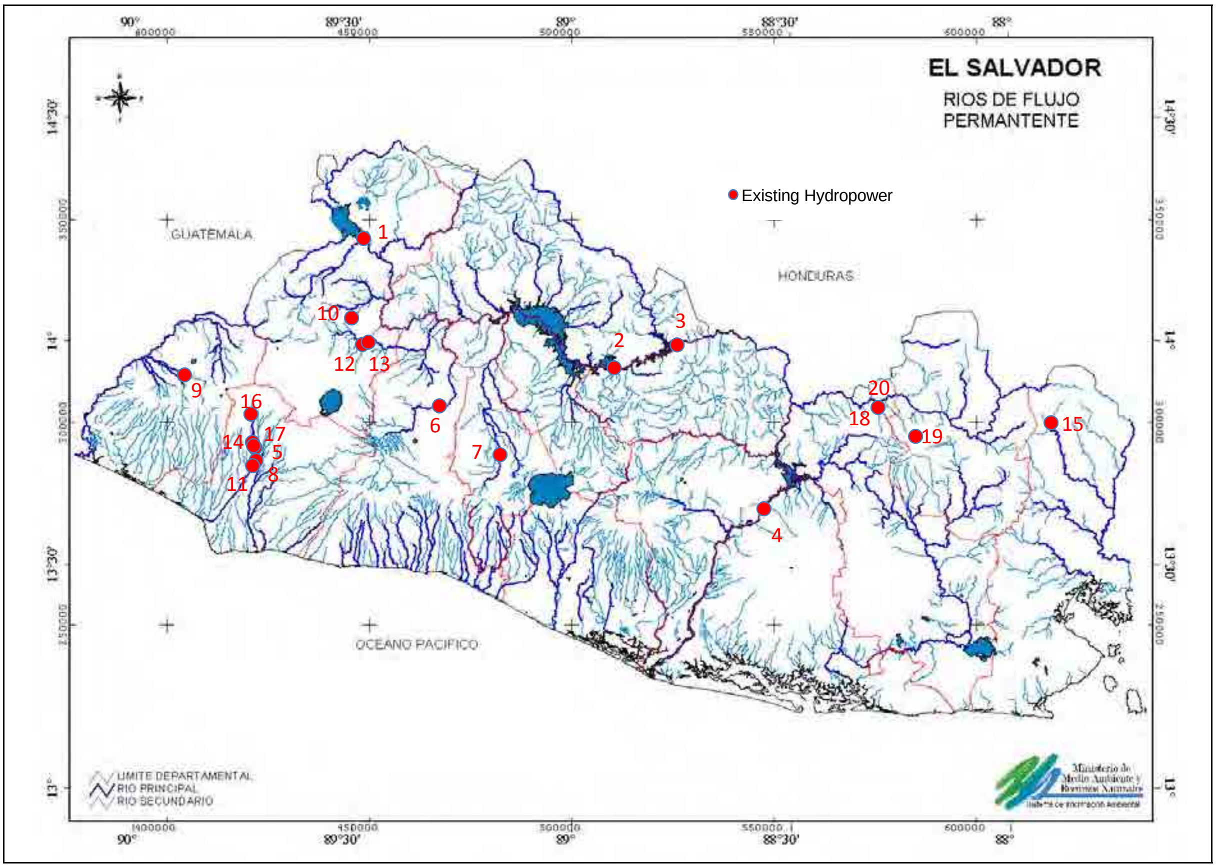
4.2.1 Current Status

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)



(Source: CNE)

Figure 4.2.1 Locations of Existing Hydropower Stations

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 20 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

4.2.3.1 Hydropower Potential Study

The following hydropower potential studies were conducted to date:

A. "Primer Plan Nacional de desarrollo Energético Integrado 1988-2000", Comisión Ejecutiva Hidroeléctrica del Rio Lempa (CEL), Enero 1988

B. "Pequeñas Centrales Hidroeléctricas en El Salvador", Estudio conjunto CEL-UCA (Universidad Centroamericana "José Simeón Cañas"), Ing. Axel Soderberg / Ing. Hermes Landaverde, Abril 1989

C. "Inventario de Ríos con Potencial Hidroeléctrico", Ing. Córdova, UCA, Mayo 1998.

D. "Electrifición con base en Recursos de Energía Renovable", Transénergie, F. Lozano / J. Cottin, MARN, UNDP-GEF, Octobre 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

The above potential studies are summarized below.

A. CEL 1988 Study (Medium and Large Hydropower)

According to the study of"Primer Plan Nacional de desarrollo Energético Integrado 1988-2000", CEL (1988), the following hydropower potential projects were identified as shown in Table 4.2.2.

Table 4.2.2 Hydroelectric Potential Sites by the CEL 1988 Study

No.	*Proyecto Project*	*Río River*	*Potencia Potential (MW)*
1	Zapotillo	Lempa	N.D.
2	Paso del Oso	Lempa	N.D.
3	El Tigre	Lempa	704
4	Rehabilitación 5 de Noviembre	Lempa	N.D.
5	Expansión 5 de Noviembre	Lempa	80
6	Expansión 5 Cerron Grande	Lempa	N.D.
7	San Marcos	Lempa	N.D.
8	El Jobo - La Angostura	Paz	72
9	Piedra de Toro - La Cabaña	Paz	66
10	Hacienda Vieja	Jiboa	N.D.
11	Santa Rita (Jiboa)	Jiboa	7.6
12	San José Loma (Jiboa)	Jiboa	5
13	San Esteban	Grande de San Miguel	20
14	San Juan	Grande de San Miguel	4.5
15	San José	Grande de San Miguel	3.2
16	El Platanar (Goascorán)	Goascorán	12.5

(Source: "Primer Plan Nacional de Desarrollo Energético Integrado 1988-2000"., CEL, enero 1988.)

B. CEL-UCA 1989 Study (Small Hydropower)

The inventory study by CEL-UCA in 1989 “Pequeñas Centrales Hidroeléctricas en El Salvador” (UCA: A. Soderberg / CEL: H. Landaverde, et.al.) was conducted for 66 rivers within the entire country of El Salvador. Of the 66 sites in the CEL-UCA study, only 11 sites were not visited because of their inaccessibility. The other 58 potential sites were inspected fortechnical and economic evaluation. Among the 58 sites, 29 sites were evaluated with a cost-benefit ratio (B/C) greater than one based on the current costs in 1989. The total installable capacity is 28,469 kW.

Table 4.2.3 Hydropower Potential Sites by CEL-UCA 1989 Study

Zone Zona	No. Projects Evaluated No. Proyectos Evaluados	Max. Potetial Instalable Potencia Maxima Intalable [kW]	Annual Enegy Production Producion Annual de Eneria [GWh]
Western (Occidental)	25	17,036	112.00
Central (Central)	24	20,633	84.83
Eastern (Oriental)	9	24,246	89.90
TOTAL	58	61,915	286.73

(Source: “Estudio Conjunto CEL/UCA Sobre Pequeñas Centrales Hiroelectricas En El Salvador”, Informe Final, CEL/UCA, Septiembre 1991)

In addition, five sites (Nahuizalzo, Sonzacate, Mirazalco, Papaloate and Pilonas) were evaluated in 1991at the pre-F/S level.

C. UCA 1998 Study (Ing. Córdova)

"Inventario de Ríos con Potencial Hidroeléctrico" (Ing. Córdova, UCA, Mayo 1998) was a kind of summary document of the CEL-UCA 1989 study. It was chosen the best river in the list of the CEL-UCA 1989 study. This study report has not been collected to date.

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

In the study of "Electrifición con base en Recursos de Energía Renovable" by Transénergie and UNDP-GEF for MARN (2002), the list of identified hydropower potential sites referred to the CEL 1988 Study and CEL-UCA 1989 Study. The project costs and economic values of each hydropower potential sites in the CEL 1988 and CEL-UCA 1989 Studies were updated from El Salvadoran colóns to US dollars in 2002 values.

E. GIZ 2011 Study (F. Lozano)

The study of GIZ 2011 Study (F. Lozano) referred to the list of hydropower potential sites in the UNDP-GEF 2002 Study and updated recent studies. However, the economic values such as inversion cost (US$), cost per kWh (US$/kWh), IRR (TIR), net present value (VAN) and B/C were not updated from 2002.

4.2.3.2 Project Study and Ongoing Project

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

The AEA is an initiative that originated from the framework of the United Nation's World Summit on Sustainable Development in Johannesburg in 2002. It was aimed at promoting renewable energy in Central America in order to contribute to sustainable development and global climate change mitigation. This organization was supported by the Ministry for Foreign Affairs of Finland, the Central American Integration System (SICA), the Central American Commission for Environment and Development (CCAD) and the Austrian Development Cooperation (ADC). Support is provided to projects for renewable energy, such as solar, wind, small hydropower, bioenergy and geothermal, for government institutions, non-governmental organizations (NGOs) and the private sector. The following projects and studies are conducted by AEA in El Salvador:

a. "Estudio de factibilidad para el desarrollo de 6 minicentrales hidroeléctricas en la zona Cacahuatique, Río Torola" El Salvador 3.02, AEA, MARN-SABES, Dr. Luis Boigues, April 2008.

a1. Six feasibility studies: i) Gualpuca in San Simon, ii) Miracapa in the Municipality of Carolina, iii) El Cabaña in the Municipality of Jucuaran, iv) El Juqiollo in the Municipality of San Simon, v) El Progreso in the Municipality of Torola, and v) Santa Rosa in San Antonio del Mosco.

a2. Construction of the Miracapa small hydroelectric power plant with installed capacity of 34 kW. It serves 45 families, and amounts to an investment of US$180,000.

a3. Construction of the El Juqiollo small hydroelectric power plant with installed capacity of 14 kW. It serves 41 families, and amounts to an investment of US$120,000.

- * The Sanitation, Health Education and Renewable Energy Association (SABES) is a Salvadoran nonprofit NGO founded in 1998 that provides social services to the community, through technical assistance during the implementation stage.
- * Since 2001, SABES developed their first micro hydropower project in La Chacra (17 kW). At present, two micro hydropower plants in Río Miracapa in Carolina (45 kW) and in El Juquillo in San Simon (14 kW) have been operating since 2006 and 2007, respectively. All the above projects are located in the Department of Morazan.

b. "Proyecto de rehabilitación de 4 pequeñas centrales hidroeléctricas", El Salvador 3.21, AEA, Compañía Eléctrica Cucumacayán S.A. de C.V. (CECSA), Pöyry Energy GmbH, Ing. Carlos Girón, March 2009.

- * A rehabilitation study was carried out by CECSA in order for four existing hydropower plants to achieve optimum operations through the installation of automated equipment and the improvement of equipment to meet international standards. The four hydropower plants are as follows: i) Cucumacayan, ii) Milingo, iii) Atehuesias, iv) San Luis II.

c. "Estudio de factibilidad para proyectos de minicentrales hidroeléctricas en 5 comunidades en los Departamentos de Morazán, San Miguel y Ahuachapán", El Salvador 3.22, AEA, SABES, Dr. Luis Boigues, Feb. 2008.

- * The F/S on the five sites in Morazán, San Miguel y Ahuachapán was conducted by SABES. The installed capacities are estimated as follows: i) El Calambre / Morazán in the La Joya village (58 kW → 75 kW), ii) El Salto (31 kW), iii) La Colmena (97 kW), iv) La Loma-Osicala (55 kW), and v) Sapo-Guanijiquil (150 kW).

d. "Aprovechamiento de energía hidraulica en sistemas de abastecimiento de agua por gravedad", El Salvador 3.28, AEA, ANDA, Ing. Karla Ciudad Real, March 2011.
   * This project involves the construction of a micro hydropower station (15 kW) in the raw water conveyance pipe from the river intake to the El Rosario water treatment plant of National Administration of Aqueducts and Sewers (ANDA) in order to reduce electricity fee by means of self-generation.

e. "Construcción de la Minicentral Hidroeléctrica El Calambre de 75 kW, en comunidad La Joya, J/ Perquin", El Salvador 3.30, AEA-SICA, SABES, Dr. Luis Boigues, UCA, Ing. Roberto Cordova, May 2006.

f. "Construcción de la Minicentral Hidroeléctrica, en comunidad San José Cureña", (75 kW), El Salvador 3.31, Proyecto en Revisión, AEA, SABES, Dr. Luis Boigues, May 2009.

g. "Construcción de la Minicentral Hidroeléctrica, en Beneficio El Salto J/Jujutla ; en el departamento de Ahuachapan", (40 kW), El Salvador 3.32, AEA, SABES, Dr. Luis Boigues, May 2009

h. "Estudio de prefactibilidad del proyecto de reactivacion de la presa hidroelectrica Venesia-Prusia", El Salvador 3.33, AEA, Compañía Eléctrica Jorge Meléndez e Hijos,
   * This is a pre-F/S on the reactivation of small and old private micro hydropower stations of Venesia-Prusia. Details are not mentioned in the AEA website.

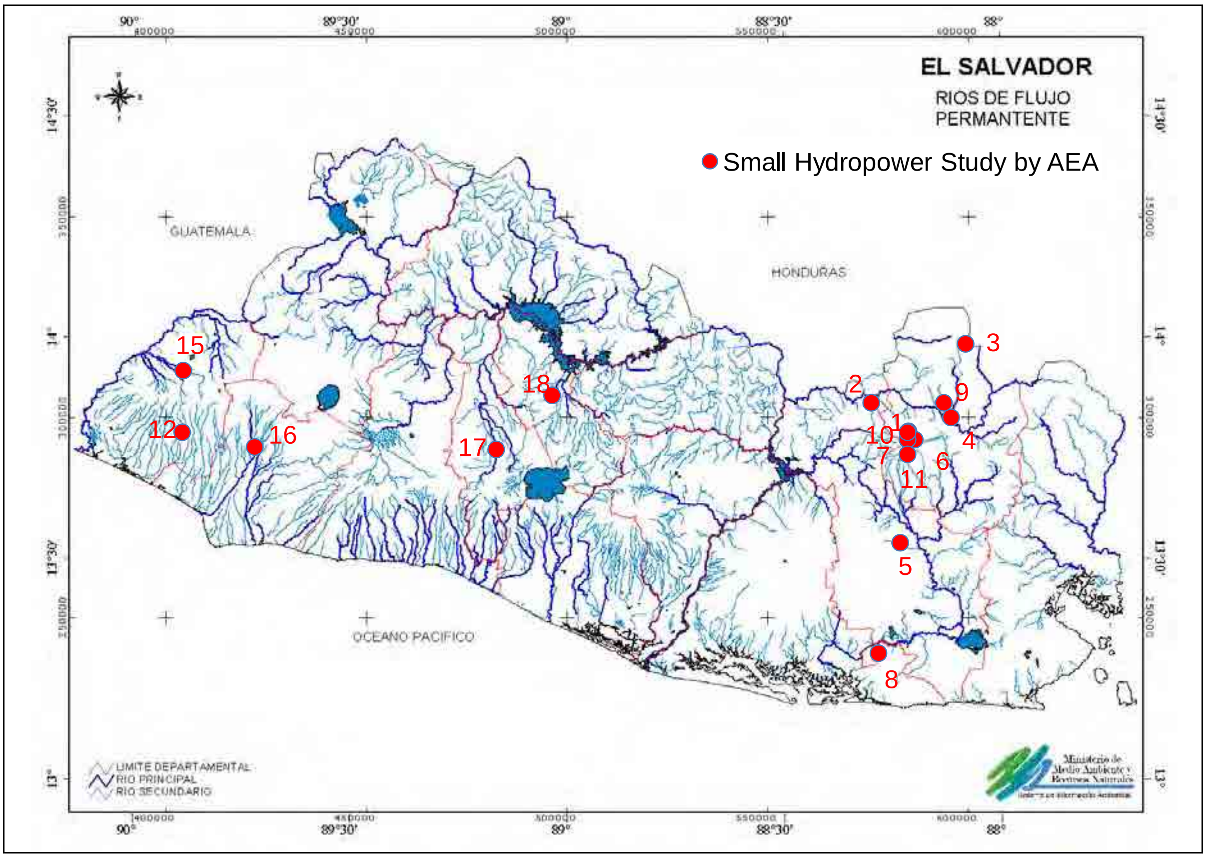
i. "Estudio de prefactibilidad-rehabilitacibsite.activacion de la presa h"studio de preEl Salvador 3.38, AEA, AGROUNION, S.A de C.V, November 2010.
   * This is a pre-F/S on the rehabilitation of the Santa Emilia I hydropower plant and the construction of the Santa Emilia II hydropower plant, which is located approximately 2.6 miles downstream. The total installed capacity is estimated at 1,180 kW.

A summary of the above studies through AEA fund is shown in Table 4.2.4. A location map of the AEA study sites is shown in Figure 4.2.2.

Table 4.2.4 Small Hydropower Project Studies Funded by AEA

No.	Name of Project Nombre de Proyecto	River Río	Department Departamento	Organization Organización	Potential Potencia [kW]	Energy Energíia [kWh/year]	Plant Factor [%]	Beneficially Beneficios [families]	Cost Inversión [US$]	Cost/kW Inversion/kW [US$/kW]	Cost/kWh Costo/kWh [US$/kWh]	IRR TIR [%]	NPV VAN [US$]	B / C	Status Estado	Study Year Estudio de Año
1	Miracapa	Carolina	San Miguel	SABES	34	275,598	93%	40	157,368	4,628	0.0018	13.9%	52,858	1.00	Operating	2005~
2	El Junquillo	La Cueva y San José	Morazán	SABES	65	455,474	80%	150	294,246	4,527	0.0673	13.2%	88,440	1.10	Operating	2006~
3	El Calambre	El Calambre	Morazán	SABES	58	310,765	61%	40	145,683	2,512	0.0212	16.46%	81,917	1.17	Under Const.	2005
4	Guanijiquil - Poza Honda	Sapo	Morazán	SABES	131	510,046	44%	150	345,474	2,637	0.0323	14.69%	140,299	1.43	F/S	2010
5	La Loma	Osicala	Morazán	SABES	55	398,252	83%	55	269,760	4,905	0.0248	15.96%	135,935	1.15	F/S	2010
6	Gualpuca	Gualpuca	Morazán	SABES	1,000	6,155,146	67%	1000	1,475,423	1,475	0.0655	26.00%	614,375	1.70	F/S	2006
7	Santa Rosa	Riachuelo	San Miguel	SABES	38	260,000	77%	50	180,000	4,700	0.0729	11.80%	29,817	1.00	F/S	2006
8	La Cabaña	Grande de San Miguel	Usulután	SABES	980	4,300,000	50%	980	2,600,000	2,637	0.0569	11.40%	181,007	1.40	F/S	2006
9	El Progreso	Aruate	Morazán	SABES	33	280,000	98%	45	200,000	6,056	0.0563	11.80%	33,848	1.00	F/S	2006
10	Potrerillos	Las Lajas y El Arco	Morazán	SABES	320	2,600,000	93%	300	975,733	3,059	0.0569	18.40%	256,856	1.50	F/S	
11	La Colmena	El Volcán	San Miguel	SABES	97	450,000	53%	50	289,651	2,986	0.0600	15.27%	124,478	1.10	F/S	2009
12	El Naranjito	El Naranjito	Ahuachapan	SABES	31	146,358	54%	200	96,852	3,124	0.0623	10.26%	2,016	0.85	F/S	2010
13	La Joya	San Jose Curuña		SABES	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
14	Venecia Prusia			SABES	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Pre-F/S	
15	Atehuecillas (Rehabilitation)		Ahuachapán	CECSA	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.		
16	Cucumacayan (Reconversion)	Grande de Sonsonate	Sonsonate	CECSA	2.3	17,895,276	90%	Grid	2,224,966	796	0.0567	42.0%	260,722	1.76	Operating	2009
17	Milingo (Reconversion)	Acelhuate	San Salvador	CECSA	800	N.D.	N.D.	Grid	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Operating	2009
18	San Luis II (Rehabilitation)	Suquiapa	Santa Ana	CECSA	750	3,347,801	51%	Grid	2,081,148	2,799	0.0665	15.6%	263,175	1.19	Operating	2010
19	Santa Emilia I				N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Pre-F/S	
20	Santa Emilia II				N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	N.D.	Pre-F/S	
	TOTAL				4,394	37,384,716		3,060	11,336,304							

(Source: AEA, http://appext.sica.int/)



(Source: AEA)

Figure 4.2.2 Small Hydropower Studies Funded by AEA

B. CEL

CEL conducted the following project studies:

a. "Estudio de Prefactibilidad (Pre-F/S) Proyectos Hidroelectricos Zapotillo, Paso de del Oso, El Tigre, San Marcos en El Río Lempa y San Esteban-Agua Zarca en El Río Grande de San Miguel, CEL, Lahmeyer International, 1995.

b. Proyecto Hydroeléctrico "El Cimarrón" (262 MW), Prefactibilidad (Pre-F/S) 1997, Factibilidad (F/S) Fase I: 2004-2005, Fase II: 2005-2006, CEL.

c. "Feasibility study on the hydroelectric complex over the Torola River in the Republic of El Salvador" (El Chaparral project; 65,7MW), Japan International Cooperation Agency (JICA), Electric Power Development Co., Ltd. (J-Power), 2004.

d. "Estudios de Prefactibilidad de los Proyectos Hidroeléctricos del Río Paz", CEL, BCIE, 2008, and additional study by IBERINSA, April 2010.

   The site of this project is located between the borders of Guatemala and El Salvador in Río Paz. In September 2006, the governments of both countries signed a Memorandum of Understanding for the development of studies. In 2008, an international bidding process for the studies was started under a grant by the Government of Spain through BCIE. The capacities of two projects were estimated at 72 MW (revised → 60 MW) for El Jobo, and 67 MW (revised → 50 MW) for Piedra del Toro.

e. Expansión Central Hidroeléctrica "5 de Noviembre" (80 MW), Factibilidad (F/S) : September 2009, CEL.

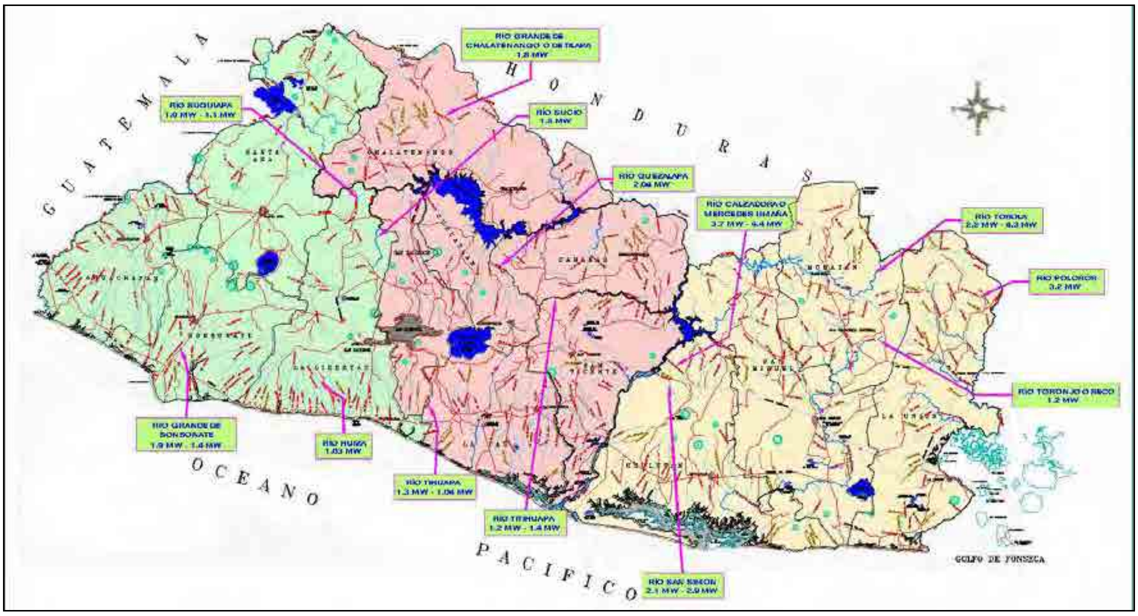
   Two additional Francis turbines and generators with total capacity of 80 MW will be installed in the existing hydropower station of "5 de Noviembre". The budget will be at US$115 million and the construction period will be 3.5 years.

f. Tercera Unidad de Cerrón Grande (86.4 MW), CEL, 2009.

   This project involves the installation of an additional power unit (third unit) with a capacity of 86.4 MW in the existing power station of Cerrón Grande. For consulting services, the contract was signed on September 25, 2009 with FICHTNER.

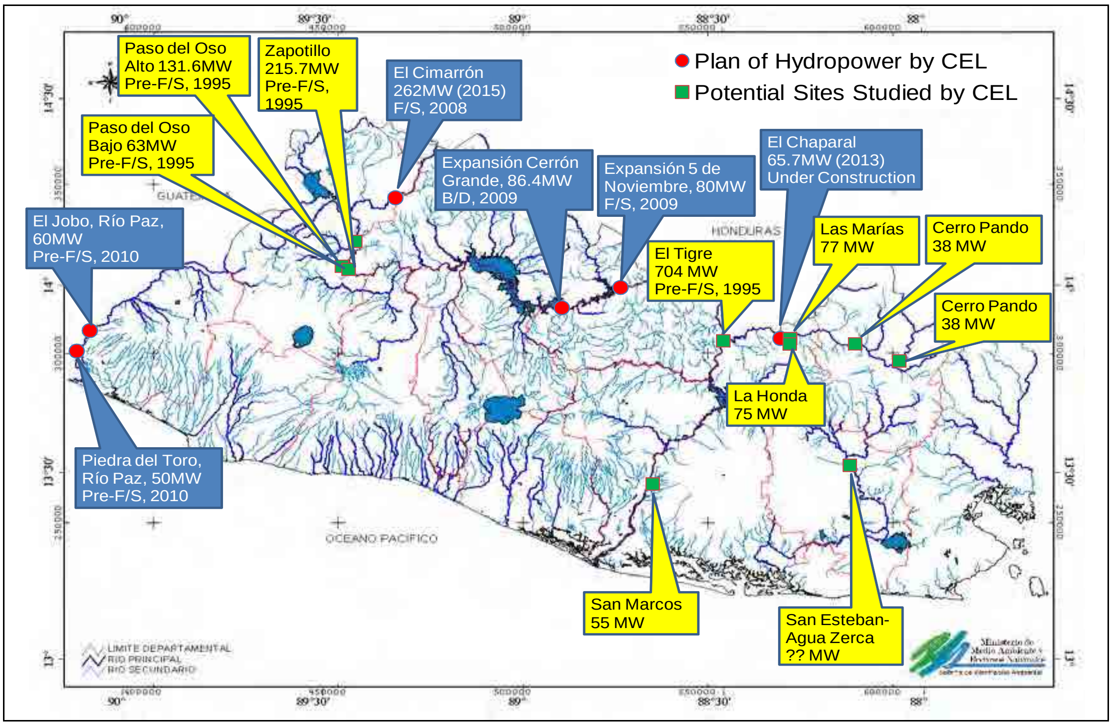
g. "Proyecto identificación de sitios con potencial para la instalación de pequeñas centrales hidroeléctricas", CEL, ACCIONA, 2011.

In order to update the potential of the small hydropower by CEL-UCA Study in 1989, CEL recently availed of the services of the Spanish consultant company ACCIONA (IBERINSA). The study includes the use of Geographic Information System (GIS) for the positioning of coordinates of each site chosen for building the small hydropower plants. This study began in January 2011 and will finish in November 2011. According to the TOR of CEL, ACCIONA will evaluate and recommend a number of projects in the range of 1-10 MW totaling to 20 MW. After reviewing the potential sites, a total of 12 candidate sites were selected for pre-F/S and basic design. In this study, discharge observation using a current meter was carried out ten times within five months for each of the 20 selected potential sites in 13 rivers. According to CEL, the river flow based on the results of discharge measurement might have decreased as compared to those from 30 years ago due to catchment deforestation. The location map of the selected 13 sites of CEL- ACCIONA study is shown in Figure 4.2.3.



(Source: CEL)

Figure 4.2.3 Small Hydropower (< 10 MW) Study Sites by CEL-ACCIONA (2011)



(Source: CEL)

Figure 4.2.4 Planned Hydropower Projects (> 20 MW) by CEL

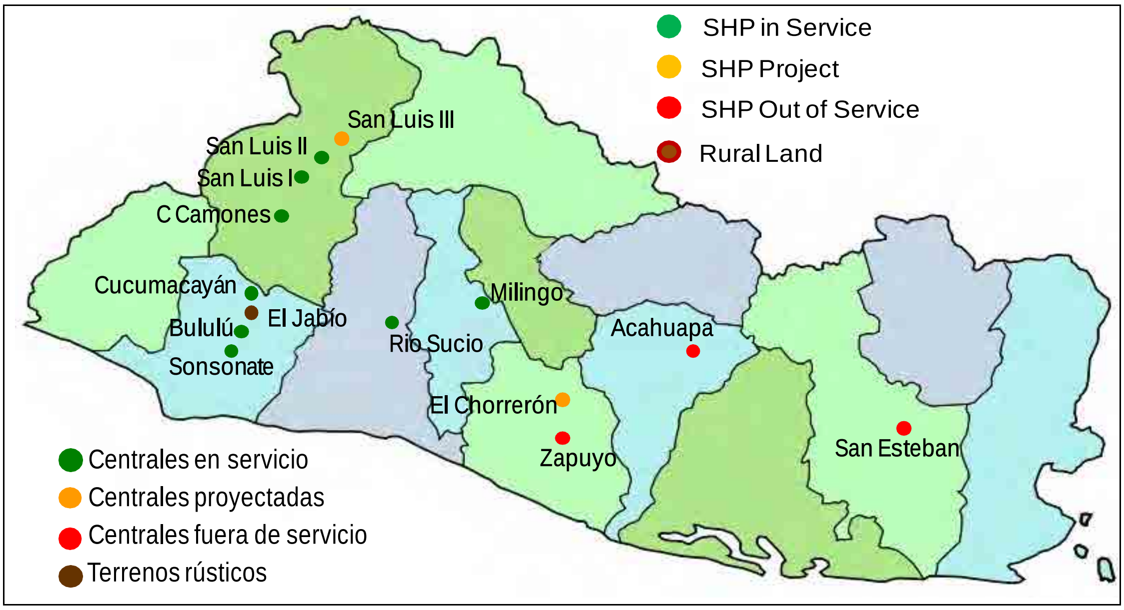
C. Cucumacayán Electric Company, Inc. (CECSA)

CECSA was established as a public company in 1954 by private investors. The administration of the company transferred to CEL in 1986, and has operated since under the name of "Compañía Eléctrica Cucumacayán Administración CEL". CEL formalized the purchase of the Cucumacayán Plant by a legislative decree in 1994, establishing itself as the Cucumacayán Electric Company S.A. (CECSA). Eleven small hydropower distribution companies were transferred to CECSA in 1995. Its equity increased to 14 hydroelectric plants as shown in Figure 4.2.5.

Table 4.2.5 Existing Hydropower Stations of CECSA

No.	Name of SMP Nombre de PCH	Location Ubicación	Unit of Generator Unidades de Generación	Potencia Total Instalada (Kw)	Gross Head Caída Bruta (m)	Design Discharge Caudal de Diseño (m^3/s)
1	Rio Sucio (*)	San Matías, La Libertad	3	2,500	31.54	10.15
2	Cucumacayán (*)	Nahuizalco, Sonsonate.	2	2,256	83	3.4
3	Milingo (*)	Ciudad Delgado, San Salvador	2	800	32.7	3.4
4	Bululú	Sonzacate, Sonsonate	2	680	11.8	7
5	San Luis I (*)	Santa Ana.	1	630	21	3.8
6	San Luis II	Santa Ana	2	768	22.37	4
7	Cutumay Camones (*)	Santa Ana	1	400	12	2.8
8	Sonsonate	Sonsonate	1	150	4.2	4.6
		Total	**14**	**8,184**		

(*) Centrales en proceso de reconversión/modernización.
(*) Under process of conversion / modernization
(Source: CECSA, 2011)



(Source: CECSA)

Figure 4.2.5 Status of Hydropower Stations of CECSA (2011)

CECSA has the following studies or plans in 2011:

[Projects in progress]:

a. Reconversion of PCH Cucumacayán.

b. Reconversion of PCH Milingo.

c. Reconversion of PCH Cutumay Camones.

d. Reconversion of PCH San Luis I.

[Projects under study]:

e. Reconversion of PCH Rio Sucio.

f. Feasibility study and design of the new PCH San Luis III

g. Feasibility study and design of the new PCH El Chorrerón.

h. Feasibility study and design of the new PCH San Luis IV.

Table 4.2.6 Reconversion Project of Existing SHP of CECSA

Project	Proyecto	Reconversión Cucumacayán	Reconversión Milingo	Reconversión Cutumay Camones	Reconversión San Luis I
Potential	Potencia	2,800 kW	1,800 kW	250 kW	680 kW
Type of Turbine	Tipo de Turbinas	Francis	Francis	Flujo Cruzado	Francis
Unit of Turbine	Unidades	2	2	1	1
Net Head	Altura Neta	82.56 mts.	39 mts.	13 mts.	13.25 mts.
Design Discharge	Caudal de diseño	4 m^3/s	3.4 m^3/s	1.5 m^3/s	3.58 m^3/s
Investment Cost	Inversión Presupuestada	US$2,435,507	US$3,219,784	US$622,541	US$1,213,845
IRR of Project	TIR del Proyecto	18.82%	44.95%	En estudio	15.43%
Start Date	Fecha de Inicio	11-Mar	11-Jun	11-Sep	11-Mar
Estimated Operating Date	Fecha estimada de operación	13-Mar	Abr/13	13-Feb	12-Jul

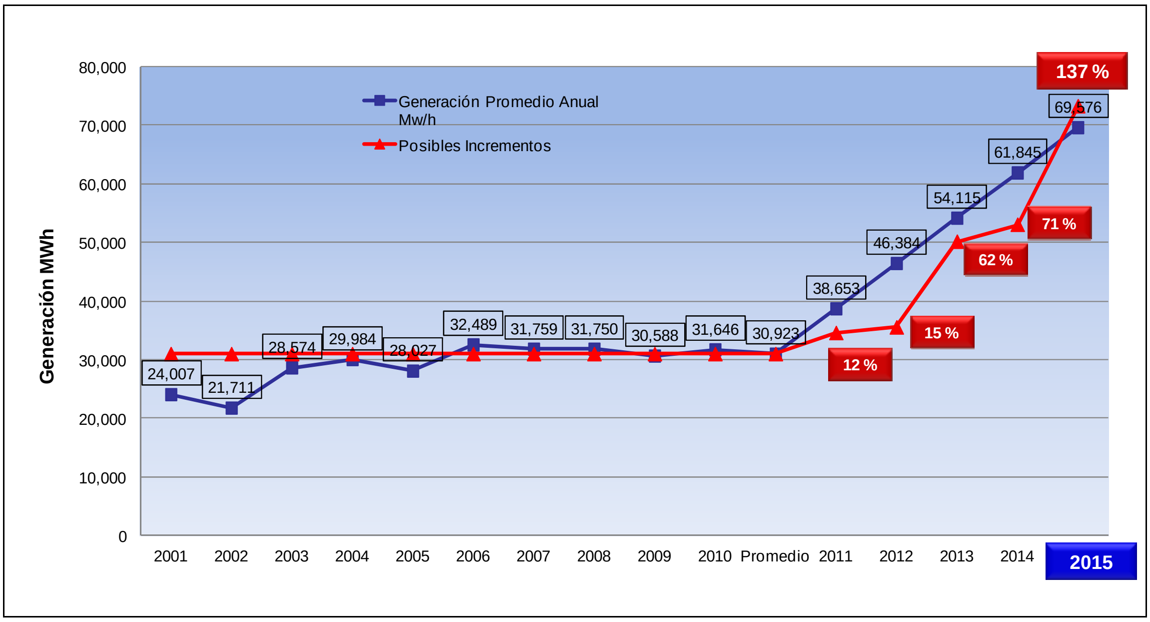
(Source: CECSA)

Table 4.2.7 Hydropower Project Study by CECSA

Project	Proyecto	Repotenciación Río Sucio	Nueva Central San Luis III	Nueva Central El Chorrerón-Jiboa	Nueva Central San Luis IV
Potential	Potencial	En estudio	425 kW (*)	2,800 kW (*)	600 kW (*)
Status	Estatus	Documentación en el BCIE	Documentación en el BCIE	TDR presentados	Documentos a presentarse Jul/11
Start Date	Fecha de Inicio	11-Feb	11-Feb	11-Feb	Ago/11
Estimated Operating Date	Fecha estimada de operación	Dic/12	Abr/13	14-Feb	14-Sep

Note: (*) Potential based on Pre-F/S
(Source: CECSA)

As shown in Figure 4.2.6, CECSA has planned to increase 137% of the annual energy production through these projects for 2015.



(Source: CECSA)

Figure 4.2.6 Expansion Plan of Energy Production of CECSA

4.2.4 Future Development Plan

According to the previous studies described in Section 4.2.3, the hydropower potential sites and projects in El Salvador are listed in Tables 4.2.10 and 4.2.11.

After reviewing the previous studies, a total of 18 sites (with capacity over 20 MW) and 86 sites (with capacity less than 20 MW) for potential hydropower projects were identified. The potential capacities of some projects were updated from previous studies by using results of recently conducted pre-feasibility studies or feasibility studies of projects.

Table 4.2.8 List of Large & Medium Hydropower Potential ≥ 20 MW

No.	Project of Energy *Proyecto de Energia*	River Río	Department Departamento	Potential (MW) Potencial (MW)	Energy (MWh) Energía (MWh)	Status Etapa	*Source* Fuente
1	Torola, El Chaparral	Torola	San Miguel	65.700	*287,770*	Under Const.	www.cel.gob.sv
2	Lempa, El Cimarrón	Lempa	Chalatenango	261.000	*1,143,180*	Pre-F/S	www.cel.gob.sv
3	Lempa, Expansión 5 de Noviembre	Lempa	Chalatenango	80.000	*350,400*	Pre-F/S	www.cel.gob.sv
4	Expansión Cerrón Grande	Lempa	Chalatenango	86.400	*378,430*	Pre-F/S	www.cel.gob.sv
5	Paz, El Jobo	Rio Paz	Ahuachapán	60.000	*262,800*	Pre-F/S	www.cel.gob.sv
6	Paz, Piedra de Toro	Rio Paz	Ahuachapán	50.000	*219,000*	Pre-F/S	www.cel.gob.sv
7	Las Marías, Torola	Torola	San Miguel	77.000	*337,260*	Pre-F/S	www.cel.gob.sv
8	Torola	Torola	San Miguel	50.000	*219,000*	Pre-F/S	www.cel.gob.sv
9	Torola, Cerro Pando	Torola	San Miguel	38.000	*166,440*	Pre-F/S	www.cel.gob.sv
10	Torola, Las Mesas	Torola	San Miguel	25.000	*109,500*	Pre-F/S	www.cel.gob.sv
11	Torola, Maroma	Torola	San Miguel	40.000	*175,200*	Pre-F/S	www.cel.gob.sv
12	El Tigre	Lempa	Cabañas/lempira	704.000	1,815,000	Pre-F/S	www.cel.gob.sv
13	Zapotillo	Lempa	Chalatenango	215.700	473,000	Pre-F/S	CEL, 1995. "Estudio de Prefactibilidad Proyectos Hidroelectricos Zapotillo, Paso de del Oso, El Tigre, San Marcos en El Río Lempa y San Esteban-Agua Zarca en El Río Grande de San Miguel, Lahmeyer International
14	Paso del Oso Alto	Lempa	Chalatenango	131.600	340,000	Pre-F/S	CEL, 1995. "Estudio de Prefactibilidad Proyectos Hidroelectricos Zapotillo, Paso de del Oso, El Tigre, San Marcos en El Río Lempa y San Esteban-Agua Zarca en El Río Grande de San Miguel, Lahmeyer International
15	Paso del Oso Bajo	Lempa	Chalatenango	63.000	132,000	Pre-F/S	CEL, 1995. "Estudio de Prefactibilidad Proyectos Hidroelectricos Zapotillo, Paso de del Oso, El Tigre, San Marcos en El Río Lempa y San Esteban-Agua Zarca en El Río Grande de San Miguel, Lahmeyer International
16	San Marcos	Lempa	Usulután	55.000	212,000	Pre-F/S	CEL, 1995. "Estudio de Prefactibilidad Proyectos Hidroelectricos Zapotillo, Paso de del Oso, El Tigre, San Marcos en El Río Lempa y San Esteban-Agua Zarca en El Río Grande de San Miguel, Lahmeyer International
17	San Esteban-Agua Zerca	Grande de San M	San Miguel	N.D.	N.D.	Pre-F/S	CEL, 1995. "Estudio de Prefactibilidad Proyectos Hidroelectricos Zapotillo, Paso de del Oso, El Tigre, San Marcos en El Río Lempa y San Esteban-Agua Zarca en El Río Grande de San Miguel, Lahmeyer International
18	La Honda	Grande de San M	San Miguel	75.000	*328,500*	Pre-F/S	CEL, 2007. "Proyecto Hidroeléctrico El Chaparral"
			TOTAL	2,077.400	6,949,000		

Note: The Italicized value of annual energy was estimated by using assumed average plant factor at 0.5
(Source: CEL)

Table 4.2.9 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.

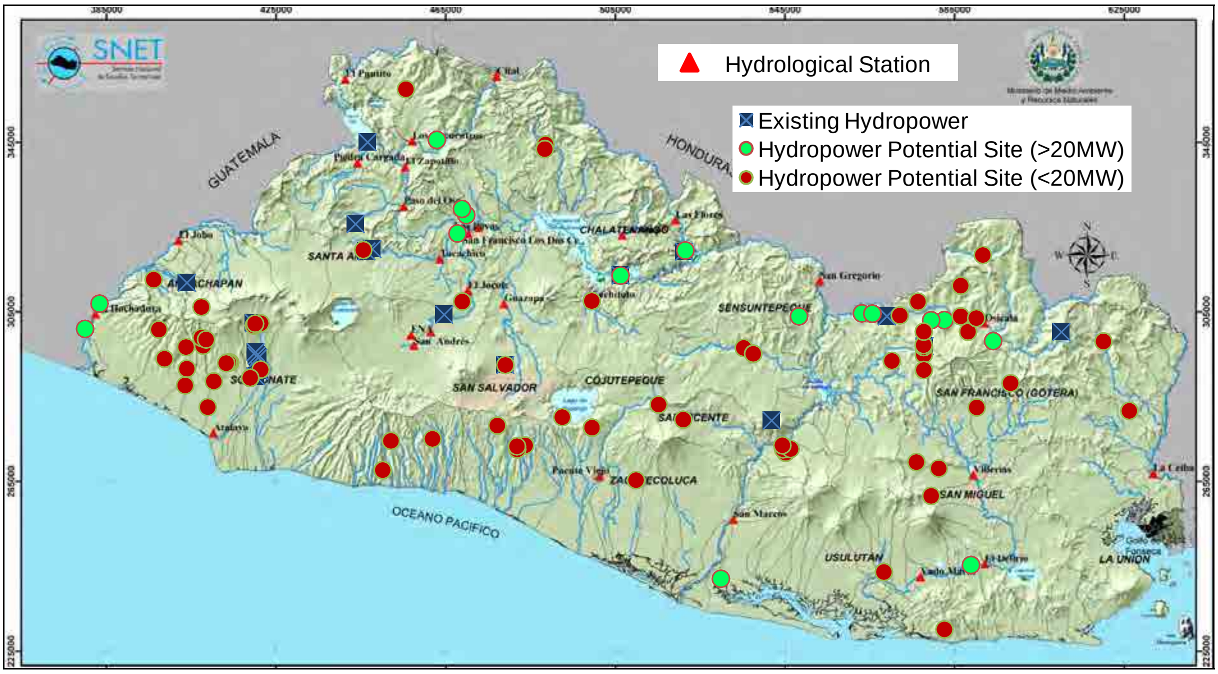
Note: The Italicized value of annual energy was estimated by using assumed average plant factor at 0.5
(Source: JICA Study Team. (Prepared by using available previous studies))

Table 4.2.9 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))

The existing hydropower plants and potential sites are shown in Figure 4.2.7.



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

Figure 4.2.7 Existing and Potential Hydropower Sites

The total capacity of hydropower potential is summarized in Table 4.2.11.

Table 4.2.10 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))

The total potential of hydropower in El Salvador is 2,235 MW, and the potential of small hydropower projects (capacity 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 (capacity less than 20MW). Since the estimated annual energy is included in the calculated values by using an assumed plant factor of 50%, further examination is necessary.

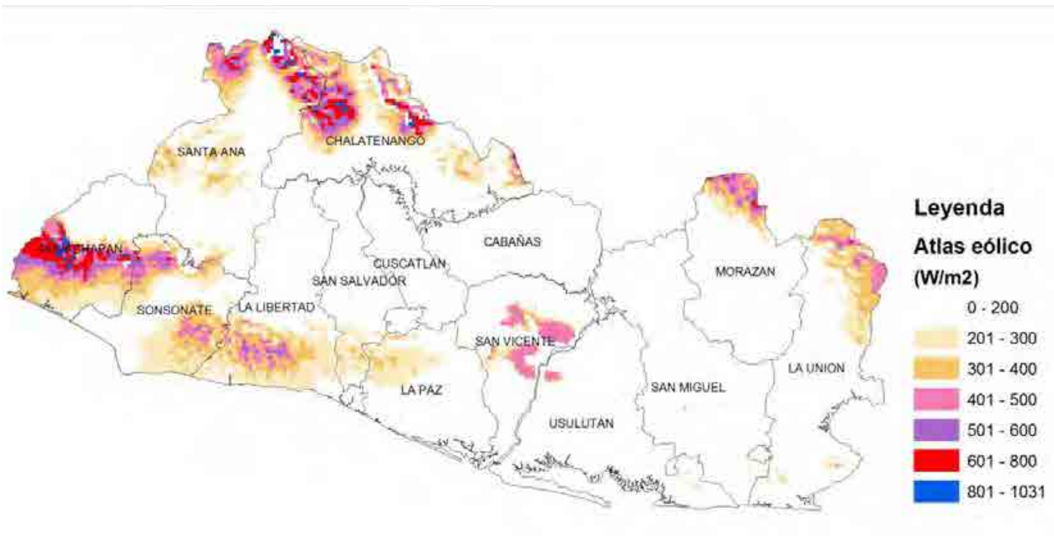
4.3 Wind Power

Based on a wind map prepared by the Solar and Wind Energy Resource Assessment (SWERA) in 2005, there are potential areas for wind power in the northern and western regions of El Salvador. The preparation of technical regulations or guidelines is necessary before introducing a wind generation system in El Salvador. Capacity development is also one of the important issues for wind power development. There is a seasonal complementary relation between hydropower and wind power. There are plans to develop wind farms at two sites having a total capacity of 72 MW.

4.3.1 Current Status

In El Salvador, wind power for generating electricity has not been developed yet. The wind potential map in El Salvador was created by SWERA, which was conducted in 2005 by the National Renewable Energy Laboratory of the US (NREL), the United Nations Environmental Programme (UNEP) and Global Environment Facility (GEF) in cooperation with MARN, Universidad Centroamericana (UCA) and Servicio Nacional de Estudios Territoriales (SNET).

In accordance with the wind potential map created under SWERA, limited areas were classified as suitable areas for wind power development. Figure 4.3.1 represents the map prepared by SWERA showing the wind power potential of El Salvador.



(Source: SWERA)

Figure 4.3.1 Wind Power Potential Map (SWERA)

Wind measurements were carried out in El Salvador by the Finnish Meteorological Institute. In accordance with the project report "Wind Speed Measurement in El Salvador 2006-2007 for Wind Energy Assessment", wind monitoring systems were installed at four different sites at La Hachadura, Metapan, Monteca and Sanishidro. The locations of the monitoring sites are indicated in Table 4.3.1.

Table 4.3.1 Locations of the Wind Monitoring Sites in the Finnish Project

Name of the Site	Elevation (m)	Latitude	Longitude
La Hachadura	53	N 13⁰51'04.6"	W 90⁰05'05.9"
Metapan	601	N 14⁰20'37.7"	W 89⁰28'48.1"
Monteca	910	N 13⁰52'37.4"	W 87⁰51'07.6"
San Isidro	740	N 13⁰47'10.7"	W 89⁰33'23.1"

(Source: Prepared by JICA Study Team based on records of Finnish Meteorological Institute)

Wind monitoring had been carried out for the Finnish project from June 2006 to July 2007. Table 4.3.2 gives a summary of the monitoring results. The results show that wind power density is highest at Metapan among the four monitored sites.

Table 4.3.2 Summary of Wind Monitoring

Name of the Site	Average Wind Speed (m/s)	Wind Power Density (W/m^2)	Main Wind Direction	Weibull Parameter (k, A)
La Hachadura (50 m agl)	4.0	161	NE	k:1.15 A: 4.0
Metapan (50 m agl)	4.8	243	N	k:1.24 A:5.3
Monteca (60 m agl)	4.2	103	NE	k:1.62 A: 4.9
San Isidro (50 m agl)	5.0	170	NE	k:1.63 A: 5.7

(agl: above ground level)
(Source: Prepared by JICA Study Team based on records of Finnish Meteorological Institute)

Power output from wind turbines was estimated based on the results of wind monitoring at the four sites. Based on the estimation performance, the Nordex N50 800 kW wind turbine was used. Table 4.3.3 shows the results of the estimation of annual power output.

Table 4.3.3 Estimated Annual Power Output

	Estimated Annual Power Output (GWh)
La Hachadura	0.670
Metapan	1.340
Monteca	0.625
San Isidro	0.844

(Source: Wind speed measurement in El Salvador 2006-2007 for wind energy assessment)

As mentioned above, there have been experiences on estimation of wind potential and power output, however there is no existing wind turbine interconnected with the national power grid in El Salvador.

4.3.2 Barriers to Introduction

Several studies on wind potential have been conducted in El Salvador. However, there is no grid-connected wind turbine in the country. Therefore, 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

Power companies frequently use phase-advanced condensers to correct the power factor. Self-excitation becomes a problem when phase-advanced condensers are used on the wind turbine side of the contactors. Any phase-advanced condenser used with a wind system for power factor correction should be placed on the utility side of the interconnection. Also, the capacity of a phase-advanced condenser should be lower than the exciting current of the generator. This prevents self-excitation as well as to prevent any electrocution hazard to those servicing the system due to voltage surges in the cable when disconnected with the commercial power grid.

B. Voltage Flicker

This problem arises with certain wind systems which use induction generators. When an induction generator is interconnected with the power grid, reactive power increases momentarily. Since the rated power output of wind generators is larger than that of household appliances, the magnitude of the inrush current can be large enough to cause a slight voltage drop in the line. The result may be voltage flicker. At this time, voltage drop occurs instantly at end users. Most medium-sized and all megawatt-size turbines use electronic controllers that connect to the grid softly, minimizing voltage flicker.

C. Harmonics and Interharmonics

The emission of harmonic and interharmonic currents from fixed-speed wind turbines is expected to be negligible in service. Variable-speed wind turbines which connect to the grid through power converters emit harmonic and/or interharmonic currents and contribute to voltage distortion. The harmonics must be filtered out before feeding power to the grid. For the grid interface, having theTotal Harmonic Distortion (THD) less than 3% is generally acceptable. The Institute of Electrical and Electronics Engineers (IEEE) limits the THD for a utility-grade power at less than 5%.

D. Safety

All wind turbines interconnected with the national grid must be disconnected by the utility workers for safety reasons. It is necessary to prevent islanding operation during outage of the connected grid. Also, the wind turbines must not be able to self-excite.

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.

A. Wind Monitoring and Power Output Estimation

There are several types of wind monitoring systems for evaluation of wind power potential such as that of NRG Systems. Monitored wind data can be examined through the software supported by the monitoring system. Power output can be calculated using the software and Microsoft Excel. If the simulation of power output around the monitoring system is necessary, software such as WAsP can be used. Both monitoring and simulation are important in the initial stage of wind power development in order to evaluate the wind potential and estimate the power output.

B. Consultant

The locations of wind power generation systems have to be decided based not only on the wind potential but also the surrounding conditions such as distance from the nearest household. The operations of rotational blades produce low frequency noise, which should be examined before the installation. It is necessary to create or maintain the access road to the location of the wind farm because the tower and blade of the wind turbine have to be transported during construction. The weight of a wind turbine depends on its capacity. For example, for a 2.5 MW wind turbine, the weight of each block of its tower is around 40 to 50 t, and that of its nacelle is around 82 t. In addition, the length of its blade is around 45 m. Furthermore, a crane truck with a maximum lifting capacity of approximately 300 to 600 t has to pass the road. A conveyance route to the location has to be examined by the consultant.

4.3.2.3 Operations and Maintenance Cost

There are wind turbines which have been installed through foreign aid for demonstration programs. In general, the grants pay for the turbine and its installation but seldom for its maintenance. Therefore, 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. According to the European Wind Energy Association (EWEA), the O&M costs of a new turbine may easily make up 20-25% of the total levelized cost per kWh produced over the lifetime of the turbine. Based on experiences in Germany, Spain, the United Kingdom, and Denmark, O&M costs are generally estimated to be around US¢1.6 to US¢2.0 (c€1.2 to c€1.5) per kWh of wind power produced over the total lifetime of a turbine. As a result, O&M costs are attracting greater attention as manufacturers attempt to significantly lower such costs by developing new turbine designs that require fewer regular service visits and less turbine downtime. The main items of O&M costs are the following:

- Insurance
- Regular maintenance
- Repair
- Spare parts
- Administration

4.3.3 Related Existing and Ongoing Studies and Projects

4.3.3.1 Nationwide Wind Map

SWERA is a GEF sponsored project. The SWERA project was a five-year effort that was aimed at developing information tools to stimulate renewable energy development. 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 4.3.4 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 4.3.4 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)

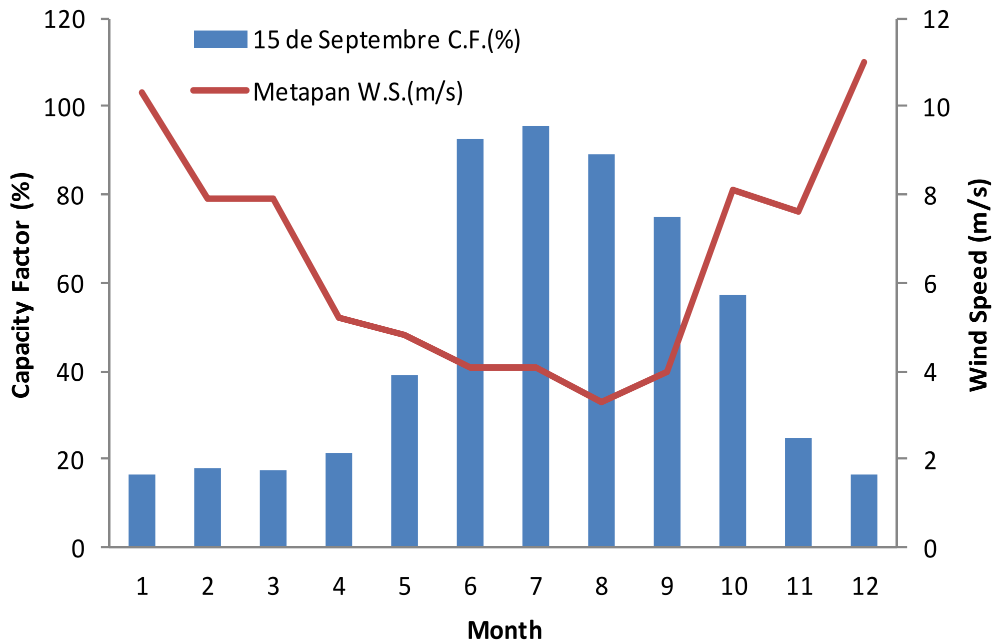
Table 4.3.5 shows the monthly average wind speed at the candidate sites. The monthly average wind speed in both places is very high from October to March. On the other hand, the monthly wind speed from April to September is relatively low. However in both sites, the wind velocity is high during the dry season when the power output from the hydropower plant is low. It is obvious to say that there is a seasonal complementary relation between hydro and wind power in El Salvador.

Table 4.3.5 Monthly Average Wind Speed at 60 m agl (m/s)

Site	2009 Dec	2010 Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Metapan	8.1	10.3	7.9	7.9	5.2	4.8	4.1	4.1	3.3	4.0	8.1	7.6	11
San Julian	5.9	8.2	6.9	5.5	4.0	4.0	4.1	4	3.5	4.0	6.8	6.4	10.9

(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)

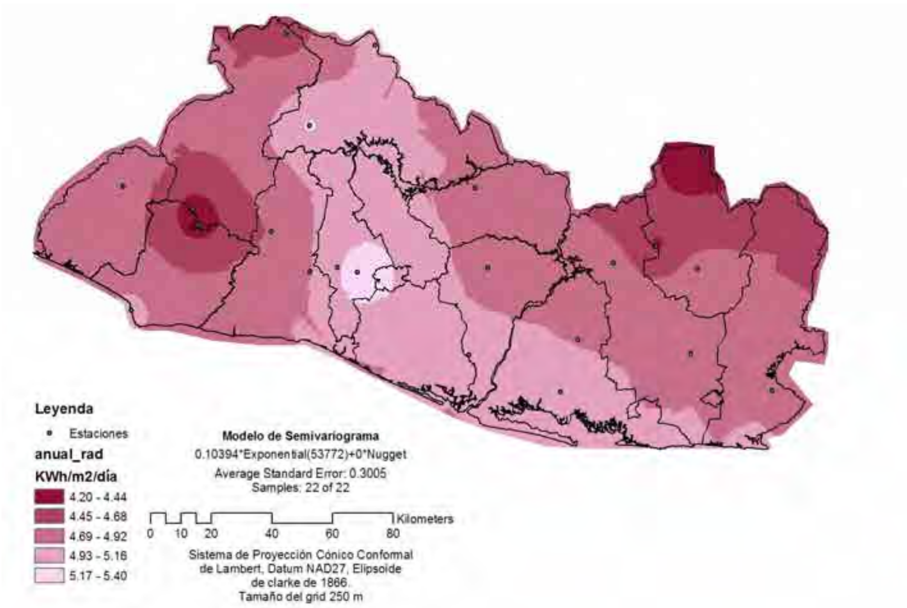
Figure 4.3.2 Wind Speed (Metapan) and Capacity Factor (15 de Septiembre, Hydropower)

4.4 Solar PV

Solar irradiation is high in El Salvador especially around the San Salvador Metropolitan Area in the central region where it reaches a high of 5.3 kWh/m^2/d. 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

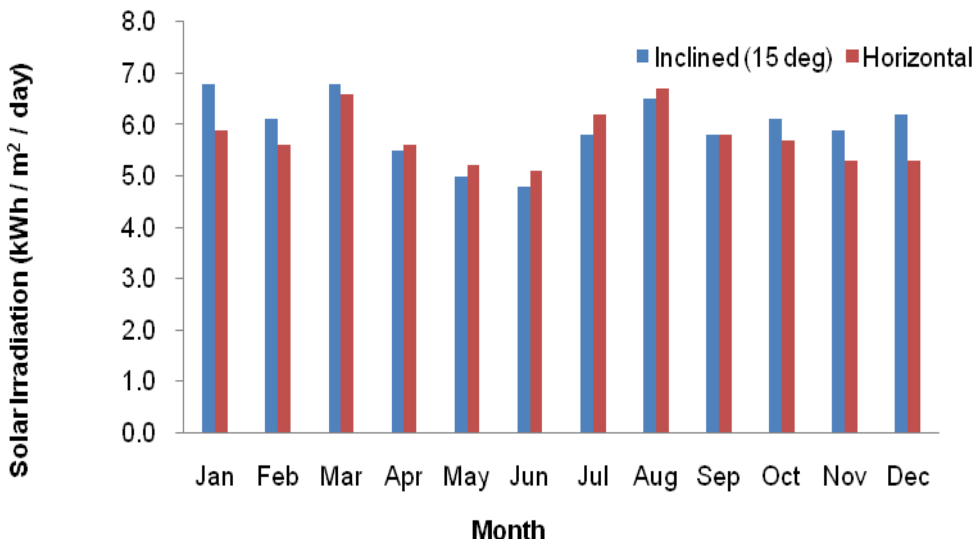
Solar irradiation in El Salvador is high at 5.3 kWh/m^2/d as compared to that in Tokyo at 3.3 kWh/m^2/day. A solar irradiation map in El Salvador was created under the SWERA project. This map, which shows the potential annual average solar irradiation, is shown in Figure 4.4.1. Solar irradiation is high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



(Source: SWERA)

Figure 4.4.1 Solar Irradiation Map of El Salvador

Figure 4.4.2 shows the horizontal and inclined (15°) solar irradiation values which was monitored at the CEL building in San Salvador City from June 2009 to May 2010. The monthly average horizontal solar irradiation is high from December to March.



(Source: CEL)

Figure 4.4.2 Monthly Solar Irradiation in San Salvador

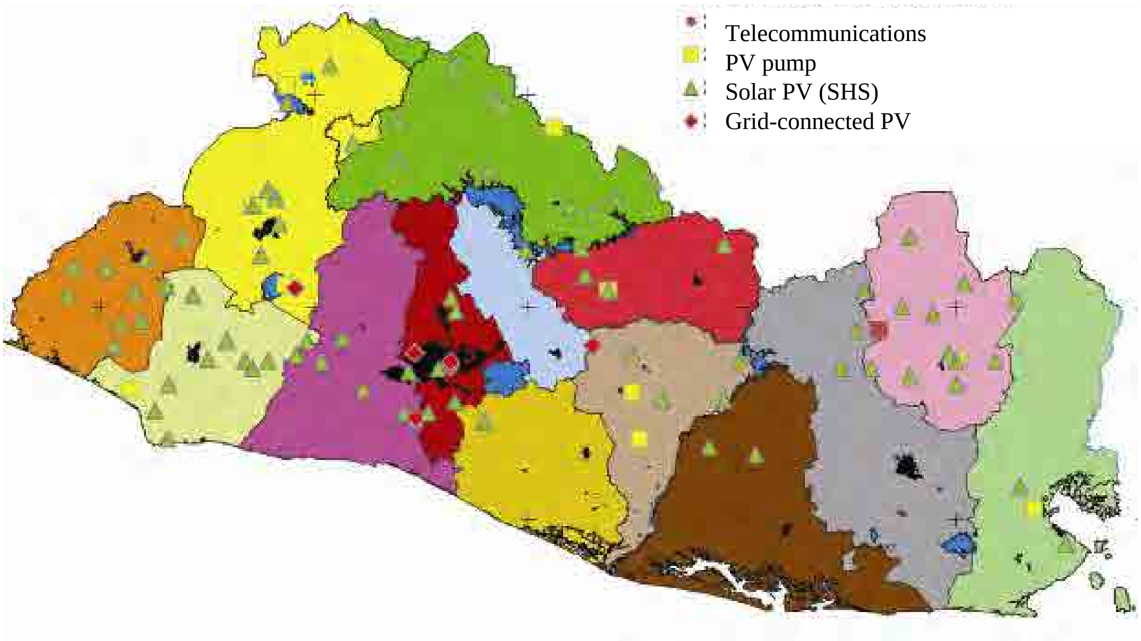
There are many solar PV systems already operational in El Salvador. Table 4.4.1 shows a list of solar PV systems in the country. Most of them are isolated systems with battery bank which are used as Solar Home Systems (SHSs). There are a limited number of grid-connected solar PV systems.

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
Drinking water	2	280
Radio communication	15	n.a.
Telecommunications	6	n.a.
TOTAL	**3,252**	**476,961**

(Source: CNE)

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: JICA Study Team)

Figure 4.4.3 Solar PV System Map of El Salvador

(Source: JICA Study Team)

Figure 4.4.4 Solar PV System of a Base Camp in the USA (91 kW)

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.

Table 4.4.2 shows indicative installed system prices of some countries in 2010 which have been studied by the International Energy Agency (IEA). Prices indicated in the table exclude Value Added Tax (VAT) and sales taxes. 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.

Table 4.4.2 Price of Grid-Connected Solar PV (US$ per W)

Country	<10 kW	>10 kW
AUSTRALIA	4.6 – 6.4	5.5 – 8.3
CANADA	6.3 – 7.8	3.9
GERMANY	3.4 – 4.2	3.0 – 3.3
DENMARK	3.6 – 5.3	3.6 – 7.1
SPAIN	3.3 – 4. 1	3.2 – 3.6
FRANCE	6.3 – 7.8	4.6 – 7.2
JAPAN	6.6	7.0
MEXICO	6.4	9.8
USA	6.7	4.2 – 5.9

(Source: JICA Study Team, based on "Report IEA-PVPS T1-20:2011 / IEA")

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. Every kind of electric regulation in El Salvador is regulated by the NEC of the USA. Regulations on solar PV systems are provided in article 690 of the NEC. However, practical guidelines for electrical technicians on interconnection of rooftop solar PV have not been prepared in El Salvador. Technical barriers on the introduction of rooftop solar PV systems are written in Section 7.3.3.

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 conducting pilot tests for three different types of PV modules, namely monocrystalline, polycrystalline and amorphous (having a capacity of 8 kW for each type). 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) is an electrical engineering and services company with headquarters in San Salvador. 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 financed by the USTDA which is still under the preparatory stage. The objective of the "CEL Solar Photovoltaic Power Pilot Project Feasibility Study" is to determine the technical, economic, and financial viability of a 3 MW grid-connected solar PV power generation pilot project in El Salvador. The feasibility study will allow the concessionaire to compile solar resource data, assess solar PV technologies, conduct a preliminary conceptual design of the project, and draft legal documents and agreements for project implementation.

4.4.4 Future Development Plan

There are plans to install a centralized grid-connected solar PV system by CEL. Table 4.4.3 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 4.4.3 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)

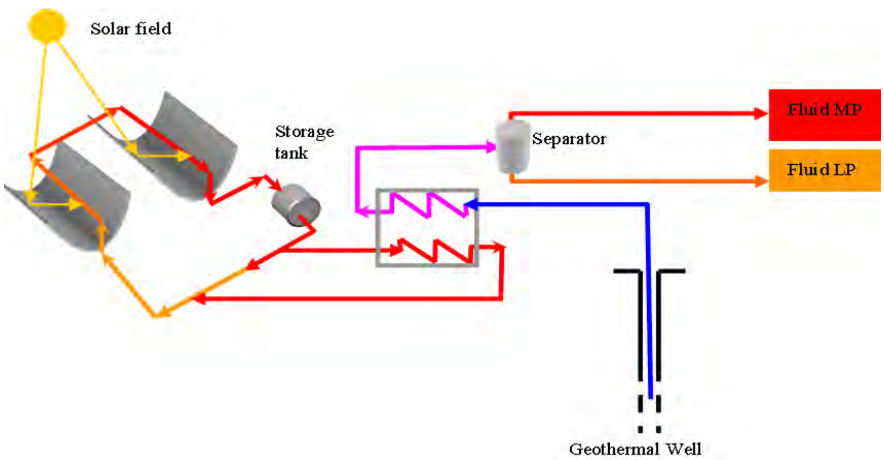
4.5 Solar Thermal

Solar thermal power system collects thermal energy through solar irradiation and uses high temperature. The collected heat drives a heat engine connected to an electrical power generator. 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

Solar thermal power plants consist of systems that use mirrors or lenses to concentrate a large area of sunlight, or solar thermal energy, onto a small area. A solar thermal power plant is called a Concentrating Solar Power (CSP) system. Electrical power is generated when concentrated light is converted to heat, which drives the heat engine connected to the electrical power generator.

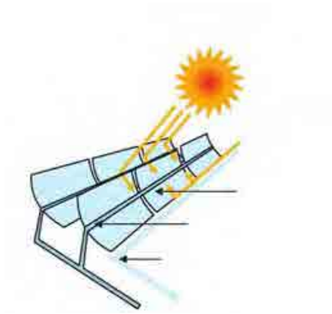
In El Salvador, a parabolic trough-type solar thermal plant is already installed as a pilot plant for geothermal and solar thermal hybrid system at the Ahuachapan geothermal field. Pilot testing is being carried out since March 2007. The objective of the pilot study is to generate steam by exchanging heat between geothermal water and synthetic oil heated by solar heaters. 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. Figure 4.5.1 shows a conceptual diagram of a solar thermal and geothermal hybrid system.



(Source: SOLAR STEAM BOOSTER IN THE AHUACHAPÁN GEOTHERMAL FIELD)

Figure 4.5.1 Conceptual Diagram of a Solar PV and Geothermal Hybrid System

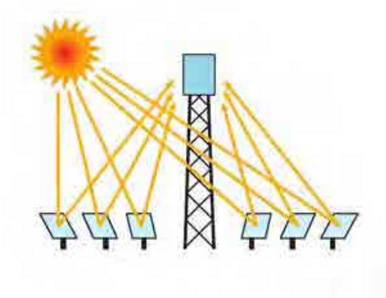
In a parabolic trough power plant, trough-shaped mirrors concentrate incidental radiation onto a pipe in the focal line of the collector. Its absorption heats a fluid medium in the pipe, generating steam in the power block through a heat exchanger. Similar to conventional power plants, the steam powers a turbine to generate electricity. By integrating thermal storage, electricity can be supplied on demand, even after sunset. The global market has been dominated by parabolic trough plants, which account for 90% of CSP plants. Figure 4.5.2 shows the concept of a parabolic trough solar thermal plant.

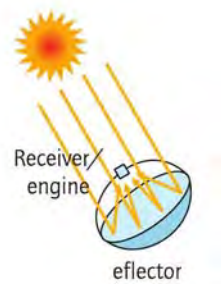


(Source: Technology Roadmap Concentrating Solar Power / IEA)

Figure 4.5.2 Parabolic Trough Type

There are other types of solar thermal power plants, such as solar tower and parabolic dish. Solar towers, also known as Central Receiver Systems (CRSs), use hundreds or thousands of small reflectors called heliostats that concentrate the sun's rays on a central receiver placed atop a fixed tower. Some commercial tower plants are now operational. The other type is the parabolic dish-type. Parabolic dishes concentrate the sun's rays at a focal point propped above the center of the dish. The entire apparatus tracks the sun, with the dish and receiver moving in tandem. Most dishes have an independent engine or generator such as a Stirling engine at the focal point.





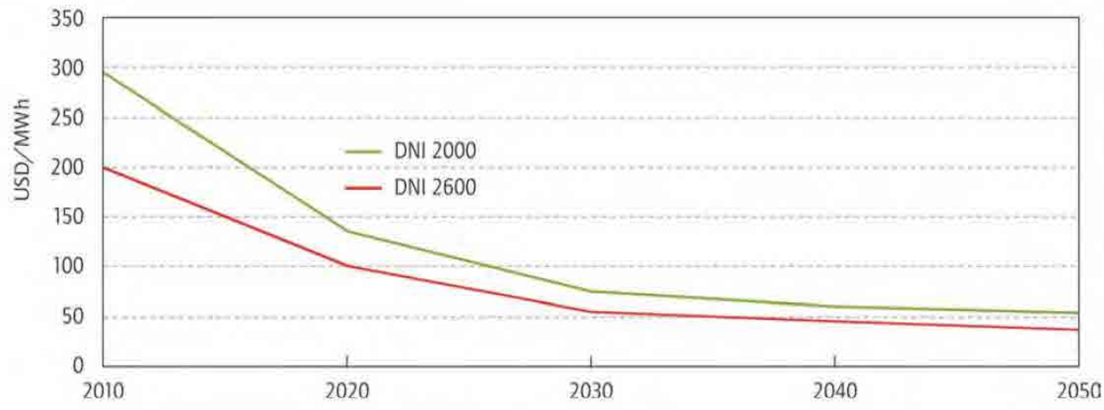
(Source: Technology Roadmap Concentrating Solar Power / IEA)

Figure 4.5.3 Solar Thermal (Left: Solar Tower, Right: Parabolic Dish)

At the end of 2010, the total installed capacity in the world is about 1,095 MW. Spain added 400 MW in 2010, taking the global lead with a total of 632 MW, while the USA ended the year with 509 MW after adding 78 MW, including two Fossil-CSP hybrid plants. CSP growth is expected to continue at a rapid pace. As of April 2011, another 946 MW has been under construction in Spain and the new total capacity of 1,789 MW is expected to be operational by the end of 2013. Furthermore, in the USA, 1.5 GW of parabolic trough and power-tower plants were under construction as of early 2011, and more contracts were signed for at least another 6.2 GW.

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. Figure 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 4.5.4 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. The technical, legal and financial frameworks needed for a public-private investment structure of a parabolic trough power plant will be analyzed in the feasibility study.

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

LaGeo 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.

In recent years, the USA and Spain, which have cultural and commercial relations with El Salvador, are rapidly introducing CSP. Besides cultural influence, there are two reasons for introduction of solar thermal systems in El Salvador. One is the need to diversify the energy matrix with renewable energy sources and the other is our excellent solar irradiation level. Therefore, the introduction of CSP may be considered in El Salvador.

4.6 Geothermal

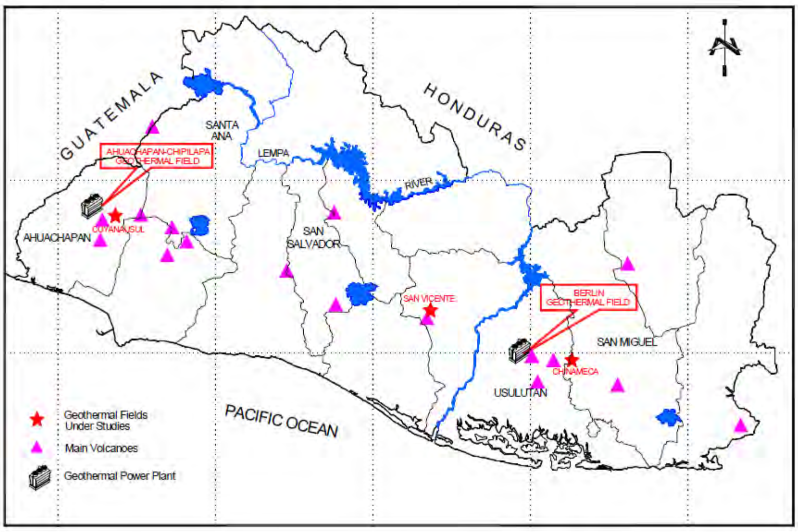
Geothermal power generation in El Salvador started in 1975 and has been increasing steadily since. The current total output is 204 MW. It is competitive in the power market. There are no serious problems with the development and utilization of geothermal energy in El Salvador from an engineering viewpoint. 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. However, this estimate and master plan should be revised several years later in line with the advancement of geothermal exploration and development in El Salvador.

4.6.1 Current Status

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

The exploration of geothermal resources in El Salvador started in 1958. Then, the first exploration well was drilled in 1968. As a result, the first geothermal power station in Central America started commercial power generation at Ahuachapán in 1975. This was the sixth in the world, following Italy (1913), New Zealand (1959), USA (1960), Japan (1966), and Former Soviet Union (1967).

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.



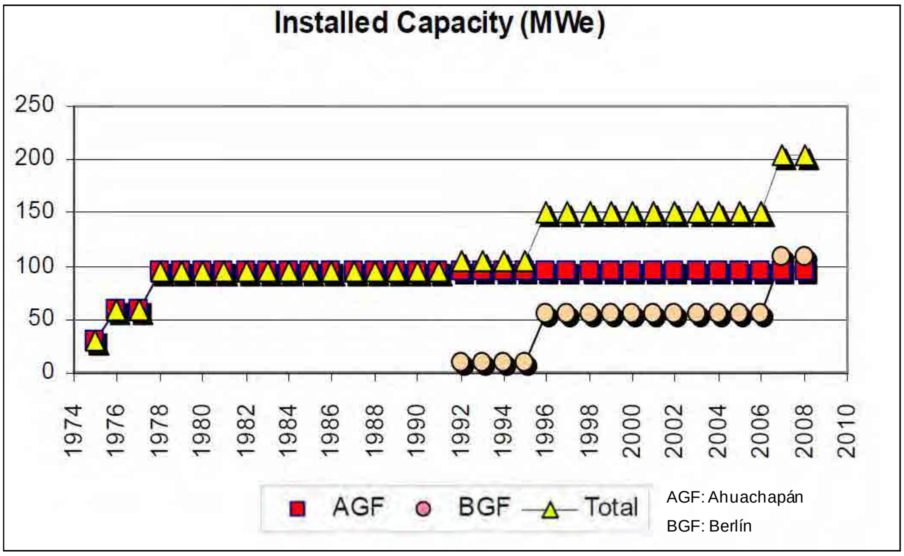
(Source: World Geothermal Congress 2005, El Salvador Country Update (2005))

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.

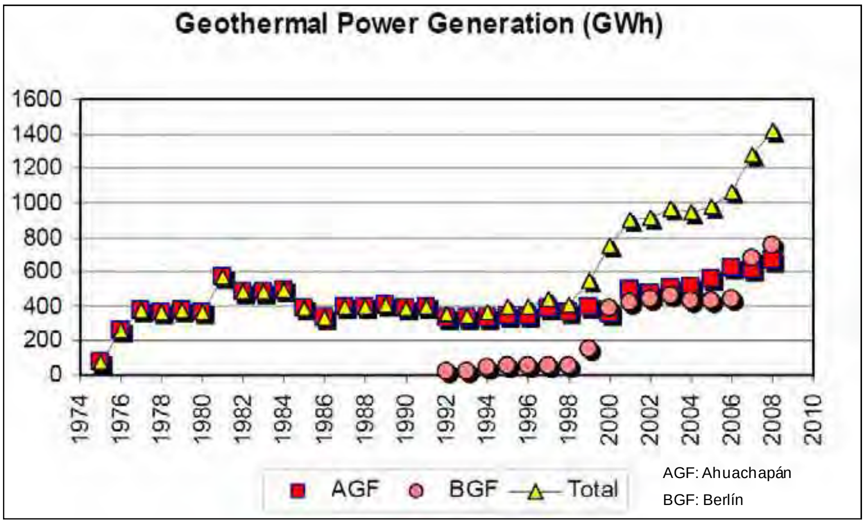
The total installed capacity in Berlín (four units) is 109.4 MW. Its running capacity at the end of 2009 was reported at 108 MW, which is 98% of the rated value. The history of growth of installed capacity in El Salvador is shown in Figure 4.6.2.



(Source: Congreso Mundial de Geotermia de 2010, El Salvador, actualización (2010))

Figure 4.6.2 History of Growth of Installed Capacity of Geothermal Power Plants in El Salvador

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.



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

Figure 4.6.3 History of Generated Electric Power from Geothermal Power Stations in El Salvador

The history of generated electric energy at the two geothermal power stations in El Salvador is shown in Figure 4.6.3. 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. Based on the report at the WGC2010, the statistics related to geothermal power generation in 2008 by LaGeo are as follows:

- Production wells in operation: 32
- Injection wells in operation: 27
- Production of steam: 13.1 million tons
- Production rate of steam: 1,350 t/h
- Average production per well: 33.1 t/h
- Separated brine reinjected: 38.2 million tons
- Generation of electricity: 1,421 GWh (annual average capacity factor: 79.4%)
- Gross specific consumption of steam: 8.2 t/MWh

The survey team visited Berlín Geothermal Power Station on October 6, 2011, and they were impressed by the high level of O&M of the plant, and the high level of awareness of environment and ecology of LaGeo, because the inside and outside of the power plant were neat and clean.

Based on the results, there appears to be no problem about the level of exploration and development of geothermal energy and production and operations of geothermal power by LaGeo. Thus, it is obvious that El Salvador is capable of continuing geothermal power development using its own human resources.

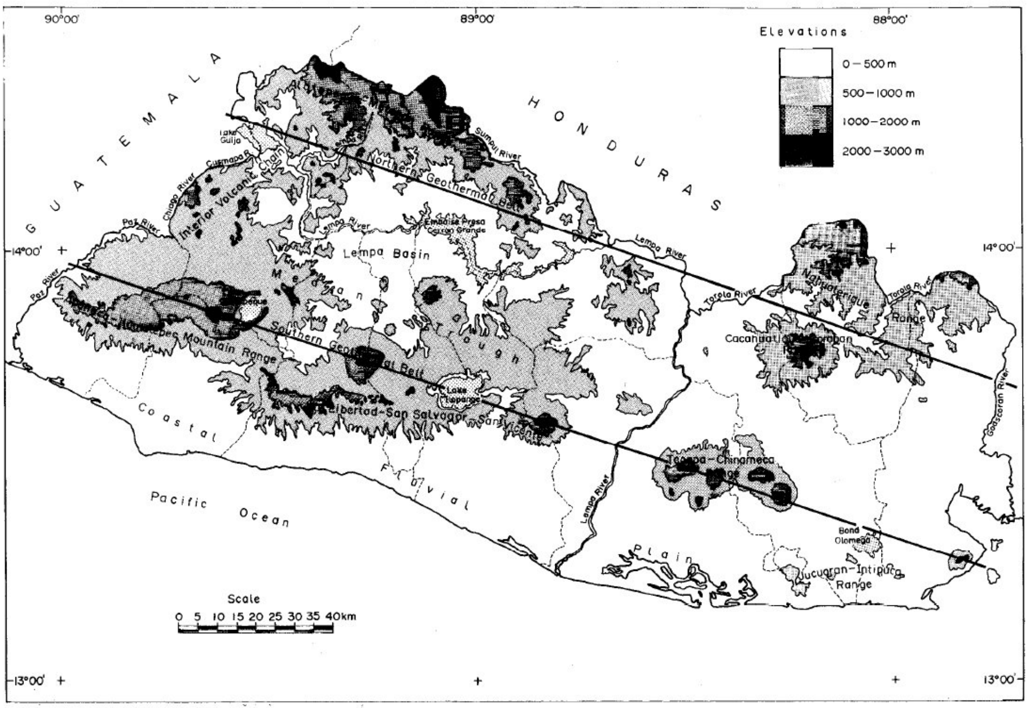
4.6.1.2 Geothermal Resources of El Salvador

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 4.6.4). Within the belts, 28 hot springs and seven fumaroles have been found (refer to Figure 4.6.5 and Table 4.6.1). Geothermal areas are zones which include hot springs and/or fumaroles. Based on geochemical temperatures calculated from chemical analysis data of hot spring waters (e.g. Fournier, 1977), there are 12 geothermal areas with estimated underground temperatures higher than 150 °C (see Table 4.6.2), and also 12 geothermal areas with estimated underground temperatures between 90 and 150 °C (see Table 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 Table 4.6.2. The locations of such fields are shown in Figure 4.6.6. 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 4.6.3.

Based on information from LaGeo, there are some more fields possible for binary-cycle geothermal power generation. Such are not included in Tables 4.6.2 and 4.6.3, but included in Table 4.6.1.



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

Figure 4.6.4 Northern and Southern Geothermal Belts in El Salvador

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

Figure 4.6.5 Location of 28 Hot Springs and 7 Fumarolic Areas in El Salvador

Table 4.6.1 List of the Hot Springs and Fumarolic Areas in El Salvador (Campos, 1988)

(a) Hot Springs

No.	Hot Spring Area well-depth (m)	Measured Surface Temperature (° C)	Measured Downhole Temperature (° C)
1	Durazneño	98	
2	Los Toles	99	
	Well TE-1 (400)		110
3	Los Salitres	85	
4	San Lorenzo	43	
5	Playón-El Salitre	70	
	Well-CH-1 (900)		220
6	La Ceiba	48	
7	Caluco	38	
8	Coatepeque	70	
9	Agua Caliente	38	
10	San Vicente (F-572)	92	
	Well SV1 (1346)		230
11	Obrajuelo-Lempa	98	
12	Parras Lempa	78	
13	San Simón	47	
14	Las Burras	68	
	Well TR2 (1905)		297
15	Jucuapa (P-244)	30	
16	Chinameca		
	Well CHI-1 (750)		159
17	Chilanguera	99	
18	Conchagua	62	
19	Metapán	79	
20	Texisteque	56	
21	Agua Caliente	64	
22	Obrajuelo	85	
23	El Salitre	42	
24	Nombre de Jesús	88	
25	Carolina	100	
26	San Isidro	73	
27	Santa Rosa	85	
28	El Sauce	69	

(b) Fumarolic Area

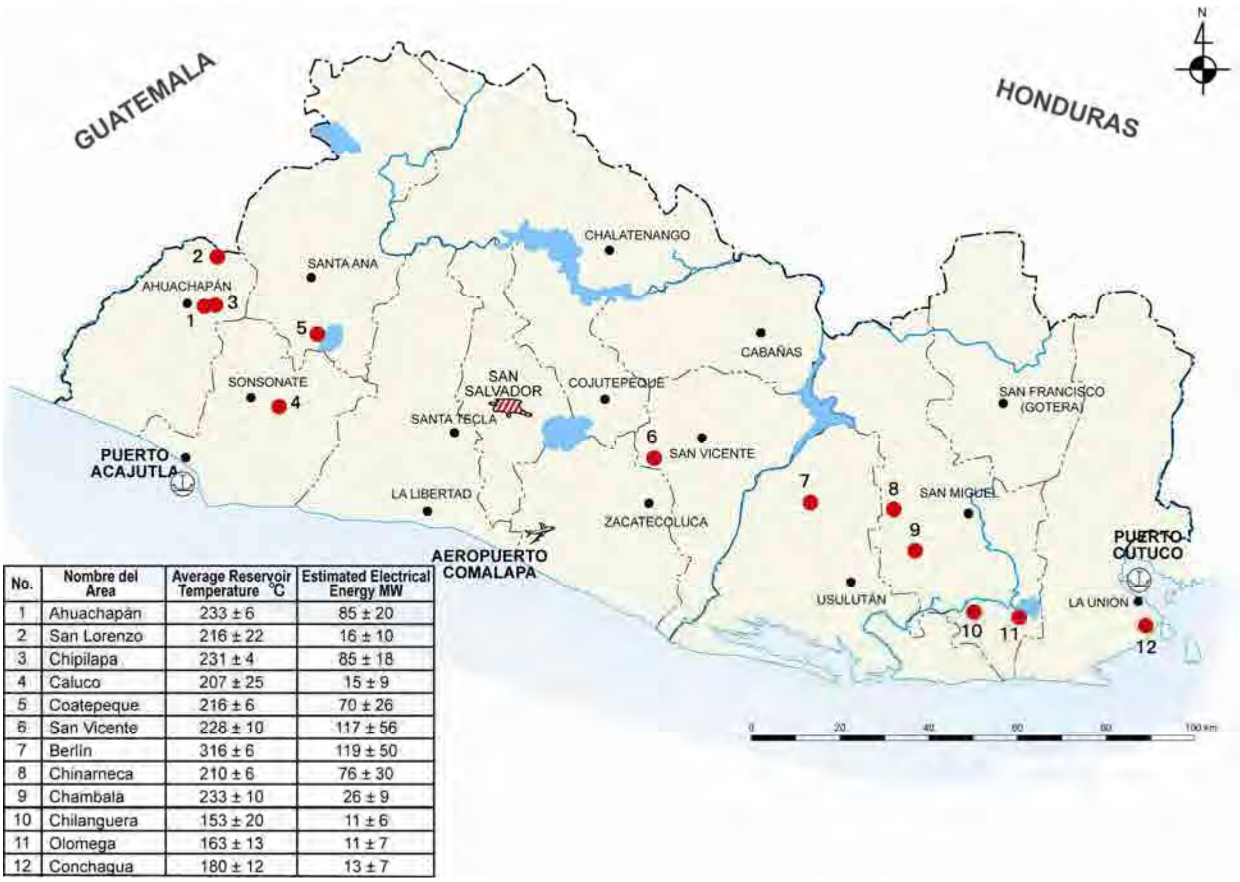
Fumarolic Area
Playón de Ahuachapán
Cuyanausul
La Labor (Chipilapa)
Infiernillos (San Vicente)
El Tronador (Berlín)
La Viejona (Chinameca)
Carolina

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

Table 4.6.2 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.)



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

Figure 4.6.6 Location of 12 High-Enthalpy Geothermal Areas in El Salvador

Table 4.6.3 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 values of geothermal power generation potential (i.e. geothermal potential) of each field are shown in Tables 4.6.2 and 4.6.3. These values were estimated using the method of the United States Geological Survey (USGS) (e.g. Muffer and Cataldi, 1978). This method first estimates the underground heat energy (i.e. stored heat) using estimated underground temperature and estimated reservoir volume. Then it estimates the geothermal power generation potential by using a recoverable factor.

In Tables 4.6.2 and 4.6.3, they were estimated as a power output which can be continued for 25 years. The values of geothermal potential shown in Tables 4.6.2 and 4.6.3 were estimated in 1988 by Campos (1988), but the same values are still employed in the latest report at the Central American Geothermal Workshop in 2009 (Montalvo and Guidos, 2009).

This method is usually applied at the early stages of geothermal exploration in order to see the approximate range of possibility of geothermal power generation. However, the estimated value is only an estimation based on approximate information which still has a certain amount of uncertainty. Thus, the estimated geothermal potential does not guarantee any actual development size. This should be considered when looking at this kind of estimated values, because the existence and availability of a geothermal resource can only be confirmed by the success of steam discharge from an exploration well. In general, the estimated geothermal potential, when there are not enough number of wells to delineate the entire picture of a reservoir, has a tendency of being overestimated (e.g. Grant and Bixley, 2011, p.49-51). Therefore geothermal potentials should be revised in line with the advancement of exploration and development.

The estimated geothermal potentials shown in Tables 4.6.2 and 4.6.3 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%. It is very high compared with those in other countries (see Table 4.6.4). This indicates that development and utilization of geothermal energy is going very well in El Salvador.

Table 4.6.4 Ratio of Installed Capacity to Geothermal Potential in the World

Country	A: Installed Capacity (MWe)	B: Geothermal Potential (MWe)	A/B (%)
USA	3,086	23,000 (No. 2)	13.4
Philippines	1,904	6,000	31.7
Indonesia	1,197	27,791 (No. 1)	4.3
Mexico	958	6,000	16.0
Italy	843	3,267	25.8
New Zealand	628	3,650	17.2
Iceland	575	5,800	9.9
El Salvador	204	791	25.8

(Source: World Geothermal Congress 2010; Country up-date report)

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%.

Regarding **A.** above, approximately two years are currently necessary to complete all the necessary procedures to get a concession for geothermal development in a new field, including six months for Environmental Impact Assessment (EIA), based on information from LaGeo. LaGeo says they are willing to contribute to fulfill the increasing power demand by effective utilization of geothermal energy. For this purpose, LaGeo desires simplification and shortening of the total length of all the permission periods such as by parallelization.

Currently, geothermal development in a new field takes six to seven years after getting the concession. This includes approximately two years at the least for power plant construction. Thus, LaGeo thinks that the length of time for getting the concession is a barrier similar to the total length of resource development. An outline of the necessary procedures for new geothermal development is shown in Figure 4.6.7.

B. and **C.** above are closely related to each other. For example, **B**. sometimes occurs when the location for geothermal exploration is a good farmland. **C**. sometimes occurs when there are inhabitants in the location of geothermal exploration. This is one of the characteristics of land use in El Salvador. Thus, informed consent is very important. If the Government of El Salvador wants to promote geothermal power development as part of the utilization of indigenous energy sources, arranging for opportunity of "informed consent" (the inhabitants of a site where a new Project is beging developed will have been notifed and agree) by the government and/or local administration can be a good option.

Drilling geothermal wells requires a lot of water, not only for drilling mud water but also for lost circulation, cooling of the wellbore, injection tests for permeability estimation, etc. In general, similar problems such as **D.** tend to occur when the drilling locations are in mountainous areas. Since there are wet and dry seasons in El Salvador, this problem may occur in the dry season when small streams in the mountainous areas become dry. In order to overcome this problem, drilling a necessary number of shallow water wells in the subsoil water aquifer can be an option.

Regarding **E.** above, a success rate of 25% in exploring wells is not bad as compared with other values in the world. Thus, this does not mean there are weaknesses in the exploration skills of LaGeo. Based on the information from LaGeo, their success rate of production wells is about 80%. This value is very good, and thus indicates the high level of exploration skills of LaGeo. Therefore, there are no serious problems in the engineering and technological capabilities of LaGeo on exploration.

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 4.6.5.

Table 4.6.5 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) Data up to october 2011

As shown in Table 4.6.5, 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.

The planned increase of 5 to 9 MW at Ahuachapán is a modification of its Unit-2 from the single-flash cycle to a double-flash cycle. The planned increase at Berlín consists of the installation of a new Unit-5. The feasibility of these two projects appears to be definite based on information from LaGeo.

Geothermal exploration in new fields has been continued in Chinameca and San Vicente. In Chinameca, the results from exploration well CHI-3 (total depth of 1,869 m) have been very favorable. Based on the results, LaGeo is considering building a new power plant with a 30 to 50 MW capacity. This new power plant is a conventional steam condensing plant. LaGeo's major efforts on new development will be directed to Chinameca, based on information from LaGeo. However, since this project is on development of a new geothermal resource, it appears that there still remains the possibility of delay of schedule by around two years due to uncertainty of resources. Thus, this possibility of delay should be kept in mind when considering the national energy mix plan.

In San Vicente, three exploration wells (or four wells based on other information) were drilled and had confirmed temperatures of 150 to 240 °C. However, reservoir permeability was found to be low at the first location. Therefore, exploration was shifted to the south at a new location. LaGeo is now considering undertaking a future exploration and development plan in San Vicente. At present, LaGeo is considering the possibility of power development of about 10 MW utilizing a binary-cycle system. However, its implementation has not been scheduled yet as described above. The development in San Vicente still appears to be under the exploratory stage.

There are possibilities for new geothermal power development in some more fields. However, at present, LaGeo has no definite development plan in another field. According to LaGeo, they will create a plan for a new geothermal power development only when the existence of a new reservoir has been confirmed through an exploration well. This appears to be a prudent policy based on a deep understanding of nature and the risks involved in geothermal resource development.

The original and detailed information from Table 4.6.5 is shown in Tables 4.6.6 and 4.6.7. For geothermal fields with a development status of RE (regional reconnaissance only) as shown in Table 4.6.6, no geothermal reservoir has been confirmed by an exploration well. Thus, their reservoir existence possibilities are still NE (not enough data for evaluation). The estimated resource potential of those fields should have been shown under "unidentified". However, LaGeo does not give their own evaluation on such fields. Thus, the "unidentified" rows are intentionally left blank in Table 4.6.6.

Table 4.6.6 Exploitable Resource Potential of 12 High-Enthalpy Geothermal Fields in El Salvador

No.	Field Name	Location	Develop. Status	Temperature (oC) Geochem.	Measured at well	Estimated Resource Potential (MWe) Unidentified Speculative	Hypothetical	Identified Possible	Probable	Proven	Reservoir Existence Possibility	Installed Capacity (MWe)	Existing Dev. Plan (MWe)	Possible Addition (MWe)	Total Potential (MWe)	Remarks
1	Ahuachapán	Ahuachapán	OP	233±6	245					100-104	1	95	5-9 [A]	?	100-104+	
2	San Lorenzo	Ahuachapán	RE	216±22							NE					
3	Chipilapa	Ahuachapán	OP	231±4		-	-	-	-	-	1	-	-	-	-	Ahuachapán
4	Caluco	Sonsonate	RE	207±25							NE					
5	Coatepeque	Santa Ana	RE	216±6							NE					
6	San Vicente	San Vicente	EX	228±10	240			10			1		10 [C]	?	10+	
7	Berlín	Usulután	OP	316±6	290					134-139	1	109.4	25-30 [A]	?	134-139+	
8	Chinameca	San Miguel	F1	210±6	235				30		1		30-50 [B]	?	30-50	
9	Chambala	San Miguel	RE	233±10							NE					
10	Chilanguera	San Miguel	RE	153±20							NE					
11	Olomega	San Miguel	RE	163±13							NE					
12	Conchagua	La Unión	RE	180±12							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)
Low : Low possibility or low temp.
2 : Inferred mainly by geochemical temp
NE : Not enough data for evaluation
3 : Inferred by geoscientific data

Speculative Geothermal power generation potential estimated from geochemical temperature and reservoir volume based on surface geology
Hypothetical Geothermal power generation potential estimated from geochemical temperature and reservoir volume based on geophysical data
Possible Geothermal power generation potential estimated from well drilling results (1 or 2 successful wells)
Probable Geothermal power generation potential confirmed by well drilling, production test and numerical modeling
Proven Geothermal power generation potential confirmed by power generation history

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

Total Potential (+) indicates further possibility

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

(Source: LaGeo)

Table 4.6.7 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* 2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	Remarks
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)
Low : Low possibility or low temp.
2 : Inferred mainly by geochemi
NE : Not enough data for evaluation
3 : Inferred by geoscientific data

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. Thus, the possibility of further geothermal power development in the future was estimated based on the estimated geothermal potential shown in Tables 4.6.2 and 4.6.3, and the ratio of installed capacity to the geothermal potential in the world as shown in Table 4.6.4.

The estimated geothermal potential of high-enthalpy geothermal fields is 644 MW (refer to Table 4.6.2). 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 as taken from Table 4.6.3 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% based on Table 4.6.4, 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

Biomass resources include agricultural residues, animal manure, wood wastes from forestry and industry, residues from food and industries such as bagasse from the sugarcane industry. Organic wastes and residues have been the major biomass sources so far. Combustion of biomass resources is a carbon-neutral process with replanting because emitted CO_2 has been previously absorbed from the atmosphere by plants. Residues, wastes, bagasse are primarily used for heat and power generation.

In the agricultural sector of El Salvador, the main agricultural crops include coffee, sugar, corn, rice and sorghum. Biomass resources have to be obtained free or at a low cost for power generation. If the cost of resources increases, continuous operations would be difficult. Therefore, it is recommended to install a biomass power plant in agricultural product processing factories such as sugarcane factories.

The annual production of main agriculture is shown in Table 4.7.1. In El Salvador, the sugar industry is one of the major agricultural industries and also has a large demand of electricity. On the other hand, the production of corn is large in El Salvador but it mainly depends on individual farmers at small owned areas. Therefore, it is difficult to use corn cob as fuel for power generation because collection is difficult. Also, coffee is one of the main agricultural industries in El Salvador. There are some coffee factories which presents the possibility of introducing a power generation system.

Table 4.7.1 Agricultural Production in El Salvador

	Sugar (1,000 MT)	Corn (1,000 MT)	Sorghum (1,000 MT)	Coffee (1,000 MT)	Rice (1,000 MT)
2005	550	725	141	79.7	17
2006	533	739	163	83.2	20
2007	516	834	181	84.0	20
2008	520	900	125	99.0	23
2009	515	820	150	93.0	21
2010	587	850	150	78.0	20
2011	566	850	150	102.0	20

(Source: United States Department of Agriculture)

From the results of discussions with CNE, bagasse, coffee husk and rice husk will be studied as biomass resources in the master plan study.

Table 4.7.2 shows the typical results of proximate and ultimate analysis of biomass resources and conventional resources such as coal and charcoal. As compared to coal and charcoal, the higher heating value (HHV) of biomass resources is smaller. However, the HHVs of bagasse and coffee husk are larger and enough for power generation. Although the HHV of rice husk is smaller than that of bagasse and coffee husk, there have been many power generation systems operated using rice husk in Asian countries.

Table 4.7.2 Proximate and Ultimate Analysis of Solid Fuel

Name	Fixed Carbon (%)	Volatiles (%)	Ash (%)	C (%)	H (%)	O (%)	N (%)	S (%)	HHV (kJ/g)
Bagasse	14.95	73.78	11.27	44.80	5.35	39.55	0.38	0.01	17.61
Coffee Husk	14.30	83.20	2.50	49.40	6.10	41.20	0.81	0.07	18.34
Rice Husk	15.80	63.60	20.60	38.30	4.36	35.45	0.83	0.06	14.40
Corncobs	18.54	80.10	1.36	46.58	5.87	45.46	0.47	0.01	18.44
Coal	55.80	33.90	10.30	75.50	5.00	4.90	1.20	3.10	31.82
Charcoal	89.31	93.88	1.02	92.04	2.45	2.96	0.53	1.00	34.78

(Source: JICA Study Team)

4.7.1.1 Sugarcane

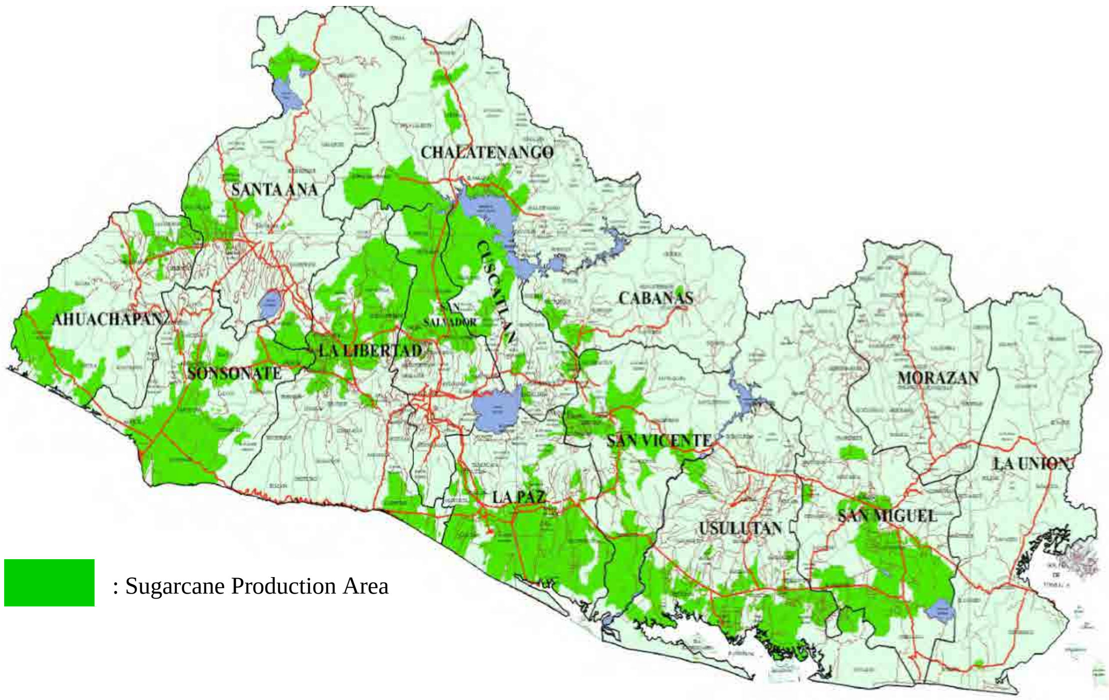
The sugar production process is energy intensive, requiring both steam and electricity. Historically, sugar mills have been designed to meet their energy requirements by burning bagasse. It is an economic means of producing electricity and disposing bagasse effectively.

Biomass power generation systems were already introduced in some sugarcane factories in El Salvador. There are six major sugarcane factories, in which three are interconnected with the national power grid. Generated power is consumed in the factories and excess power is supplied to the power grid. Bagasse is a by-product of the sugar production process in factories. Table 4.7.3 shows the production of sugarcane in each department. La Paz Department has the highest sugarcane production among all departments.

Table 4.7.3 Sugarcane Production in Each Department (2009-2010)

Department	Area (ha)	Production (t/year)	Yield (t/ha)
AHUACHAPÁN	4,317	318,947	73.88
SANTA ANA	2,571	197,756	76.90
SONSONATE	9,876	785,611	79.55
CHALATENANGO	1,050	82,713	78.80
LA LIBERTAD	7,764	622,046	80.12
SAN SALVADOR	5,342	419,245	78.49
CUSCATLAN	3,184	227,622	71.50
LA PAZ	13,137	1,026,901	78.17
CABAÑAS	591	46,718	79.11
SAN VICENTE	5,381	427,989	79.54
USULUTÁN	7,267	574,041	78.99
SAN MIGUEL	2,683	216,579	80.71
MORAZÁN*	n/a	n/a	n/a
LA UNIÓN*	n/a	n/a	n/a
TOTAL	63,162	4,946,168	78

* Information was not available from factories
(Source: JICA Study Team)



(Source: Ministry of Agriculture and Livestock)

Figure 4.7.1 Sugarcane Production in Each Department

There are six sugarcane companies in El Salvador. CASSA (COMPAÑÍA AZUCARERA SALVADOREÑA, S.A de C.V), El Ángel (INGENIO EL ANGEL), and La Cabaña (INGENIO LA CABAÑA) have been generating power and supplying electricity to the national grid. Table 4.7.4 shows the list of sugarcane factories.

Table 4.7.4 List of Sugarcane Factories

Sugarcane factory	Area of Sugarcane Field (ha)	Total Sugarcane (t)	Sugar Production (t)
Central Izalco (CASSA)	17,698	1,650,506	191,223
El Ángel	12,276	1,027,792	123,814
Chaparrastique	8,793	748,622	89,556
La Cabaña	9,339	757,055	89,642
Injiboa	8,145	538,333	60,042
La Magdalena	3,667	271,711	32,225
TOTAL	59,918	4,994,018	586,502

(Source: SIGET)

(Source: JICA Study Team)

Figure 4.7.2 Sugarcane Factory (La Cabaña)

Table 4.7.5 shows the installed capacity of biomass power generation which utilizes bagasse in El Salvador. CASSA merged with Chaparrastique and started to supply power to the grid in January 2011. Thus, CASSA has the largest installed capacity, with 66 MW, among the three sugarcane factories in 2010. “El Angel Cogeneration Project” was registered as a CDM project in 2007.

Table 4.7.5 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)

In general, sugarcane companies generate electricity during the harvest season from November to April. Table 4.7.6 below shows the monthly power output of the three factories. Similar to wind power, there is a seasonal complementary relation between bagasse and hydropower generation.

Table 4.7.6 Power Output, Self-Consumption and Sold Electricity of Sugarcane Companies in 2010

Sugarcane Company	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
CASSA													
Generated Power (MWh)	30,124	29,740	33,200	29,897	2,998	-	-	-	-	-	15,408	32,995	174,362
Self-Consumption (MWh)	11,914	11,028	12,172	10,481	891						5,918	12,578	64,981
Sold Electricity (MWh)	18,210	18,713	21,028	19,416	2,108	-	-	-	-	-	9,490	20,417	109,381
EL ANGEL													
Generated Power (MWh)	13,676	13,322	15,168	11,706	0	-	-	-	-	1.6	4,535	13,045	71,455
Self-Consumption (MWh)	5,812.1	5,289.3	5,820.2	4,316.9						1.6	2,101.2	5,300.0	28,641.3
Sold Electricity (MWh)	7,864.2	8,033.2	9,347.8	7,389.6	-	-	-	-	-	0.0	2,434.2	7,744.9	42,813.9
LA CABAÑA													
Generated Power (MWh)	5,865	6,390	7,127	6,761	826	-	-	-	-	-	3,116	6,832	36,917
Self-Consumption (MWh)	1,833.0	1,752.9	1,938.1	1,827.2	136.5	-	-	-	-	-	661.2	1,307.2	9,456.1
Sold Electricity (MWh)	4,032.0	4,637.1	5,188.9	4,933.8	689.5	-	-	-	-	-	2,454.8	5,524.8	27,460.9

(Source: SIGET)

(Source: JICA Study Team)

Figure 4.7.3 Steam Turbine Generator

4.7.1.2 Coffee

Table 4.7.2 shows the coffee production in each department in El Salvador. The annual coffee production is large in La Libertad Department and the Western Region (Ahuachapán, Santa Ana and Sonsonate). There are many coffee factories in El Salvador. Therefore, the potential of coffee husk at each factory should be smaller than that of a sugarcane factory. Moreover, about 30% of fresh cane weight becomes bagasse. Over half of the energy in sugarcane is left in bagasse. On the other hand, only 4.3% of the weight of red coffee grain is calculated as coffee husk.

In the survey, 67 coffee factories were identified and information on coffee production was received from 46 factories. The factory with the largest production is around 10,600 t per year (234,010 qq/year). Therefore, the amount of coffee husk will be around 456 t per year from the factory.

10,600 t/year x 4.3% = 455.8 t/year

The annual power output using coffee husk is roughly estimated at 136 MWh at the factory.

455.8 t/year x 0.3 MWh/ton = 136 MWh/year

The consumption rate of bagasse for power generation at 0.3 MWh per t was applied in the estimation because HHV of coffee husk is similar to that of bagasse. The output corresponds to 24-hour operations in 80 days by a 70 kW generator.

136 MWh/year / 24hours / 80 days = 0.07 MW (70 kW)

Table 4.7.7 below 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) / 12hours / 300 days = 0.29 (290 kW)

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

Eastern Region: 206 (MWh/year) / 12hours / 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 4.7.7 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

In Asian countries such as Thailand, power generation systems using rice husk is common technology. On the other hand, rice production is small in El Salvador as shown in Table 4.7.8. The annual rice production in La Libertad Department is largest among all departments. Approximately 25% of the weight of rice is calculated as rice husk. In the case of Thailand, fuel consumption of a 1 MW power plant is 12.3 t/h. Accordingly, the fuel consumption rate is at 81.3 kWh per t. The total amount of rice husk in the country is at 8,871 tons and it can generate 639,909 kWh/year.

8,871 t/year x 81.3 = 639,909 kWh/year

This estimated power output corresponds with operations of a 100 kW generator with 73.0% of capacity factor throughout a year. The potential of rice husk is too small as compared to the sugarcane industry.

639,909 kWh/year / (100kW x 24 x 365) = 73.0%

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) / 12hours / 300days =24.2 kW

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

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

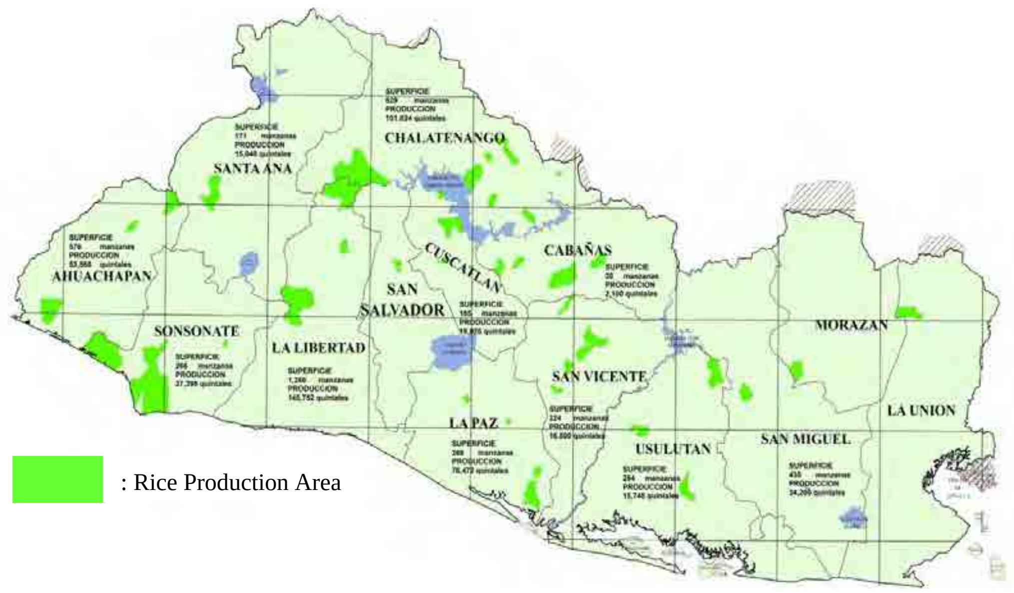
Figure 4.7.4 shows the rice production area in El Salvador. The rice production areas are widely distributed nationwide, and it seems that each area is too small to install a steam turbine type generator. On the other hand, it is possible to install an under-100 kW-class biomass gasification plant for power generation.

Table 4.7.8 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)



(Source: Ministry of Agriculture and Livestock)

Figure 4.7.4 Rice Production in Each Department

4.7.2 Barriers to Introduction

4.7.2.1 Woody Biomass

Generally, forest biomass is a renewable source of energy, in contrast, El Salvador is the second most deforested country in Latin America. According to information of PRISMA (National Dialogue Towards a Memory Book Forest in El Salvador), the surface is about 20,000 km2 and 50% is afforested and 41% are high levels of erosion. According to the 2003-2005 period, the forest coverage reached 19.1% of the country. The following law exists to prevent deforestation:

"Legislative Decree No. 1030 of 26 April 1997, Protection of The Criminal Code Natural Resources"

"Section 258: Whoever destroys, burned, cut or damaged. In whole or in part, forest or other natural or cultivated vegetation which they would legally protected, shall be punished with imprisonment from three to six years. Exceptions to any penalty for farmers engaged in agricultural work strictly cultural. "

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.

"Turbococinas, rural cooking stove substitution program in El Salvador" is a small-scale CDM program related to woody biomass resources. The program is expected to reduce the rate of deforestation in the country. This program started in March 2010 and will continue for ten years.

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. Table 4.7.9 shows the development plan. The installation of a new bagasse power plant with 25 MW capacity has been implemented during the visit to El Angel. In El Angel, there are currently two generators with capacities of 10 MW and 12.5 MW. A new generator with 25 MW capacity will replace the existing 10 MW generator, so the total capacity will be 37.5 MW at El Angel in December 2011. There is also a plan to install a bagasse generation system with 15 MW capacity at La Cabaña around 2015. 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 4.7.9 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. The potential capacity of biogas resources such as animal waste and wastewater is examined in this section.

4.8.1 Current Status

Anaerobic digestion, which is a series of processes of decomposition in the absence of oxygen, is the most promising method of treating the organic fraction of municipal solid waste and other organic wastes. Around the world, the pollution of air and water from municipal, industrial and agricultural operations continues to grow. The concept of the ‘four Rs’, which stands for reduce, reuse, recycle, and renewable energy, has generally been accepted as a useful principle for handling waste.

Anaerobic digestion process occurs naturally in the bottom sediments of lakes and ponds, in swamps, peat bogs, intestines of ruminants, and even in hot springs. Methane formation is also the process which stabilizes landfill sites. One technology that can successfully treat the organic fraction of waste is anaerobic digestion. When used in a fully-engineered system, anaerobic digestion not only prevents pollution but also allows for energy, compost and nutrient recovery. Thus, anaerobic digestion can convert disposal problem into a profit center.

Anaerobic bacteria convert biomass into a biogas or LFG that can be used to generate energy. Biogas is also produced during anaerobic digestion in landfills and as such, it is referred to as landfill gas. Biogas is sometimes called swamp gas, landfill gas, or digester gas. When its composition has a higher standard of purity, it can be called renewable natural gas.

4.8.1.1 LFG

There is an LFG power plant in El Salvador. LFG is formed when anaerobic bacteria consume organic materials in waste that has been disposed of in a landfill. These bacteria cause a breakdown of food waste, paper, wood, etc., into simpler forms like organic acids. In general, the gas contains 50% of methane (CH_4).

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.

Table 4.8.1 Landfill of El Salvador

	Year			
	1998 (a)	2001 (b)	2006 (c)	2009 (d)
Total landfills	0	1	9	14
Total municipalities served with landfills	0	11	39	252
Percentage of municipality served by landfills (%)	0	4%	12%	96%
Sanitary disposal coverage (%)	0	46%	48%	75%
Total urban population served by landfills (million)	0	1.3	1.9	3.6
Percentage of population served by sanitary landfills (%)	0	35%	54%	99%

a) Analysis of the solid waste sector in El Salvador, PAHO, MOH, 1998
b) First national survey of solid waste in El Salvador, 2001
c) Second national survey of solid waste in El Salvador, 2006
d) Statistical data of solid waste unit, 2009
(Source: MARN (www.marm.gob.sv))

The table below shows the weight of solid waste per day in each department of El Salvador in 2007. Most of the solid waste is disposed at the landfills in San Salvador. Around 55% of the total solid waste in the country and around 80% of solid waste in landfills are disposed in San Salvador.

Table 4.8.2 Weight of Solid Waste per Day

	Total of Solid Waste (t/day)	Landfill Disposal (t/day)	Landfill / Total (%)
SAN SALVADOR	1,768.78	1,609.62	91.0
LA LIBERTAD	368.19	226.29	61.5
SANTA ANA	270.56	0.00	0.0
SAN MIGUEL	231.01	0.00	0.0
SONSONATE	109.82	34.99	31.9
USULUTAN	82.11	49.88	60.7
CUSCATLAN	72.46	58.98	81.4
LA PAZ	55.46	0.00	0.0
LA UNION	51.79	0.00	0.0
AHUACHAPAN	50.29	15.81	31.4
CABAÑAS	42.58	0.00	0.0
SAN VICENTE	32.60	0.00	0.0
CHALATE NANGO	30.09	0.00	0.0
MORAZAN	21.23	2.97	14.0
TOTAL	3,186.97	1 ,998.54	62.7

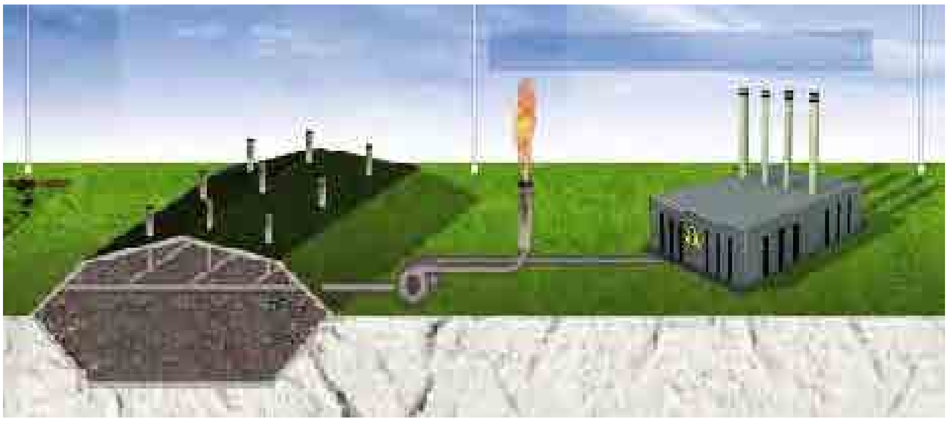
(Source: PRACTICAS DE DESECHOS SÓLIDOS EN CENTRO AMERICA El Salvador, MARN, 2007)

The site survey of Nejapa biogas power plant was carried out.. 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. Biothermica Energie Inc. (Biothermica), a Canadian company, has conducted a feasibility study funded by CIDA through its Industrial Cooperation Program in 2003. “Landfill Gas to Energy Facility at the Nejapa Landfill Site” was registered as a CDM project in 2006. Based on the results of the feasibility study, AES Nejapa installed a biogas generation system in 2008.

The landfill is located 6 km outside of Nejapa. 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. Cells 1 to 3 have been partially completed and cell 4 is currently active. After completion, the site will cover 47 ha. 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. The following figure shows the concept of an LFG power station.

Methane is collected from the landfill by suction blowers. A part of the collected methane is used for flaring, and the rest is used as fuel for power generation. Most of the generated power is supplied to the national power grid while the rest is consumed in the power station



(Source: Biothermica)

Figure 4.8.1 Concept of LFG Power Station

In the landfill, there are 60 vertical wells equipped with pumps as shown in following figure. Also, there are horizontal collection pipes located underground.

(Source: JICA Study Team)

Figure 4.8.2 LFG Suction Pump

The following table shows a summary of information on the Nejapa biogas power plant. 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.

Table 4.8.3 Summary of Information on Nejapa Biogas Power Station

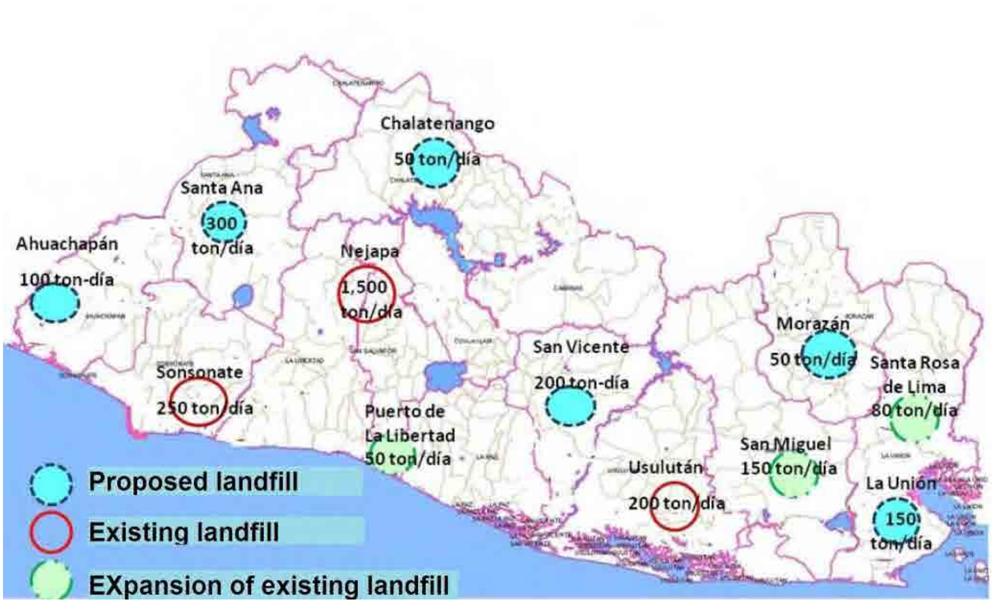
Installed capacity	6.3	MW
Output voltage of generator	13.8	kV
Connected grid	23	kV
Amount of waste	2000	t/day
Production of CH_4	32,000 to 40,000	m^3/day
CH_4	48-52%	
Consumption rate for power generation	600 to 650	m^3/h
Annual power output	40,000	MWh/year
Self-consumption	3,000	MWh/year
Initial installation cost	US$58,000,000	
Cost of a generator	US$500,000	
Annual O&M cost	US$700,000/year	
No. of staff	30	
Capacity factor	87%	
CO_2 Reduction	200,000 tons/year	

(Source: JICA Study Team)

(Source: JICA Study Team)

Figure 4.8.3 Overview of the Biogas Power Station

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



(Source: MARN)

Figure 4.8.4 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:

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

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

Table 4.8.4 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

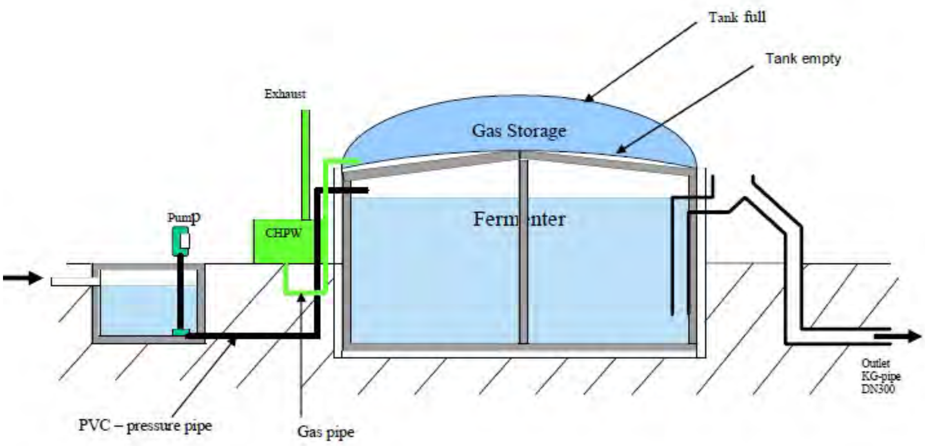
Biogas is produced during anaerobic digestion of organic substrates such as manure, sewage sludge, and organic fractions of household and industry waste. Biogas can be used as a fuel source to generate electricity for on-farm use, sale to the power grid, or heating or cooling needs. Biologically stabilized byproducts of anaerobic digestion can be used in a number of ways, depending on local needs and resources. Successful byproduct applications include use as crop fertilizers, bedding, and aquaculture supplements.

Large-scale digesters are introduced preliminary in industrial countries. Moreover, small-scale digesters are found worldwide. Biogas consists mainly of methane and carbon dioxide and it can be utilized as a renewable energy source in combined heat and power plants. Production and utilization of biogas has the following environmental advantages:

- It is a renewable energy source.
- It reduces the release of methane to the atmosphere compared to traditional manure management or landfills.
- It can be used as a substitute for fossil fuel.
- Output slurry can be used as organic fertilizer which is produced simultaneously with biogas.

Biogas is the gaseous product of anaerobic digestion of organic matter. It is typically made up of methane (CH_4), carbon dioxide (CO_2), hydrogen (H_2), nitrogen (N_2) and a few impurities including hydrogen sulfide (H_2S).

Biogas is used in many different applications worldwide. In rural communities, small-scale digesters provide biogas for single-household cooking and lighting. There are about eight million of these systems in China, about 440,000 in India and 20,000 in Bangladesh. The figure below shows a typical model of a small-scale biogas system.



(Source: Biogas Production and Utilisation IEA BioEnergy)

Figure 4.8.5 Typical Model of a Small-scale Biogas System

Large-scale digesters provide biogas for electricity production, heat and steam, chemical production, and vehicle fuel. Digestion of sewage sludge provides significant benefits when recycling the sludge back to land as organic fertilizer. The digestion process sanitizes and also reduces the odor potential from the sludge. Typically between 30% and 70% of sewage sludge is treated by anaerobic digestion depending on national legislation and priorities.

Livestock have various sizes. Therefore, the unit of GV (livestock unit) is adopted for the estimation of potentials. GV shows the number of livestock per 500 kg of weight.

Table 4.8.5 GV (Livestock Unit)

Type of Livestock			GV
Cattle			
	0 to 1	years	0.3
	1 to 2	years	0.7
	more than 2	years	1
	OX, Handling		1.2
Pig			
	under 12	kg	0.01
	12 to 20	kg	0.02
	20 to 45	kg	0.06
	45 to 60	kg	0.16
Poultry			
Broiler			
	0.8 to 1.2	kg	420
	under 0.8	kg	625
Hens			
	under 1.6	kg	300

(Source: Biogas-Praxis)

a. Biogas from cattle

The table below shows information on the number of cattle in El Salvador. The largest number of cattle is in the Oriental Region. However, cattle generally breed in open spaces in El Salvador. Therefore, there is difficulty in collecting cattle’s manure for anaerobic digestion in a biogas system. Biogas digesters have to be installed beside cattle farms, wherein cattle breeds in stalls, in order for manure to be collected easily for sustainable operations of such biogas system.

Table 4.8.6 Number of Cattle in El Salvador

	CALF (nos)	VEAL (nos)	STEER MALE (nos)	STEER FEMALE (nos)	YOUNG BULL (nos)	BULLS (nos)	OX (nos)	DRY COWS (nos)	DAIRY COWS (nos)
AHUACHAPAN	5,439	5,146	1,991	5,330	639	1,027	457	6,103	9,990
SANTA ANA	9,328	10,918	2,202	11,195	955	1,891	514	12,429	19,763
SONSONATE	7,042	9,936	2,169	9,452	1,526	1,252	622	11,211	19,691
Western Region Total	**21,809**	**25,999**	**6,362**	**25,976**	**3,120**	**4,170**	**1,593**	**29,742**	**49,444**
CHALATENANGO	10,188	13,634	2,400	13,866	1,295	2,549	180	12,438	24,299
LA LIBERTAD	7,074	8,090	2,462	7,656	762	1,510	1,069	10,424	17,101
SAN SALVADOR	5,134	6,375	1,301	5,842	640	1,165	661	5,838	12,300
CUSCATLAN	2,373	2,081	730	2,456	398	464	448	2,916	4,355
LA PAZ	7,477	9,176	3,481	10,498	1,241	1,614	1,690	13,250	17,745
CABAÑAS	10,027	10,765	2,707	11,947	1,340	2,155	423	12,851	18,544
SAN VICENTE	8,453	8,689	4,307	12,306	1,264	1,429	946	12,879	15,797
Central Region Total	**50,727**	**58,809**	**17,390**	**64,571**	**6,940**	**10,886**	**5,417**	**70,595**	**110,140**
USULUTAN	11,953	12,892	7,249	17,721	3,877	3,289	4,936	18,978	25,445
SAN MIGUEL	17,326	18,248	5,182	19,006	2,842	3,859	4,025	21,725	31,863
MORAZAN	10,684	11,110	1,114	9,943	1,395	2,076	474	11,042	17,428
LA UNION	22,109	23,367	2,162	19,824	2,411	4,362	939	27,670	37,643
Eastern Region Total	**62,073**	**65,617**	**15,707**	**66,493**	**10,525**	**13,586**	**10,375**	**79,416**	**112,379**
TOTAL	***134,610***	***150,426***	***39,459***	***157,041***	***20,584***	***28,643***	***17,384***	***179,753***	***271,963***

(Source: MAG/ Census of Agriculture, October 2007)

The following table shows the estimated power output from cattle in each department. 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..

Table 4.8.7 Estimated Power Output and Power Potential from Cattle

	GV*	Estimated Power Output (MWh/year)	Estimated Potential (kW)
AHUACHAPAN	29,826	26,352	3,008
SANTA ANA	57,544	50,842	5,804
SONSONATE	53,833	47,562	5,430
Western Region Total	**141,203**	**124,756**	**14,242**
CHALATENANGO	66,676	58,910	6,725
LA LIBERTAD	48,218	42,601	4,863
SAN SALVADOR	32,817	28,994	3,310
CUSCATLAN	13,691	12,096	1,381
LA PAZ	56,858	50,235	5,735
CABAÑAS	58,172	51,396	5,867
SAN VICENTE	55,012	48,604	5,548
Central Region Total	**331,444**	**292,837**	**33,429**
USULUTAN	91,328	80,690	9,211
SAN MIGUEL	103,440	91,392	10,433
MORAZAN	52,482	46,369	5,293
LA UNION	115,310	101,878	11,630
Eastern Region Total	**362,560**	**320,329**	**36,567**
TOTAL	***835,207***	***737,922***	***84,238***

(Source: JICA Study Team)

b. Biogas from pigs

The table below shows information on the number of pigs in El Salvador. The largest number of pigs is in the Central Region. There are eight pilot projects of biodigesters at piggeries which are being implemented under AEA.

Table 4.8.8 Number of Pigs in El Salvador

	PIGLET MALE (nos)	PIGLET FEMALE (nos)	FATTENING PIGS MALE (nos)	FATTENING PIGS FEMALE (nos)	GROWING PIGS FEMALE (nos)	BOARS (nos)	FEMALE PIGS FOR REPRODUCTION (nos)	PIGS FOR SELLING (nos)	PIGS PRODUCTION FOR FATTENING (nos)
AHUACHAPAN	954	847	2,121	730	112	42	263	714	11,028
SANTA ANA	1,889	1,769	2,233	1,484	473	115	1,117	4,491	8,517
SONSONATE	2,421	1,470	4,045	2,974	3,431	204	2,091	5,998	8,097
Western Region Total	**5,264**	**4,086**	**8,399**	**5,188**	**4,015**	**360**	**3,471**	**11,203**	**27,642**
CHALATENANGO	621	686	646	607	61	22	135	793	334
LA LIBERTAD	4,812	2,484	8,632	3,734	1,518	146	2,598	8,223	22,656
SAN SALVADOR	457	517	589	443	561	39	347	387	2,737
CUSCATLAN	220	398	311	105	24	5	90	907	211
LA PAZ	1,002	1,090	923	1,037	209	52	359	1,778	746
CABAÑAS	3,809	3,322	7,823	5,534	2,871	200	2,883	2,607	32,673
SAN VICENTE	1,522	812	1,143	693	147	14	137	1,345	1,756
Central Region Total	**12,442**	**9,309**	**20,066**	**12,153**	**5,390**	**478**	**6,550**	**16,039**	**61,114**
USULUTAN	2,353	2,640	1,121	1,199	95	58	291	1,167	730
SAN MIGUEL	2,473	2,374	3,276	2,374	484	180	653	3,312	4,046
MORAZAN	1,386	1,192	1,842	1,376	360	137	367	1,930	10,432
LA UNION	2,343	2,660	1,988	1,288	444	204	1,082	6,291	2,482
Eastern Region Total	**8,555**	**8,867**	**8,227**	**6,236**	**1,382**	**580**	**2,393**	**12,700**	**17,690**
TOTAL	***26,261***	***22,261***	***36,692***	***23,577***	***10,787***	***1,418***	***12,414***	***39,942***	***106,445***

(Source: MAG/ Census of Agriculture, October 2007)

The following table shows the estimated power output from pigs in each department. 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.

Table 4.8.9 Estimated Power Output and Power Potential from Pigs

	GV*	Estimated Power Output (MWh/year)	Estimated Potential (kW)
AHUACHAPAN	2,152	1,425	163
SANTA ANA	2,650	1,755	200
SONSONATE	3,670	2,431	277
Western Region Total	**8,473**	**5,611**	**641**
CHALATENANGO	317	210	24
LA LIBERTAD	6,510	4,312	492
SAN SALVADOR	733	485	55
CUSCATLAN	235	156	18
LA PAZ	662	439	50
CABAÑAS	7,541	4,994	570
SAN VICENTE	701	464	53
Central Region Total	**16,699**	**11,059**	**1,262**
USULUTAN	614	406	46
SAN MIGUEL	1,824	1,208	138
MORAZAN	2,361	1,563	178
LA UNION	1,977	1,309	149
Eastern Region Total	**6,775**	**4,487**	**512**
TOTAL	***31,948***	***21,158***	***2,415***

(Source: JICA Study Team)

A biogas project funded by AEA was carried out at Granja de los Hermanos Jove in 2008. The total project implementation cost was around US$39,000. There are 25,000 pigs in the farm. The capacity of a biodigester is 25 m^3. However, the amount of manure is more available for production of biogas. The gas produced is used for cooking and heating room of piglets. The amount of emission reduction of CO_2 was estimated at 3,607 t per year. Compost production was estimated at approximately 5,300 t per year. The farm is currently seeking for financial aid for the construction of three additional digesters for the power generation system.

(Source: JICA Study Team)

Figure 4.8.6 Biodigester of Granja de los Hermanos Jovel

c. Biogas from poultry

The table below shows information on the number of poultry in El Salvador. 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.

Table 4.8.10 Number of Poultry in El Salvador

	NEWLY HATCHED CHICKS (nos)	FOR FATTENING CHICKENS (nos)	GROWING CHICKENS (nos)	CHICKENS LAY EGG (nos)	FATTENING CHICKENS PRODUCTION (nos)
AHUACHAPAN	20,426	171,748	32,441	122,504	750,097
SANTA ANA	110,560	70,532	255,300	305,007	438,430
SONSONATE	33,464	121,975	74,113	336,226	467,222
Western Region Total	**164,450**	**364,255**	**361,854**	**763,737**	**1,655,749**
CHALATENANGO	27,196	63,380	11,727	203,228	136,423
LA LIBERTAD	5,078,933	7,794,172	598,405	1,181,461	46,242,417
SAN SALVADOR	771,255	427,351	1,030,719	2,475,338	1,420,767
CUSCATLAN	43,473	219,648	219,867	578,505	474,443
LA PAZ	88,516	237,036	257,392	687,275	1,874,532
CABAÑAS	73,134	146,736	106,766	320,228	231,646
SAN VICENTE	3,285	41,601	7,251	34,131	500,365
Central Region Total	**6,085,794**	**8,929,924**	**2,232,128**	**5,480,165**	**50,880,593**
USULUTAN	54,710	51,157	28,984	105,658	94,232
SAN MIGUEL	83,398	299,903	80,986	253,948	547,977
MORAZAN	15,732	80,163	6,559	38,450	156,257
LA UNION	19,913	36,750	10,776	58,388	134,674
Eastern Region Total	**173,753**	**467,973**	**127,305**	**456,443**	**933,140**
TOTAL	**6,423,997**	**9,762,152**	**2,721,287**	**6,700,346**	**53,469,483**

(Source: MAG/ Census of Agriculture, October 2007)

The following table shows the estimated power output from poultry in each department. 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.

Table 4.8.11 Estimated Power Output and Power Potential from Poultry

	GV*	Estimated Power Output (MWh/year)	Estimated Potential (kW)
AHUACHAPAN	2,687.6	12,033	1,374
SANTA ANA	2,949.7	13,206	1,508
SONSONATE	2,683.6	12,015	1,372
Western Region Total	**8,320.9**	**37,254**	**4,253**
CHALATENANGO	1,182.2	5,293	604
LA LIBERTAD	141,901.7	635,312	72,524
SAN SALVADOR	15,823.8	70,845	8,087
CUSCATLAN	4,053.5	18,148	2,072
LA PAZ	7,929.7	35,502	4,053
CABAÑAS	2,272.8	10,176	1,162
SAN VICENTE	1,419.6	6,356	726
Central Region Total	**174,583.4**	**781,632**	**89,227**
USULUTAN	832.9	3,729	426
SAN MIGUEL	3,138.6	14,052	1,604
MORAZAN	723.8	3,241	370
LA UNION	648.1	2,902	331
Eastern Region Total	**5,343.5**	**23,923**	**2,731**
TOTAL	***188,247.7***	***842,810***	***96,211***

(Source: MAG/ Census of Agriculture, October 2007)

4.8.1.3 Industrial Waste

Coffee Factory

There is a coffee factory that uses biogas from industrial waste. This coffee factory is located at Quezaltepeque City in La Libertad Department, around 15 km from San Salvador. The factory processes coffee beans at around 3,450 t per year. The table below shows the amount of wastes from the factory. The plant has obtained environmental permission from MARN.

Table 4.8.12 Waste from the Coffee Factory

Waste	Amount of Waste (t/year)
Pulp	5339.16
Mucilage	1067.83
Wet Parchment	1601.75

(Source: JICA Study Team)

The monthly average wastewater for recycling is 61.85 m^3. Also, the total number of days of operation of the factory during the harvest season, from September to February, is 176 days. Thus, the total amount of wastewater becomes 247.4 m^3 per season. Also, wastewater is recycled at the treatment facility. Recycled water is used to reduce water consumption in the factory. At the end of the treatment process, sludge is exhausted. The amount of sludge is around 2.5 m^3 per year. Sludge is dried and deposited in farmlands. There is another treatment facility for wastewater that uses an upflow anaerobic sludge blanket (UASB) bioreactor. This reactor treats wastewater and produces biogas from the coffee pulper. This type of reactor is used for wastewater with a high amount of organic material.

(Source: JICA Study Team)

Figure 4.8.7 UASB

Wastewater is supplied into the digester. Also, based on operational experiences, the digester can reduce BOD from 12,000 to 200 with proper operations. 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. The annual power consumption of the factory is 475 MWh. Also, the introduction of power generation systems using produced biogas or gasification technology is considered; however, the initial investment cost for facilities of such systems is high and not affordable at around US$2,000,000.

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. Basically, all of the pollutants are exhausted by human activities. High concentrations of organic and inorganic materials deteriorate natural water reservoirs. In El Salvador, water quality index, which is called Indice de Calidad de Aguas (ICA), has been used for monitoring the water quality of rivers and natural water resources. ICA has been used since 2002 for the purpose of studying the reduction of polluted river and monitoring of water quality for aquatic life. Table 4.8.13 shows the parameters of water quality index.

Table 4.8.13 Parameters of ICA and Weights

Parameter	Unit	Weight
Dissolved oxygen	% saturation	0.17
Coliforms	NMP/100 mL (maximum number)	0.15
pH	pH	0.12
BOD	mg/L	0.10
Nitrate	mg/L	0.10
Phosphate	mg/L	0.10
Temperature (rate of change)	ºC	0.10
Turbidity	NTU	0.08
Total dissolved solid	mg/L	0.08

(Source: MARN (2009))

The mathematical expression of ICA is as follows:

$$ICA = [\sum_{1}^{9} (Sub\ i)\ Wi\ ]$$

Where:

Wi : Relative weight assigned to each parameter (Subi). The range is between 0 and 1; sum of the weights becomes 1

Sub1: Subindex of the parameter i

Table 4.8.14 Range of ICA

Water Quality	Range of ICA	Uses
Excellent	91 to 100	Provides the development of aquatic life
Good	71 to 90	Provides the development of aquatic life
Regular	51 to 70	Restricts the development of aquatic life
Bad	26 to 50	Restricts the development of aquatic life
Worst	0 to 25	No aquatic life

(Source: MARN (2009))

According to MARN, water quality was monitored at 124 sites. There were no sites categorized in the ICA as having excellent or good water quality. However, 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.

Information on the water treatment facility was obtained from ANDA. For the estimation of biogas production from wastewater at water treatment facilities, it is necessary to grasp the current situation of such facilities. It is necessary to understand certain information on water treatment facilities in the country in order to consider the development of biogas production at water treatment plants. There are 66 water treatment plants with not enough capacity to produce biogas. Table 4.8.15 shows the 18 water treatment facilities which serve more than 10,000 beneficiaries. The table also shows the water treatment facilities owned or managed by ANDA. The table also shows installed capacity, volume of water treatment plants and type of treatment system. In addition, the number of beneficiaries of each plant is shown in the table.

The information indicated in the table is useful to estimate biogas production. However, it is necessary to have more accurate data obtained from water analyses in order to estimate output volume and components of biogas.

Table 4.8.15 Water Treatment Facility (More Than 1000 Beneficiaries)

Department	Name and Type of Plant	Number of Beneficiaries	Capacity (L/s)	Volume (m^3)	Place of Discharge
Ayutuxtepeque	Urb. La Santisima Trinidad, Sediment tank and percolating filter	24,000	41.67	26.04	-
Cuscatancingo	Urbanizacion Ciudad Futura, Sediment tank and percolating filter	15,000	26.04	26.04	El Chaguiton River
Santa Tecla	Urbanizacion Alpes Suizos I, Sediment tank and percolating filter	10,086	17.51	-	La Reandnaga stream
Ilopongo	Urb. AltaVista I, Sediment tank and percolating filter	21,000	36.46	31.25	Amaando stream
	Urb. AltaVista II, Sediment tank and percolating filter	15,000	26.04	20.83	Amaando stream
	Urb. Cumbres de San Bartolo, Sediment tank and percolating filter	16,800	29.17	5.73	Amaando stream
	Urb. Cumbres de San Bartolo II, Sediment tank and percolating filter	16,775	29.12	-	Amaando stream
	Urb. Vista al Lago, Sediment tank and percolating filter	21,000	36.46	2.08	-
La Libertad	Urb. Camposverdes de Lourdes, Sediment tank and percolating filter	18,000	31.25	20.83	Sucio River
	U. Camposverdes de Lourdes II, Anaerobic reactor and anaerobic filter	18,000	31.25	-	River Colon
	Urb. Complejo Lourdes, Septic tank and anaerobic filter	18,000	31.25	15.20	River Colon
	Urbanizacion Nuevo Lourdes, RAFA and anaerobic filter	24,000	41.67	10.20	River Colon
	Urb. Brisas de Zaragoza, Activated sludge	12,000	20.83	1.56	River San Antonio
La Paz	Mpio. de Santiago Nonualco, Stabilization ponds	12,000	20.83	12.80	River Jalponga
	Urbanizacion Montelimar, Sediment tank and percolating filter	12,720	22.08	20.83	-
	Urb. Santa Isabel El Pedregal, Sediment tank and percolating filter	24,000	41.67	2.08	River Jiboa
San Miguel	Mpio. El Transito, Imhoff tank and lagoon	10,566	18.34	-	-
	Urbanizacion Ciudad Paraiso, Upflow anaerobic reactor and anaerobic filter	12,000	20.83	5.70	-

(Source: ANDA)

4.8.2 Barriers 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 must comply with 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

It is necessary to deepen and extend the studies to develop projects related to biogas in landfills 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 4.8.16 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

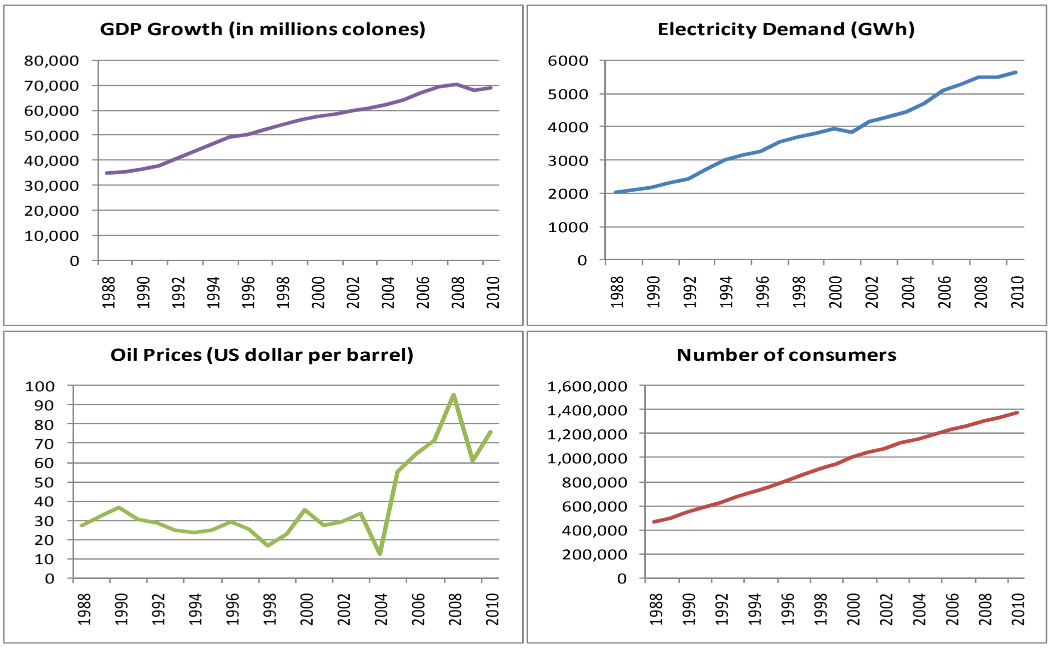
5.1 Review of Demand and Supply Forecast by the Government

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. CNE presented to the JICA Study Team the results of demand and supply forecast in the middle of September and at the beginning of November 2011. CNE and the JICA Study Team discussed on how the latter would provide information so that the former can simulate the development scenario as prepared in the renewable energy master plan.

The outlines of demand and supply forecast are described hereunder.

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. In this section, detailed explanation on the multiple linear regression system is not given, except on the data used for the forecast and the results of the forecast. Since the power sector of El Salvador applies the wholesale market system, power suppliers may differ each year. Therefore, the demand forecast is regarded as reference for three scenarios, namely “High”, “Reference”, and “Low”. Details of the data used for analysis and the results of the forecast are as described in Figure 5.1.1.



(Source: CNE)

Figure 5.1.1 Trend of Parameters Used for Demand Forecast

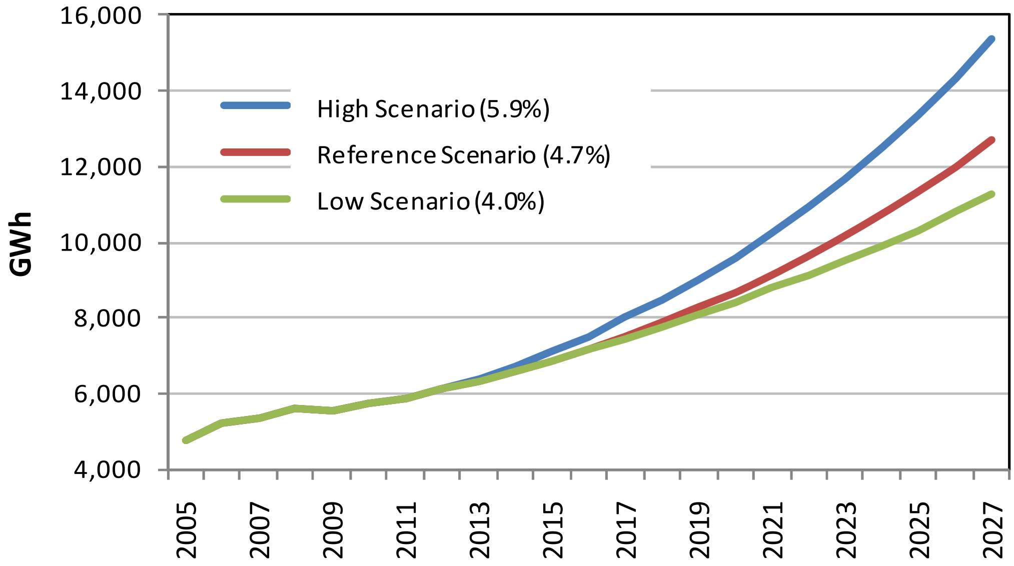
Demand forecast targeted from the years 2012 to 2026 to estimate the demand considering the following assumptions that are specific to the wholesale electricity market:

Conditions

- Study Period: from 2012 to 2026 (15 years)
- Standard of constant price: 2010
- Discount Rate: 12%
- The maximum size of power generation unit: 250 MW
- Target area of forecast: Isolated system of El Salvador
- Reliability of the power supply system: 99.73% or more (Annual power interruption: Less than 24 hours)
- Number of scenarios: Three (High, Reference, Low)
- Assumptions of GDP forecast: The following table is used for forecasting the 15 years of GDP

Year / Scenario	GDP Forecast			
	2011 - 2012	2013 – 2015	2016 - 2020	2021 - 2026
High	2.8%	4.0%	4.5%	5.0%
Reference	2.8%	3.0%	3.5%	4.0%
Low	2.8%	3.0%	3.0%	3.0%

By applying the above conditions, the results are as shown in Figure 5.1.2 and Table 5.1.1. For the Reference scenario, the demand is expected to be more than double of the current demand in 15 years.



(Source: CNE)

Figure 5.1.2 Demand Forecast of the Three Scenarios

Table 5.1.1 Demand Forecast in GWh and Peak Demand (MW) for Reference Scenario

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)

5.1.2 Generation Expansion Plan

5.1.2.1 Conditions Applied for the Generation Expansion Plan

CNE prepared several scenarios for the generation expansion plan in order to satisfy the forecasted demand in the previous section. Individual projects for short to medium term applied for generation expansion plans and major features are as shown in Table 5.1.2. However, some of the project cost information are as of 2007, which are rather outdated. Therefore, it is necessary to update such figures as per the latest available information.

Table 5.1.2 Renewable Energy Generation Projects of Short to Medium Term

Name of the Project	Type	Power Output (MW)	Investment Cost (US$/kW)	Annual Operations Cost (US$/kW)	Expected Year of Installation
Chaparral Hydropower	Hydropower	66.1	4,997	16.9	2015
Expansion of 5 de Noviembre	Hydropower	80	2,208	16.9	2016
Cimarrón Hydropower	Hydropower	261	2,871	16.86	2022
Optimization of Ahuachapán	Geothermal	5.00	6,066	55.0	2015
Berlín Geothermal Unit 6	Geothermal	4.85	4,273	55.0	2016
Berlín Geothermal Unit 5	Geothermal	26.46	2,890	55.0	2017
Chinameca Geothermal	Geothermal	47.25	2,359	55.0	2017
Expansion of La Cabaña	Biomass	15	2,000 (*)	―	2015 (*)
Expansion of El Ángel	Biomass	15 (10 MW retire, 25 MW input)	960 (*)	―	Nov. 2011 (*)

*: According to interview results by the JICA Study Team
(Source: CNE, JICA Study Team)

Apart from the above listed projects, several other projects from state-owned companies (e.g. CEL) and private companies were considered in the formulation of the generation expansion plans. In order to formulate the generation expansion plans, least cost method was applied based on generation cost of each project. Furthermore, the candidate projects for thermal power development, as shown in Table 5.1.3, were applied to formulate the generation expansion plans.

Table 5.1.3 Candidate Thermal Power Projects to Meet Increasing Demand

Type	Output (MW)	Investment Cost (US$/kW)	Fixed O&M Cost (US$/kW-year)	Variable O&M Cost (US$/MWh)	Expected Year of Installation
Gas Turbine	100	885	9.7	2.7	2014
Diesel Power	100	1,700	47.1	7.5	2014
Natural Gas Combined Cycle	250	1,349	30.4	1.7	2016
Coal Steam Turbine	250	3,028	33.8	2.1	2016
Natural Gas Power	100	1,700	47.1	7.5	2018

(Source: CNE)

5.1.2.2 Reference Expansion Plan

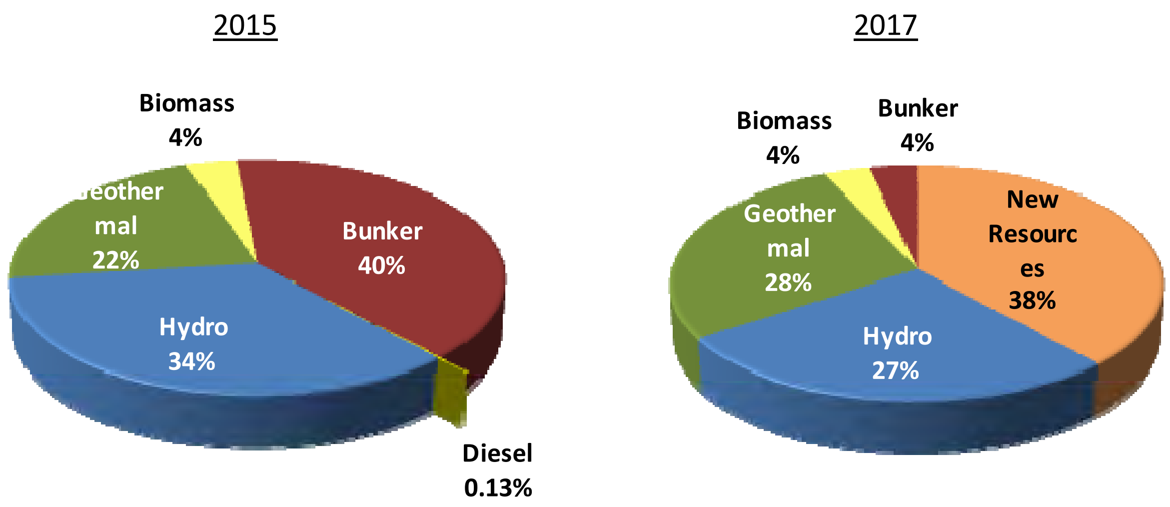
CNE conducted simulations using conditions as shown in the previous section and formulated the Indicative Generation Expansion Plan (Reference Scenario) shown in Table 5.1.4. As shown by the gray-colored cells of Table 5.1.4, the total power output of renewable energy project, including that from medium 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 5.1.4 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)

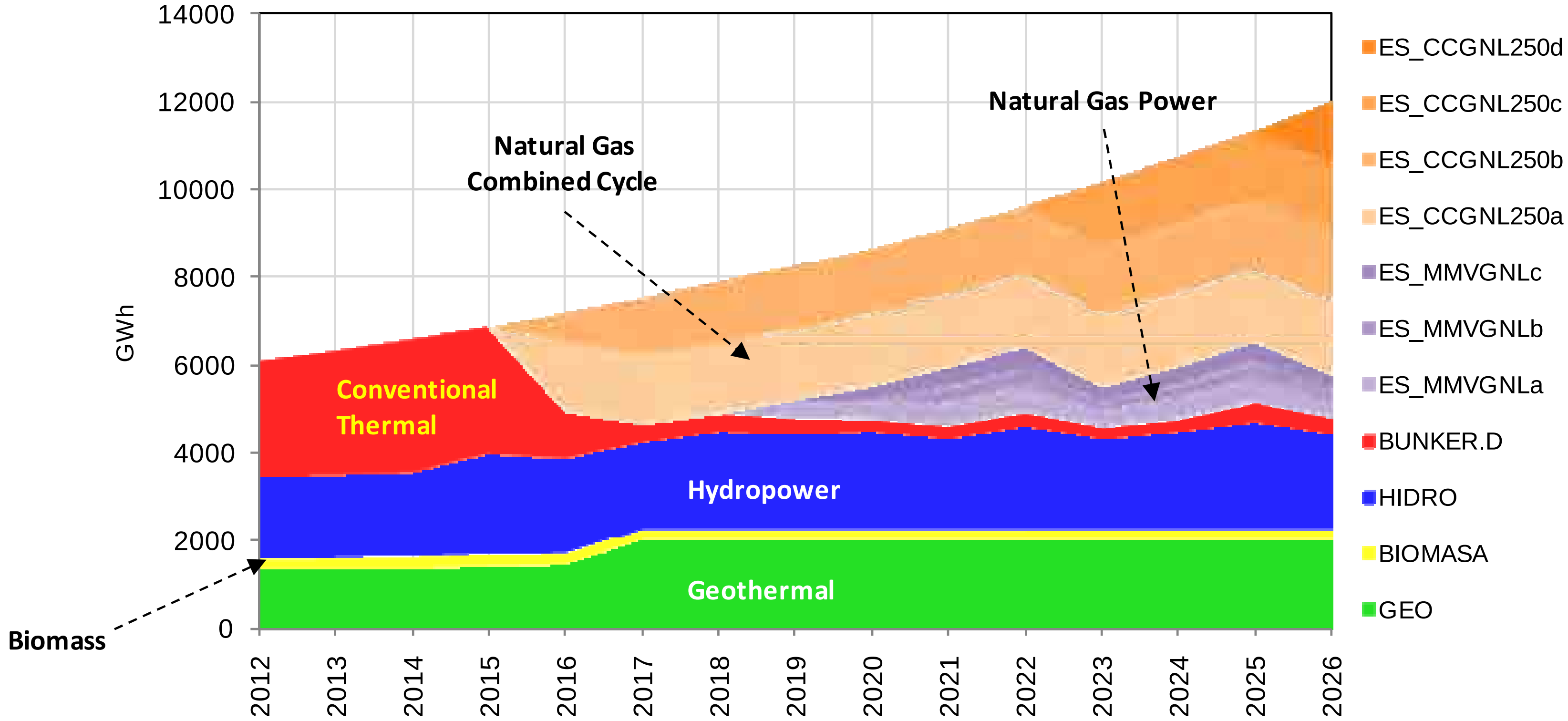
As presented in the table above, the Government of El Salvador intends to intensively promote renewable energy sources from 2011 to 2016, in order to greatly renovate the country's energy matrix. Such intention is as shown in Figure 5.1.3, which aims to decrease dependency on conventional thermal power generation.



Source: CNE

Figure 5.1.3 Change of the Energy Matrix Based on the Short-Term Generation Expansion Plan

Figure 5.1.4 shows the changes of the energy matrix in terms of the annual amount of power generation for a period of 15 years, from 2012 to 2026, which the same period as in the generation expansion plan formulation. This figure also shows drastic changes in the energy matrix between 2015 and 2017 by replacing conventional thermal power plants to renewable energy sources or natural gases in order to improve the energy matrix.

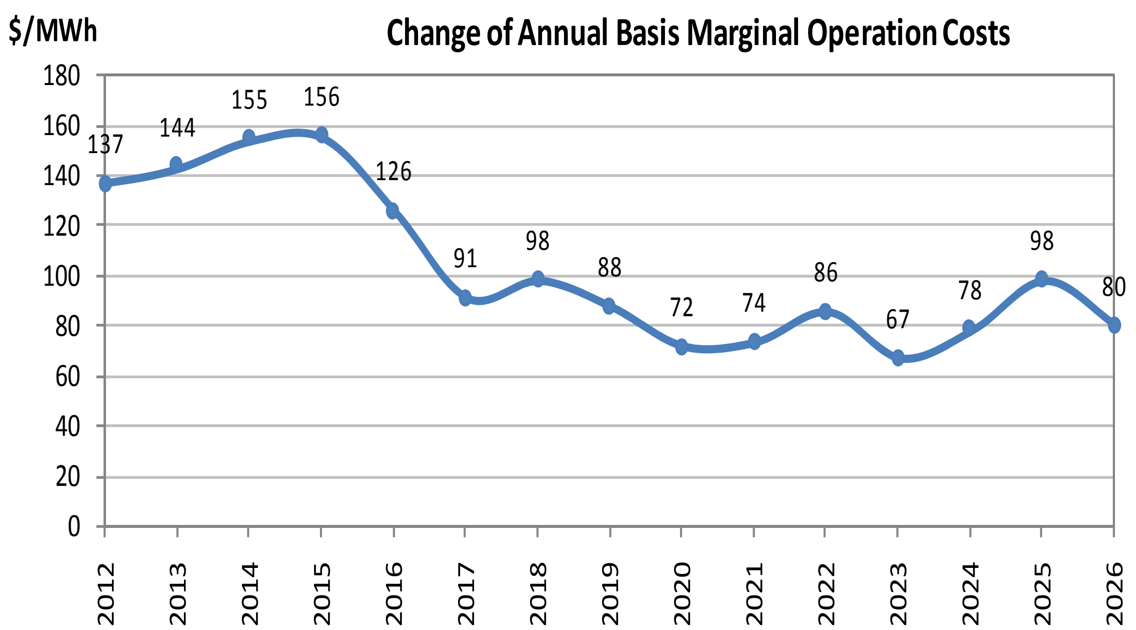


(Source: CNE)

Figure 5.1.4 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 5.1.5 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.

To achieve the above energy matrix, the Government of El Salvador decided to introduce “Long-term Contract through Bidding (maximum period: 15 years)” in August 2011. The system was introduced aiming at (1) reducing power generation costs through biddings, and (2) achieving stable power supply based on long-term contracts. In the past, long-term contracts were concluded between generation companies and distribution companies through bilateral negotiation. As a concrete plan to realize “Long-term Contract through Bidding,” “350 MW Power Procurement Plan” is in progress. Detailed information of the plan is described in sub-section 5.1.2.4.



(Source: CNE)

Figure 5.1.5 Simulation Results of Annual Marginal Operational Costs

5.1.2.3 Other Scenarios for the Generation Expansion Plan

CNE calculated marginal operational costs for six other scenarios based on the Reference Expansion Scenario. According to the simulation results as shown in Table 5.1.5, the Renewable Energy Scenario is quite competitive in terms of marginal cost. Therefore, it is possible to implement this scenario. However, according to CNE, the Renewable Energy Scenario only takes the development costs into account for calculations. Operation and maintenance costs are not considered as the detailed information is not available at the moment. Therefore, it is necessary to compare the marginal operational costs by applying actual possible operation and maintenance costs.

Table 5.1.5 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 5.1.6 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. In the study, analyses will be made to formulate the master plan by focusing two representative scenarios of (1) the Reference Scenario described in sub-section 5.1.2.2 and (2) the Renewable Energy Scenario. For the analysis, the latest development plans prepared by generating companies such as CEL and LaGeo will be referred to.

Table 5.1.6 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)

5.1.2.4 350 MW Power Procurement Plan

To realize generation expansion plans given in sub-sections 5.1.2.2 and 5.1.2.3, the Government of El Salvador is making plans to procure power sources amounting 350 MW in total (hereinafter the plan is called as "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 and supervised by SIGET. 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). The 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 Preliminary Examination on Potential for Renewable Energy Introduction

As described in sub-section 5.1, CNE prepared plural scenarios for generation expansion plan. Of the scenarios, the target directions for the study are “Reference Scenario” and “Renewable Energy Scenario.” Based on the collected material and information (described in Chapter 4) during the initial stage of the study (information collection and examination stage), the above two scenario were reviewed. Both of above scenarios are based on the existing plans prepared by generating companies. Therefore, these scenarios can be regarded as appropriate.

There are some possibilities of delay in the timing of installation of individual projects due to current social and economic situations as some of the planned projects are of private companies. In such cases, it is necessary to adjust the details of the scenarios; however, as a long-term plan for the next 15 years, these scenarios can be regarded as appropriate.

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

Of the two scenarios described in the previous section, namely “Reference” and “Renewable Energy” scenarios, their consistency with the power development plan is examined.

“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. In the reference scenario, the ratio of renewable energy sources including medium to large hydro, is less than 20%.

“Renewable Energy Scenario” consists of 44% of renewable energy sources (including medium to large hydro) and 56% of natural gas thermal power. Due to the high ratio of renewable energy sources with low plant factors such as solar PV and wind, it is important to confirm the power supply capacity by examining expected plant factors for relevant energy sources at the time of introduction. 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.

For formulation of the master plan described in Chapter 10, the above consistency with the power development plan will be carefully examined.

Chapter 6 Review of Regulations Related to Transmission and Distribution Networks

Chapter 6 presents a review of the laws, regulations and standards on electric power transmission and distribution networks related to renewable energy. Firstly, the outlines of the laws, regulations, and standards related to transmission and distribution networks are presented. Secondly, the problems encountered in the laws, regulations and standards for electrical connection of generators running on renewable energy to the transmission and distribution networks are presented. Also, connection problems of power generation projects running on renewable energies are explained and grouped into the following three categories:

Connection of small hydropower,

Connection of unstable energy sources such as solar PV and wind, and

Connection of other renewable energy sources such as geothermal and biomass.

Furthermore, demarcation of functions and areas related to generation, transmission and distribution, the transmission and distribution electrical losses, and the countermeasures reducing these losses are explained in accordance with requested from CNE.

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: laws and regulations of overall electric sector, standards for electrical interconnection, standards for operations, and specifications of electrical equipment.

Table 6.1.1 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 interconnection to 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 Operation 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)

The following are important aspects of laws, regulations, and standards used in El Salvador for the transmission and distribution of electric power.

6.1.1 General Electricity Law (Legislative Decree No. 843, 1996)

The General Electricity Law (GEL) was created to regulate private or public activities related to the generation, transmission, distribution and marketing of electric power in El Salvador. Some of the most important issues related to transmission and distribution networks are the following:

A transmission network is defined as the integrated set of equipment for the transmission of electric power for voltages greater than or equal to 115 kV. A distribution network is defined as the set of equipment for the transmission of electric power for voltages lower than 115 kV. Interconnection is defined as the link that allows two operators (transmitter and distributor, or among distributors) to transfer electric power between their facilities.

Generating entities are allowed free access to the transmission and distribution facilities, with no limitations other than those specified by law.

Transmitters and distributors will be forced to allow the interconnection of their facilities and the use thereof for the transport of electricity, except when it represents a hazard to the safety or operation of the system, the facilities, or people.

The Transactions Unit (UT in Spanish) is responsible for operating and maintaining the security of the transmission system, as well as for ensuring the minimum quality standards for transmission services.

It is important to point out that the transmission network belongs to the Transmission Company of El Salvador (ETESAL in Spanish), which also performs the physical maintenance of such. Each distribution company also manages its own networks and reports the technical aspects of its operation to SIGET.

6.1.2 Regulation of the GEL (Executive Decree No. 70, 1997)

The regulations of the GEL sets forth the necessary procedures to comply with the provisions made by the GEL and the General Superintendence for Electricity and Telecommunications (SIGET in Spanish), the entity responsible for verifying its compliance. Some of the most important issues related to transmission and distribution networks are the following:

The operating decisions taken by the UT in generation and transmission systems, as well as its power to control generation units and transmission facilities, aim to guarantee the security of the system, as well as ensure that the minimum quality standards for all services and supplies are met.

The UT will plan and coordinate the dispatch of generating units and the operations of the transmission system facilities in order to meet the demand with the lowest possible expected rationing and operation costs, subject to compliance with the standards of service quality and safety set forth in the Regulation of Transmission System Operation and Wholesale Market based on Production Costs.

The electricity distribution activities include the provision, installation, maintenance, and reading of measuring equipment.

The expansions or extensions of the transmission and distribution systems carried out by the operators (transmitter and distributor), may be carried out without the intervention of SIGET, provided that they comply with the standards accepted by this entity.

6.1.3 Technical Standards for Electrical Interconnection and End User Access to the Transmission Network (Agreement No. 30-E SIGET-2011, January 2011)

These technical standards aim to determine 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 guarantee the quality and safety of the system. Basically, this rule is applied in the prefeasibility and feasibility study stages for any project involving the interconnection of power grids. Some of the most important issues related to transmission and distribution networks are the following:

In order to perform the interconnection, the respective application must be submitted to the transmitter or distributor. This application describes the technical characteristics of the equipment or facilities that will be interconnected, the interconnection point, the maximum power that will be demanded or injected based on the type of interconnection, and the expected date for the commissioning of the interconnection service, in addition to the requirements established in Titles III, IV, V and VII of the standards.

Titles III, IV, V and VII set forth the requirements for the interconnection to transmission and distribution facilities, regarding the feasibility, interconnection request, necessary studies, and construction and operation input, among others.

Those involved in the interconnection will be responsible for the operation and maintenance of the facilities they own and which are used for that purpose, unless mutually agreed otherwise as specified in the interconnection agreement.

6.1.4 Regulation of Transmission System Operation and Wholesale Market Based on Production Costs (SIGET Agreement No. 335-E-2011, July 2011)

The Regulation of Transmission System Operation and Wholesale Market based on Production Costs (ROBCP in Spanish) contains the standards and procedures for the operations of transmission systems, and for managing the transactions of the wholesale electricity market in El Salvador. The annexes in ROBCP contain a set of technical standards, methods and/or procedures developed by the UT to implement the general criteria and procedures defined in ROBCP. Some of the most important annexes related to transmission and distribution networks are the following:

Annex 10 (Operation in Real Time) defines the standards and procedures for real time operations that market participants (e.g., distributors and transmitters) must comply with. It also defines the general guidelines with which the UT will restore the transmission system in the fastest and most efficient way possible, when faced with zero voltage or a total collapse, all the while taking into account all safety criteria.

Annex 12 (Quality and Operational Safety Standards) establishes the minimum performance standards for the quality and safety of the transmission system required for both normal and emergency operations. The following technical aspects are described therein: frequency regulation, voltage regulation, harmonic distortion, voltage fluctuations, protective equipment, load-shedding scheme (for low frequency, low voltage and overloads), system operating parameters, and the reliability of the generation and transmission system, among others.

6.1.5 Standards for the Quality of Service of Distribution Systems (SIGET Agreement No. 192-E-2004, December 2004)

The Standards for the Quality of Service of Distribution Systems (NCSSD in Spanish) aim to regulate the ratings and benchmarks used to assess the quality with which electricity distribution companies provide electricity services to the users of the distribution network, the allowable tolerances, control methods, and compensation for the following parameters, which are also considered and included in the rate:

The quality of the supply or service provided, which is mainly related to service interruptions,

The quality of the electricity being supplied, which involves the following: levels of voltage, disturbances in the voltage wave (flickering and harmonic voltages), and

The commercial service quality, which is related to the following: customer service, customer service channels, accuracy of measuring equipment.

The latest update made to the standards is shown in SIGET Agreement No. 320-E-2011, which amends the NCSSD, as well as the methodology for monitoring the quality of the electricity.

6.1.6 National Electrical Code of the United States of America (NEC), Spanish Edition, 2008 (NFPA, 2008)

In SIGET Agreement No. 294-E-2011 dated June 22, 2011, it was set forth that the 2008 Spanish edition of the NEC was to be adopted as a reference. The said code was published by the National Fire Protection Association (NFPA) as a technical standard for end user electrical installations.

The 2008 NEC 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, including improvements and all provisional or temporary upgrades and installations. It also contains the safety and quality requirements for all natural or legal persons who design and build civil infrastructure works related to buildings, houses, sewers, roadways, etc.

6.1.7 Standards 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)

This document aims to regulate the construction of 46 kV, 23 kV, 13.2 kV, 4.16 kV and 240/120 V electrical distribution networks. It also aims to improve the construction quality of contractors, performances of distributors and institutions that are generally associated with this sector.

All designers of distribution networks before the design stage have to consult the expansion plan of distribution networks where they intend to connect.

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

The grid-connection issues of power generation projects based on renewable energies are explained into the following three categories;

Issues of small hydropower introduction,

Issues of unstable power source introduction (such as solar PV and wind), and

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 on the introduction of SHPs with capacity up to 20 MW are mentioned below. Especially, permission for grid connection and issues in normal and abnormal operations are explained.

6.2.1.1 Permission for Grid Connection

SHP projects up to 20 MW are commonly connected to the transmission and distribution networks of medium voltage (MV) levels of 13.2 kV, 23 kV and 46 kV in El Salvador[1]. The technical standards of interconnection[2] of SIGET allow connection to any of the networks (transmission and distribution). In case small hydropower generation up to 20 MW is connected to the distribution networks, the distribution company can modify and adapt their facilities such as feeders, transformers or protection devices prior to the connection.

In conclusion, there are no problems on the permission for grid connection in the current regulations.

6.2.1.2 Normal Operations

A. Voltage Regulations

The technologies of the generating units of SHP are classified as synchronous generators and asynchronous (or induction) generators. Synchronous generators have the advantage of adequate voltage control through their excitation systems by injection and absorption of the reactive power. In case synchronous generators used in distributed generation[3] voltage control is not performed, only constant power factor control is performed. On the other hand, induction generators need capacitors (fixed or switched) for starting operations because induction generators consume reactive power, and do not perform voltage regulation.

SIGET's technical standards on quality[4] define the maximum voltage deviations in MV to be ±6% for urban zone, ±7% for rural zone and ±8.5% for isolated system, in order to avoid damage to equipment.

In order to comply with SIGET's standards above, it is necessary for SHP generators to actively regulate the voltage at the connection point (point of common coupling: PCC).

[1] The distribution networks in El Salvador include electrical facilities of voltage levels from 46 kV to 120/240 V as distribution lines and transformers. The transmission network includes 230 kV and 115 kV transmission lines, power transformers at 115/46 kV, 115/23 kV, and 115/34.5 kV.

[2] Technical Standards for Electrical Interconnection and End User Access to the Transmission Network (Agreement No. 30-E SIGET-2011, January 2011)

[3] Distributed generation is commonly defined as one that is directly connected to distribution networks, very close in proximity to end users, and has no centralized dispatch.

[4] Standards for the Quality of Service of Distribution Systems (SIGET Agreement No. 192-E-2004, December 2004).

B. 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 (capacity) of generation. In these cases, there is an increased power flow in existing power lines which were not designed for such power capacity, and require changes in some electrical facilities (increase line capacity, adjustment of protective equipment, among others).

Therefore it is necessary to define regulations on the size of SHPs to be connected to distribution networks in order to avoid the increase of electrical loss.

6.2.1.3 Abnormal Operations

A. Islanding Operations

Generation systems could possibly be operated with islanding operations in case of isolated systems in rural areas (off-grid). However in the case of distributed generation operations, it is prohibited to adopt islanding operations (e.g., after a failure) intentionally or unintentionally.

There are no regulations regarding islanding operations of generators connected to distribution networks. It is necessary to establish such regulations.

B. Protection Schemes

SHPs have basic protection schemes related to minimum and maximum voltages, minimum and maximum frequencies, and over current, among others.

The technical standards on the interconnection of SIGET state 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 SHPs which are connected to the distribution networks.

6.2.1.4 Power Quality

A. Voltage Flicker

There have been no reported problems on voltage flicker caused by SHPs.

B. Harmonic Distortion

There have been no reported problems on harmonic distortion caused by SHPs.

C. Voltage Fluctuation (Sag and Swell)

There have been no reported problems on voltage fluctuation caused by SHPs.

6.2.1.5 Other Issues

A. Maintenance

Synchronous generators require more complex control than induction generators, both for synchronization with the transmission and distribution systems, and for controlling excitation systems.

The technical standards on the interconnection of SIGET state that it is necessary to do maintenance activities to meet the technical and safety standards.

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.

6.2.2.1 Permission for Grid Connection

Small solar PV energy projects are commonly connected to the distribution networks of low voltage (LV) levels (less than 600 V) in El Salvador[5]. Generally, solar PV projects are connected to distribution networks of MV levels of 13.2 kV, 23 kV and 46 kV. On the other hand, there are currently no wind energy projects connected to the electric system in El Salvador, but the connection to the distribution networks of MV levels of 13.2 kV, 23 kV and 46 kV is expected.

The technical standards on the interconnection of SIGET allow connection to any of the networks (transmission and distribution), and when solar PV or wind generators (up to 20 MW) are connected to the distribution networks, the distributor can modify and adapt their facilities for connection.

In conclusion, there are no problems on the permission for grid connection in the current regulations.

6.2.2.2 Normal Operations

A. Voltage Regulations

The technologies used in generating units of solar PV energy are based on static inverters. Such technologies are programmed to produce only active power while interconnected and it results in a unity power factor. Inverter technology has evolved to insulated gate bipolar transistor (IGBT) switching schemes which are able to control power factor and limit harmonics.

The technologies of the generating units involved in wind energy are classified as static inverters, and synchronous and asynchronous (or induction) generators.

[5] National Electrical Code of the United States of America (NEC), Spanish Edition, 2008 (NFPA 2008). NEC 2008 has been defined as technical standard applicable to electrical facilities in El Salvador.

SIGET's technical standards define the maximum voltage deviations in MV to be ±6% for urban zone, ±7% for rural zone and ±8.5% for isolated system, and in LV to be ±7% for urban zone, ±8% for rural zone and ±8.5% for isolated system, in order to avoid damages of equipment.

In order to comply with SIGET's standards above, it is necessary for solar PV and wind generators to actively regulate the voltage at the connection point (PCC).

B. Electrical Losses

In general, solar PV and wind energy generators can reduce electrical losses in neighboring distribution networks.

Solar PV and wind generators used as distributed generation could increase electrical losses depending on their location and size of generation. Similar to the case of SHP, some modification of electrical facilities (increasing line capacity, adjustment of protective equipment, etc.) are required.

Therefore it is necessary to define regulations on the size of solar PV and wind generators to be connected to distribution networks in order to avoid the increase of electrical loss.

6.2.2.3 Abnormal Operations

A. Islanding Operations

In case of distributed generation operations, it is prohibited to adopt islanding operations (e.g., after a failure) intentionally or unintentionally.

There are no regulations regarding islanding operations of generators connected to distribution networks. It is necessary to establish such regulations.

B. Protection Schemes

Solar PV generators have basic protection schemes related to minimum and maximum voltages, minimum and maximum frequencies, and inverse power, among others[6]. Wind generators have basic protection schemes similar to solar PV generators, but it could necessarily be additional protection for asynchronous machines.

The technical standards on the interconnection of SIGET state 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 solar PV and wind generators that are connected to distribution networks.

6 Guidelines for interconnection of Solar PV generating equipment in South America (2011)

6.2.2.4 Power Quality

A. Voltage Flicker

In distribution networks, the most common cause of voltage flicker[7] is a rapid variation of load current in solar PV and wind generators. The main causes of voltage flicker in distribution networks are starting of a large generation unit, sudden and large variations of the output of generation unit, and interactions between generators.

In particular, it has been observed in wind generators that the potential causes of voltage flicker are wind turbine variations or power output variation. However, the design of modern wind turbines has been changed such that large variations of output power can be effectively avoided (variable speed) within a short period of time.

SIGET's technical standards on quality define the maximum short time flicker perceptibility (Pst) as 1 for MV and LV buses or nodes.

There are technical standards for voltage flicker in the current regulations, but it is necessary to define the responsibilities for flicker emission in LV connections.

B. Harmonic Distortion

In the past, 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 (e.g., 25th, 35th, and higher).

SIGET's technical standards on quality define the maximum total harmonic distortion of voltage and current in buses or nodes as 8% and 20%, respectively.

There are technical standards for harmonic distortion in the current regulations, but it is necessary to review the current limits of LV connections in order to avoid damage in the equipment of end user facilities.

C. Voltage Fluctuation (Sag and Swell)

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 a technically advanced solution to compensate voltage sag in distribution systems.

There are no regulations regarding the voltage fluctuation of generators connected to distribution networks. It is necessary to establish such regulations.

[7] Voltage flicker is an impression of unsteadiness of visual sensation induced by a light stimulus.

6.2.2.5 Other Issues

A. Maintenance

Low maintenance can be applied to solar PV panels and asynchronous (induction) machines of wind generators.

SIGET's technical standards on interconnection state that it is necessary to do maintenance activities to meet the technical and safety standards.

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

Geothermal generation in El Salvador is classified as conventional generation since it has a significant presence in the current power dispatch of wholesale market. Other renewable power sources such as biomass and biogas have been developed in El Salvador that depend on resource availability, for example, bagasse for biomass energy depends on harvest season of sugar cane.

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

6.2.3.1 Permission for Grid Connection

In case of geothermal generation, it is considered to be directly connected to the transmission networks of 115 kV, except binary generation which has small capacity less than 5 MW.

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 of MV levels of 13.2 kV, 23 kV and 46 kV.

SIGET's technical standards on interconnection allow connection to any of the networks (transmission and distribution), and when small generators (up to 20 MW) are connected to distribution networks, the distributor can modify and adapt their facilities for connection.

In conclusion, there are no problems on permission for grid connection in the current regulations.

6.2.3.2 Normal Operations

A. Voltage Regulations

Geothermal generation uses synchronous generators which provide adequate tension control. Biomass and biogas systems may use asynchronous or synchronous generators, depending on the generation capacity.

SIGET's technical standards on quality define the maximum voltages deviations in MV to be ±6% for urban zone, ±7% for rural zone and ±8.5% for isolated system, in order to avoid damage to equipment.

In order to comply with SIGET's standards above, it is necessary for biomass and biogas generators to actively regulate the voltage at the connection point.

B. Electrical Losses

In general, geothermal generation can reduce electrical losses in neighboring transmission and distribution networks. Biomass and biogas generation connected in distribution networks could increase electrical losses depending on their location and size of generation. Similar to the case of SHP, some modification of electrical facilities (increasing line capacity, adjustment of protective equipment, etc.) are required.

Therefore, it is necessary to define regulations on the size of biomass and biogas to be connected to distribution networks in order to avoid the increase of electrical loss.

6.2.3.3 Abnormal Operations

A. Islanding Operations

Generation systems could possibly be operated with islanding operations in case of isolated systems in rural areas (off-grid). However, in the case of distributed generation operations in biomass and biogas projects, it is prohibited to adopt islanding operations (e.g., after a failure) intentionally or unintentionally.

There are no regulations regarding islanding operations of generators connected to distribution networks. It is necessary to establish such regulations.

B. Protection Schemes

Geothermal power generation has similar protective devices of high power generators. The generation of biomass and biogas have basic protection schemes for the maximum and minimum voltage, maximum and minimum frequency, among others.

SIGET’s technical standards on interconnection state 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 biomass and biogas generation that are connected to distribution networks.

6.2.3.4 Power Quality

A. Voltage Flicker

There have been no reported relevant problems on voltage flicker caused by geothermal, biomass and biogas.

B. Harmonic Distortion

There have been no reported relevant problems on harmonic distortion caused by geothermal, biomass and biogas.

C. Voltage Fluctuation (Sag and Swell)

There have been no reported relevant problems on voltage fluctuation caused by geothermal, biomass and biogas.

6.2.3.5 Other Issues

A. Maintenance

In biomass and biogas generation, synchronous generators require more complex control than induction generators, both for synchronization with transmission and distribution systems and for controlling excitation systems.

SIGET's technical standards on interconnection state that it is necessary to do maintenance activities to meet the technical and safety standards.

6.3 Demarcation of functions and areas of Generation, Transmission and Distribution

The Electricity Law (Legislative Decree No.843, 1996) rules the activities for electricity's generation, transmission, distribution and marketing. Some concepts defined in this law are listed below:

High Voltage (HV): the voltage level is equal or higher than 115 kV;

Low Voltage (LV): the voltage level is less than 115 kV;

Connection: is the link that allows a final user to receive electrical energy from a transmission or distribution network;

Final User: is who purchases electricity for their own use

Transmission Network: is the integrated set of power transportation facilities in HV;

Distribution Network: is the integrated set of power transportation facilities in LV.

Also, the law allows generation utilities unrestricted access to transmission and distribution facilities. In this regard in Section III (Interconnection) notes that transmitters and distributors will be obliged to allow the interconnection and use of their facilities for the electricity transportation, except when it represents a danger to the operation, system's security of facilities and safety of people.

In general, generation projects based on renewable energies are connected to the transmission and distribution network through the point of common coupling (PCC). Figure 6.3.1 below shows the main components of an electrical connection for renewable energy generation projects.

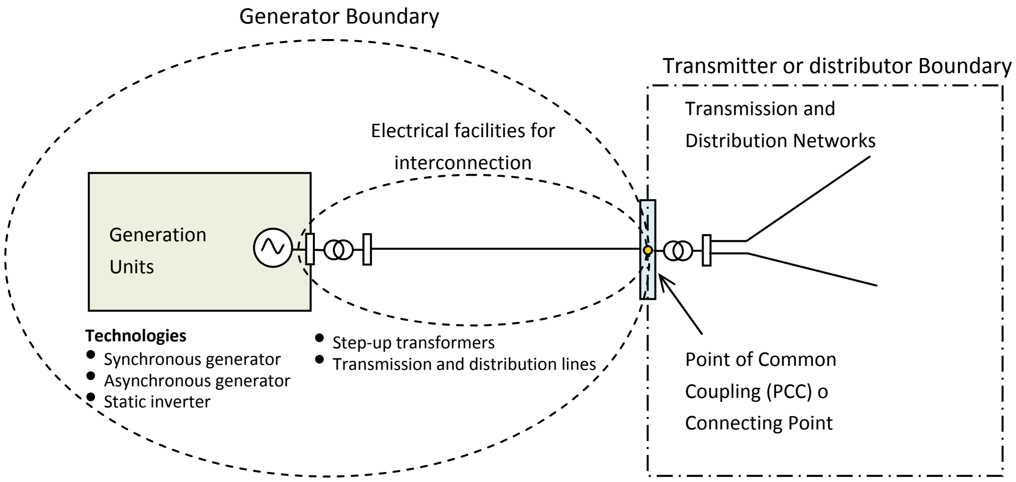


Figure 6.3.1 Relationship among Transmitter, Distributor and Generator

The demarcation of the areas corresponding to the generator, transmitter and distributor are shown in the above figure. For connection to the transmission grid, the generator asks the transmitter to perform the maintenance of these facilities. For connection to distribution networks, the generator is assumed to perform the maintenance of facilities. In transmission and distribution systems, the generator is an owner of the interconnection facilities.

The functions of generators connected to transmission and distribution networks are explained as follows.

6.3.1 Generator connected to the Transmission Network

There is only one transmission company named ETESAL, who is responsible for the transmission network. The generators are interconnected to the transmission network from the following two cases:

Case I: Generator connected in 115 kV

Case II: Generator connected to a transmission substation in 23 kV or 46 kV.

Figure 6.3.2 shows the technical characteristics for the interconnection of a generator to the transmission network.

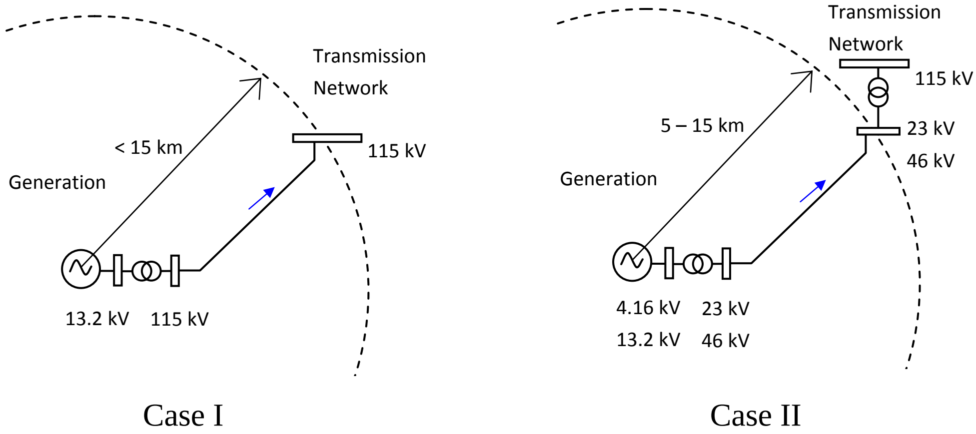


Figure 6.3.2 Generator interconnected to the Transmission Network

Case I corresponds to large generation projects larger than 20 MW or so, executed by hydroelectric company like CEL, geothermal company like La Geo and thermal companies like Duke Energy, Nejapa Power and INE. Only LaGeo projects and CEL may be considered based on renewable resources, but in the case of CEL these projects are not considered small hydro (up to 20 MW). The projects are implemented by setting the transmission substation 115 kV should be near the power house. In this case, transmission line 115 kV project in El Salvador is approximately less than 15 km.

Case II corresponds to generation projects above 5 MW approximately, executed by biomass companies like CASSA, El Angel and La cabaña. These projects are connected to transmission substations, but in the buses of 46 kV or 23 kV. The length of project lines varies from 5 to 15 km, depending on the location of the primary resource.

According to the "Regulation for Transmission System Operation and Wholesale Market based on production cost" (SIGET Agreement No.335, August 2011), in both cases, the generator can participate in the wholesale market, primarily because they are connected to transmission networks and have an installed capacity greater than 5 MW.

According to the "Electrical Interconnection Technical Standards and Final User Access to the Transmission network" (Agreement SIGET No.30, January 2011), Title IV sets out the procedures, requirements and responsibilities for the interconnection of a generator to the transmitter's facilities.

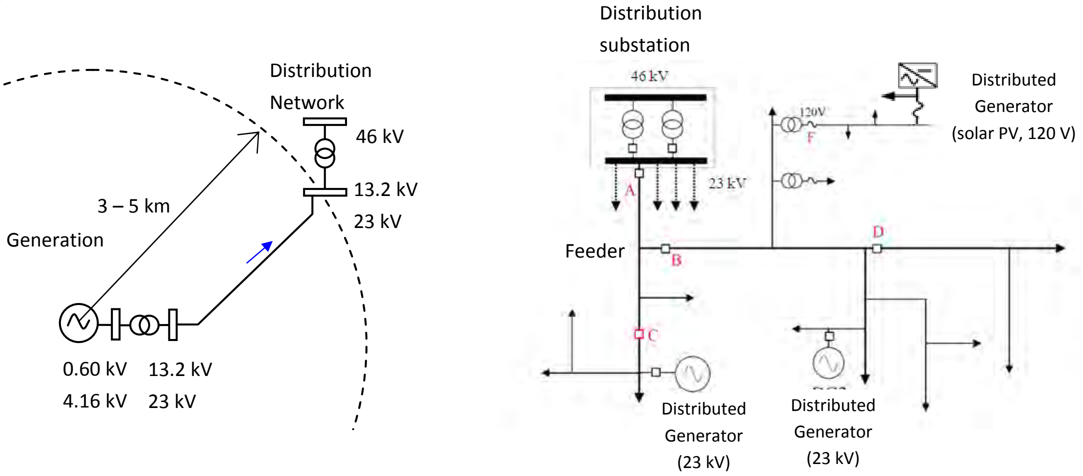
6.3.2 Generator connected to distribution networks

We have the following distribution companies in El Salvador: CAESS, CLESA, EEO, DEUSEM, DELSUR, EDESAL, among others, and the first four belong to the company AES. The generators are interconnected to the distribution network from the following two cases:

Case I: Generator connected to a distribution substation in 13.2 kV or 23 kV.

Case II: Generator connected to the primary or secondary distribution networks.

Figure 6.3.3 shows the technical characteristics for an interconnection of a generator to the distribution network.



Case I Case II

Figure 6.3.3 Generator interconnected to the Distribution Substations

Case I corresponds to generation projects under 20 MW approximately, implemented by various hydroelectric companies such as CECSA, Papaloate Hydro, Hydro Sensunapan, among others. In this case the projects are mostly small hydro and are always connected to the nearest distribution substation voltage levels 23 kV or 13.2 kV, this because of economic reasons, the generator may choose to connect to distribution networks instead of connecting to the transmission. The length of the lines of the projects ranges from 3 to 5 km, depending on the location of the primary resource.

Case II corresponds to distributed generation projects, this means generators connected to the distribution networks in the feeders of primary and secondary networks. Generators connected to the primary network in 13.2 kV or 23 kV can consider renewable energy sources like wind and solar PV. Generators connected to the secondary network in 120 V may consider solar PV and for its connection static converters are used.

According to the "Regulation for Transmission System Operation and Wholesale Market based on cost of production" (SIGET Agreement No.335, August 2011), only Case I could participate in the wholesale market for this it must ensure a power output greater than 5 MW still connected to the distribution network. The remaining generators participate in the retail market and establish supply contracts in accordance with "Regulations Applicable to the Activities of Power Marketing" (Executive Decree no.90, November 2000).

According to the "Electrical Interconnection Technical Standards and Final User Access to the Transmission Network" (Agreement SIGET No.30, January 2011), Title III establishes the procedures, requirements and responsibilities for the interconnection of a generator to the distribution facilities.

6.4 Transmission and Distribution Loss

According to request of CNE, an examination of the current status of the transmission and distribution losses is made. Furthermore, measures to reduce the transmission and distribution losses are proposed.

The electrical losses are divided into: power and energy. In practice, the utilities only record energy loss and this kind of information will be used below.

6.4.1 Current Status

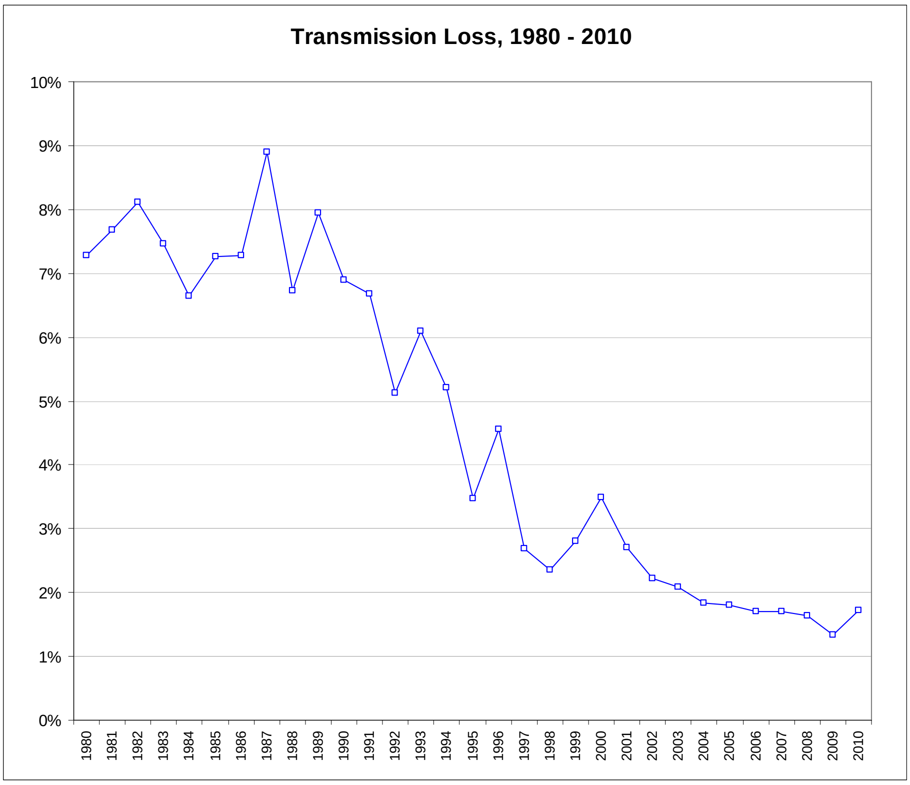
6.4.1.1 Transmission Loss

Transmission losses are related to losses due to heating of the line conductors and transformer parts of the transmission network.

The transmission losses are determined by the SIGET from the information recorded by the meters of energy companies. These losses are equal to the difference between the total injected energy (generation and energy import from SIEPAC[8]) minus the total absorbed energy (loads and energy export to SIEPAC) in the transmission network.

Figure 6.4.1 shows the annual losses of the transmission network in El Salvador for the period 1980-2010. The percentage of transmission losses are calculated with respect to the total injection to the transmission network, as shown in the table.

[8] SIEPAC is a planned system used for the electrical interconnection of the six Central American countries (Panama, Costa Rica, Honduras, Nicaragua, El Salvador and Guatemala). The electrical facilities of SIEPAC include transmission lines in 230 kV with total length of 1800 km.



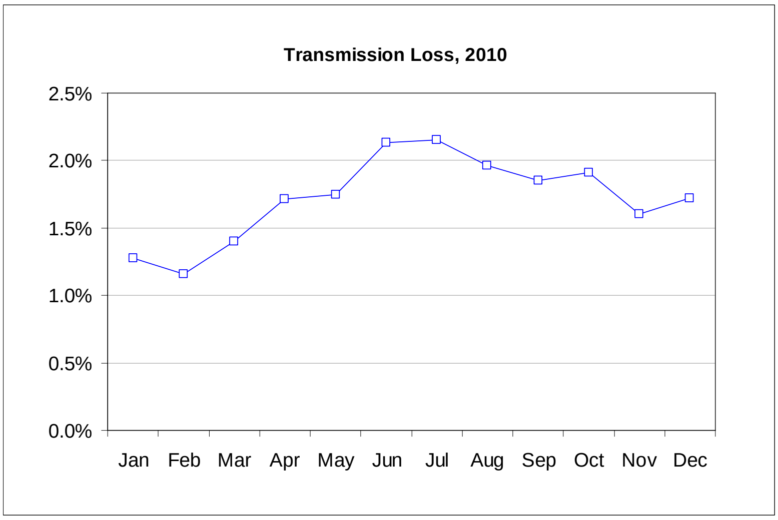
Years	Injections to Transmission System (GWh)	Transmission Loss	
		(GWh)	(%)
1980	1,427.6	104.0	7.28%
1981	1,355.9	104.1	7.68%
1982	1,375.7	111.5	8.11%
1983	1,485.8	110.9	7.46%
1984	1,559.1	103.5	6.64%
1985	1,650.5	119.9	7.26%
1986	1,711.5	124.6	7.28%
1987	1,843.0	164.1	8.90%
1988	1,964.4	132.3	6.73%
1989	1,979.4	157.1	7.94%
1990	2,165.7	149.2	6.89%
1991	2,235.6	149.4	6.68%
1992	2,369.1	121.3	5.12%
1993	2,797.4	170.6	6.10%
1994	3,064.0	159.5	5.20%
1995	3,235.5	112.3	3.47%
1996	3,361.3	152.9	4.55%
1997	3,636.3	97.9	2.69%
1998	3,775.2	88.8	2.35%
1999	3,888.5	108.9	2.80%
2000	4,073.2	142.0	3.49%
2001	3,955.5	106.8	2.70%
2002	4,249.4	94.7	2.23%
2003	4,403.4	91.8	2.08%
2004	4,538.2	83.6	1.84%
2005	4,765.0	85.8	1.80%
2006	5,196.7	88.2	1.70%
2007	5,352.6	91.0	1.70%
2008	5,566.0	90.8	1.63%
2009	5,574.8	74.9	1.34%
2010	5,735.7	98.8	1.72%

(Source: Electricity Statistics Bulletin N° 12, 2010 (SIGET, June 2011))

Figure 6.4.1 Annual Losses of Transmission Network, 1980 – 2010

The maximum and minimum transmission losses were 8.9% (1987) and 1.34% (2009), respectively. The transmission losses decreased after this period and currently are below 2% because after the civil war were made to the maintenance works and reinforcement necessary in transmission network.

Figure 6.4.2 shows the monthly losses of the transmission network in El Salvador in 2010.



Month 2010	Injections to Transmission System (GWh)	Transmission Loss	
		(GWh)	(%)
Jan	461.2	5.9	1.28%
Feb	449.3	5.2	1.16%
Mar	507.8	7.1	1.40%
Apr	489.2	8.4	1.72%
May	498.7	8.7	1.74%
Jun	472.9	10.1	2.14%
Jul	487.9	10.5	2.15%
Aug	473.9	9.3	1.96%
Sep	469.8	8.7	1.85%
Oct	491.7	9.4	1.91%
Nov	467.9	7.5	1.60%
Dec	465.5	8	1.72%
TOTAL	5735.8	98.8	1.72%

(Source: Electricity Statistics Bulletin N° 12, 2010 (SIGET, June 2011))

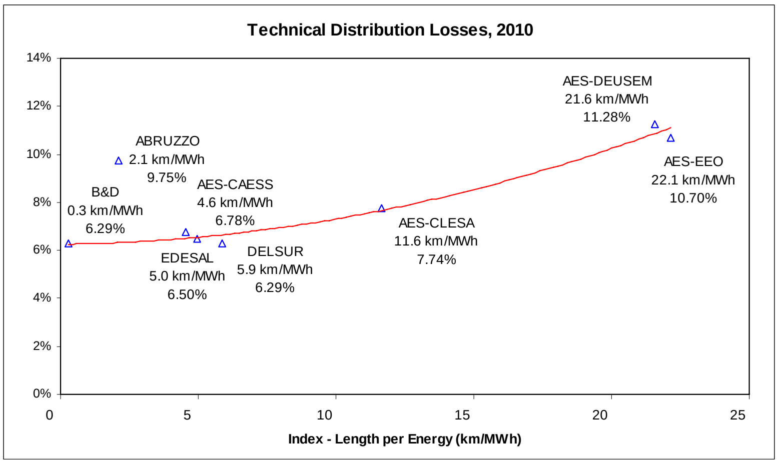
Figure 6.4.2 Monthly Losses from the Transmission Network, 2010

The transmission losses were maximum and minimum 2.15% (July) and 1.16% (February), respectively, which are calculated with respect to the total energy injection. In the rainy season (May to November) hydroelectric generators must operate and, consequently, the transmission losses increase because the energy travels long distances through transmission lines from hydroelectric generators to the loads. In the dry season thermal generators must operate and, consequently, transmission losses are reduced because these generators are commonly located near the loads, so the energy travels short distances.

6.4.1.2 Distribution losses

The energy losses of the distribution network are composed of: technical and non technical losses. Distribution technical losses are related to transport of electric energy and these include: loss of the conductor, losses of transformers coils, among others. Non-technical distribution losses are caused by human error, intentional or not, and includes power theft, errors in the measurement of energy, among others.

Figure 6.4.3 shows the technical losses for each distribution company in El Salvador in 2010 versus a performance index defined as the total length of distribution networks (primary and secondary networks) per total energy sales.



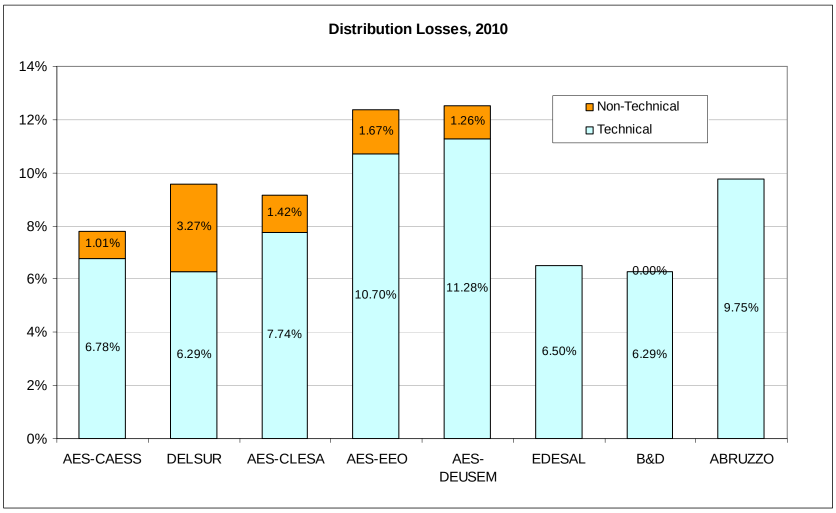
Utility	Total Length (km)	Total Energy (MWh)	Technical Distribution Losses (%)
AES-CAESS	9157	2,005,826	6.78%
DELSUR	6612	1,124,908	6.29%
AES-CLESA	9311	799,745	7.74%
AES-EEO	10562	477,110	10.70%
AES-DEUSEM	2362	109,599	11.28%
EDESAL	145	29,134	6.50%
B&D	4	14,686	6.29%
ABRUZZO	4	1,902	9.75%

(Source: Electricity Statistics Bulletin N° 12, 2010 (SIGET, June 2011)

Figure 6.4.3 Technical Energy losses of the Distribution Network, 2010

The indexes for AES-EEO (departments of San Miguel, Morazan, La Union and Northern Usulutan) and AES-DEUSEM (central and southern Usulatan department) have high values because these companies cover rural areas. The indexes of DELSUR and AES-CAESS have low values because these companies cover urban areas of the San Salvador department. B&D and ABRUZZO distribution companies are small (about 4 km each) and its indexes have low values. According to the figure above, the technical loss increases when the index value increases, that is, higher technical losses are expected in rural areas.

Figure 6.4.4 shows the technical and non technical losses for each distribution company in El Salvador in 2010.



Utility	Total Distribution Losses (%)	
	Technical	Non-Technical
AES-CAESS	6.78%	1.01%
DELSUR	6.29%	3.27%
AES-CLESA	7.74%	1.42%
AES-EEO	10.70%	1.67%
AES-DEUSEM	11.28%	1.26%
EDESAL	6.50%	(*)
B&D	6.29%	0.00%
ABRUZZO	9.75%	(*)

(*) No defined

(Source: Electricity Statistics Bulletin N° 12, 2010 (SIGET, June 2011))

Figure 6.4.4 Technical and Non-technical Losses of the Distribution Networks, 2010

The maximum and minimum non-technical losses are in AES-CAESS and DELSUR, respectively. Non-technical losses of DELSUR are higher because it does not have adequate loss reduction politics.

6.4.2 Measures on How to Reduce Transmission and Distribution Loss

The electrical loss of any component of an electrical network (transmission and distribution) is defined according to the following:

Definition: $P_{loss} = R\,I^2$

R Resistance (in Ohms)

I Current flow in lines or transformers (in Amperes)

P_{loss} Power loss in lines or transformers (in Watts)

In general, the measures for reducing transmission and distribution losses can be summarized as follows.

Installation of devices for reactive compensation (capacitors, synchronous compensator, generator with AVR (automatic voltage regulator), etc.) in several buses or nodes.

Remarks:Reactive compensation is defined as an operation mode used to inject or absorb reactive power. The aim of this mode is to control the voltage in some bus or node of the system (transmission or distribution). When the system maintain the buses voltages close to rated voltages, the current flows in lines or transformers decrease and power losses decrease.

Location of generator (conventional or distributed) close to the load centers.

Remarks:When generators are connected close to the loads, the power flows in electric networks (lines or transformers) decrease, the current flows decrease and power losses decrease.

Electric networks optimization, for example: replace conductors; add new parallel circuit, etc.

Remarks:When electric networks are optimized, commonly the resistances of electrical networks (lines or transformers) are decreased and power losses decrease.

6.4.2.1 Transmission Loss

The transmission losses in El Salvador are acceptable, with values less than 2% and do not need a plan to reduce losses. However, as an additional way of ensuring that the electrical losses remain low following measures are mentioned:

According to 6.4.2-(1), new power plants based on renewable energy can reduce the transmission losses if they operate in voltage regulation mode, for example: geothermal, hydro and biomass generation connected into transmission network could operate with AVR.

According to 6.4.2-(2), if there are several alternative of generation projects based on renewable energy with costs slightly similar, choose projects (greater than 20 MW) that produce a greater reduction in transmission losses, that is, those that are located close to the loads. It could be difficult to allocate new power plants of geothermic, hydro and biomass close to the loads because it depends of the resource location.

According to 6.4.2-(3), Transmission Expansion Plan chooses reinforcements to allow the reduction of total investment cost of the plan. One of the benefits of this is the reduction of the transmission losses. The Indicative Plan of Generation Expansion can include the renewable energy scenario with large projects connected to the transmission to evaluate the benefits in electrical losses reduction.

Elaborate the Indicative Plan of Generation Expansion including the renewable energy scenario with large projects connected to transmission networks.

Elaborate the Transmission Expansion Plan including the Indicative Plan of Generation Expansion. In general terms, the transmission expansion plan obtains some transmission alternatives to reduce the operational costs and transmission losses.

It is important to upgrade the transmission alternatives when new large power plants based on renewable energy can be connected to the transmission networks.

6.4.2.2 Distribution Loss

It can be considered the following measures in the Master Plan:

According to 6.4.2-(1), new power plants based on renewable energy can reduce the distribution losses if they operate in voltage regulation mode, for example: hydro and biomass medium power plants connected into distribution network could operate with AVR. Commonly small power plants based in hydro, biomass, wind and solar PV energy connected into distribution network could not operate in voltage regulation mode.

According to 6.4.2-(2), new power plants based on renewable energy could be allocated close to the loads, for example: wind and solar PV energy. It could be difficult to allocate new power plants of hydro and biomass close to the loads because depend of the resource location.

According to 6.4.2-(3), networks optimization plan of distribution facilities must be made with this procedure:

Elaborate the Electric Interconnection Studies considering the electric facilities for interconnection of the power plant.

Determine the decreasing (or increasing) of the power losses in the sections of the distribution network (feeder) in the comparison with the reference scenario (without project of renewable energy). It could be useful include a practical procedure to calculate power losses using basic information of the distribution feeder and the project of renewable energy.

In case of increasing of the power losses, it could be necessary reinforcements in the feeder to decrease the power losses and maintain the operational conditions (voltage control, power quality, among others).

It is important to upgrade the distribution alternatives (new feeders, change of conductors, etc.) when new power plants based on renewable energy can be connected to the distribution networks.

6.5 Recommendations on how to promote renewable energy introduction

From the view point of transmission and distribution networks, recommendations are provided on how to promote renewable energy introduction. The recommendations are given with the following three aspects:

(1) Transmission Networks
(2) Distribution Networks
(3) Interconnection of Transmission and Distribution Network

6.5.1 Recommendations related to Transmission Networks

The current regulatory mechanism should be modified to include the followings related to transmission networks:

- Transmission Expansion Plan
  Currently, the Transmission Expansion Plan is prepared to meet the growing demand and incorporates the Indicative Plan of Generation Expansion which is to be realized by CNE.
  To promote renewable energy development with small scale widely in the country, coordination of:
  (1) Transmission expansion plan;
  (2) Electrical distribution plan; and
  (3) Generation expansion plan for small scale renewable energy
  will be recommended.

- Financing of investments in transmission reinforcements
  Investments in transmission are large and do not always generate sufficient returns to the transmitter. Generation projects that are connected to the transmission network must invest in interconnection.

If the transmitter perform the necessary reinforcements for the interconnection of new power generation, the developer of generation project must ensure that their projects will be executed. One way to ensure that investment transmitter is not in vain, it is recommended that the transmitter get guarantee letters from the developer of generation project with 80% of project costs. Another important point is the improvement of the law of right of way to expedite transmission projects related to renewable energy generation.

6.5.2 Recommendations related to Distribution Networks

The current regulatory mechanism should be modified to include the followings related to distribution networks:

- Classification of renewable energy projects as distributed generation
  Distributed generation is defined as connected to the electrical system through the distribution networks (primary or secondary network). Distributed generation is not planned and not dispatched by the system operator (UT for El Salvador). Unlike conventional generation distributed generation is installed near the demand.
  According to the current regulations, there is no classification of renewable energy projects based on the concept of distributed generation. This concept is necessary for the promotion of small scale renewable energy generation projects connected to distribution networks. For this, incentive mechanisms are necessary to be created related to the benefits that brings this type of generation to distribution networks (low electrical losses, improved voltage profile, etc.). It is also important to analyze the problems with the connection of distributed generation in distribution network, for example, the problem of unintentional islanding operation caused by a fault in the distribution network.
- Technical standards of equipments
  Renewable energy projects like solar PV and wind do not currently have technical standards of their equipment for electrical interconnection with the distribution networks. It is recommended that technical standards of equipment to be established for the electrical interconnection in medium and low voltages by adopting technical standards of the distribution networks in El Salvador.
- Advances in “Smart grids”
  “Smart grids” can be defined as an aggregate of multiple networks and multiple power generation companies with multiple operators employing various levels of communications and coordination in the electrical networks. With this concept, individual houses begin generating more wind and solar electricity, enabling them to sell surplus energy to their utilities. The concept of “smart grids” is keeping the introduction of new policies in the electricity sector for energy efficiency, real time management of power flows and to provide the bi-directional metering needed to compensate local producers of power. This new paradigm is currently under investigation and there are different pilot projects such as E-Energy projects in Germany.
  The introduction of the concept of "smart grids" in El Salvador will depend on the maturity of

related technologies and technical standards to be implemented[9].

6.5.3 Recommendations related to Interconnection of Transmission and Distribution Networks

The electrical interconnection of generation projects to transmission and distribution networks in El Salvador must comply with the guidelines of the "Technical Standards of Electrical Interconnection and End User access to Transmission Network" (SIGET, 2011). There are issues imposed by these regulations for the development of new generation projects based on renewable energy. Table 6.5.1 lists issues and recommendations.

Table 6.5.1 Issues and Recommendations to Promote the Introduction of Renewable Energies related to Interconnection Technical Standards of SIGET

No.	Issues		Recommendations
1	In the Art.6 is defined as "small generator" to all producers of electricity from renewable energy sources, whose capacity is less than or equal to 20 MW and whose purpose is to sell part or all of their production. However, technical standards currently being introduced the classification of distributed generators. These are characterized by connecting directly to the distribution network, close to the charges and not part of the office of wholesale market[1].	⇒	Include the classification of distributed generators determining a maximum capacity (MW) and the definition of distributed generation. There is no consensus on the maximum capacity of distributed generators. The technical standard IEEE[2] 1547-2003 defines distributed generation as one with less than 10 MVA of capacity.
2	In Article 46 it is mentioned that in the case of small generators, the distributor may construct, modify or adjust any electrical facility necessary to ensure access to the distribution system. The costs of such activity will be considered in determining the distribution charge of the next five-year. It is important to consider the benefit that the distributor has when distributed generators are connected to their networks. It is necessary to grasp measured reduction of technical losses and improving voltage profiles.	⇒	It is necessary to define the technical benefits that can bring a small generator connected to distribution networks. It is proposed to establish a general technical procedure for calculating electrical losses, which should complement the marketing standard[3] to define the allocation of charges for electrical losses.
3	Generation projects seeking to interconnect to the distribution system must conduct the necessary studies outlined in Chapter 4. In addition, Article 47 states that the distributor may request additional information in order to perform studies to establish safety and correct operation of its facilities. In practice, the distributor offers its own procedure for the interconnection of generators to the distribution network (for example, interconnection procedures AES). This creates duplication of	⇒	The distributors know technical issues of interconnection, but interconnection procedures proposed by the distributors should be reviewed and regulated by SIGET. To avoid duplication of studies, it is proposed that Article 43 paragraph i) make mention that the studies described in Chapter 4 are referential and finally the necessary studies will be defined in interconnection procedures with information on

[9] IEEE 2030 Guide for Smart Grid Interoperability of Energy Technology and Information Technology Operation with the Electric Power System (EPS), and End-Use Applications and Loads

No.	Issues		Recommendations
	studies and increase the development time of projects.		the distribution and review of SIGET.
4	In some cases the developers of generation projects that are to be interconnected to the distribution prefer that the engineering department of the distributor performs the studies, not a consultant, to eliminate the review process.	⇒	It is important that developer allows to consultants to carry out studies because the distributor will not always have sufficient resources to solve the new problems of interconnection. This also encourages the development of new capabilities into existing human resources in El Salvador. In this case SIGET could establish mechanisms to simplify the review process of the studies.
5	Potential studies for interconnection of generators in distribution facilities are: Load Flow, Short-circuit, Protection Coordination, Transient Electromagnetic and Transient Stability. Commonly, interconnection procedures of the distributor include all these studies, without exception, and some additional ones. In this regard, there are no criteria for distinguishing that which studies are needed for small generation projects or for those when operated as distributed generation.	⇒	The study of AEA[4] 2011 proposes to less rigorous studies for generators whose expected maximum injection power is 10% of the capacity of the substation. The small generation projects less than 5 MW do not require electromagnetic transient studies and transient stability, due to the impact of these generators to the electric system is minimal compared to conventional generation units (greater than 20 MW). In the case of projects related to unstable energy sources (wind and solar PV), studies should include harmonics, because these generating units are based on static converters. In the event that the project operates as distributed generation is important to include the study related to the commonly islanding operation.

References:
1 Network integration of distributed power generation (P. Dondi, Journal of Power Sources, 2002).
2 IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE STD 1547, 2003)
3 Regulation applicable to the activities of Power Marketing (Executive Decree No.90, November 2000)
4 Study and Proposed Regulatory Mechanism for the Promotion of Renewable Energy in El Salvador (AEA-CNE, August 2011).

With regard to No. 1 of Table 6.5.1, Appendix A (Assessment of distributed generation capacity) shows that the maximum capacity of distributed generation is approximately 5 MVA in El Salvador. This value is recommended considering that it might be used the IEEE technical standard 1547-2003 (IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems), which covers the connection of distributed generators with a capacity less than 10 MVA.

With regard to No. 2 of Table 6.5.1, Appendix B shows the electrical loss calculation procedure for establishing the profit of electrical interconnection of generators in distribution systems. This procedure is based on the connection of generators in the distribution systems which are involved in the charges of electrical losses.