Geothermal Resources in Latin America & the Caribbean

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Acknowledgment

The **Database of Geothermal Resources in Latin American & the Caribbean** was compiled and built by Liz Battocletti of Bob Lawrence & Associates, Inc. for Sandia National Laboratories under Contract No. AS-0989.

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The photographs on the cover and title pages feature Nicaragua. The background photo is William Teplow, Vice President for Exploration of Trans-Pacific Geothermal Corp. standing beside a large steam vent at the El Hoyo Volcano in the El Hoyo-Monte Galán region (Photo credit: Trans-Pacific Geothermal Corporation courtesy of the National Renewable Energy Laboratory's Online Photo Library). From left to right, the smaller photos are the Momotombo Geothermal Power Plant and the Momotombo Volcano (Photo credit: Liz Battocletti).

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Introduction

Latin America and the Caribbean, from México to Argentina to the islands of Saba and Statia south to Saint Vincent, have approximately 50,770 MWe of geothermal power generation potential (see table on pages 3 and 4). Currently, however, for many reasons, only 1,169 MWe, a mere 2% of the region's enormous geothermal resources has been developed.

The **Database of Geothermal Resources in Latin America and the Caribbean** details geothermal resources suitable for power generation in the countries of Central America, the Caribbean, and South America. This report is a two-dimensional representation of a three-dimensional Database.

The Database includes information on 152 specific geothermal sites, representing at least 5,000 MWe in potential (potential is not known for all sites). Information is not included for those countries and sites which do not have high-enthalpy resources suitable for power generation (defined here as temperatures over 100EC). Data thus is not included for the numerous sites across the region which are suitable for direct use applications.

The Database includes:

- Power Profile - basic information on the country, e.g., population, installed capacity, power generation breakdown, electricity prices, etc.;
- Power Summary - brief description of the county's power sector and privatization;
- Government / Legislation - relevant government agencies and laws; and
- Geothermal Sites / Projects - includes a Site Summary for each:

  1. Name
  2. Location
  3. Status
  4. Installed Capacity (MWe)
  5. Potential (MWe)
  6. Temperature (EC)
  7. Chronology
  8. Notes

General data contained in the Database comes from several sources including the CIA World Factbook 1998, the Economic Commission for Latin America and the

Caribbean (ECLAC) of the United Nations[1], and La Organización Latinoamericana de Energía (OLADE)'s Sistema de Información Económica-Energética (SIEE®).

Site- or project-specific data comes from publically available sources which are listed in the Bibliography.

Dynamic Database

The Database was designed to be dynamic rather than static. Created using Microsoft® Access 97, it can be easily updated or modified to include specific data which the industry would find most useful. In addition, the Database can be made more comprehensive by adding pertinent data, e.g., local population and market data, location of transmission lines and roads, etc., using the Geographic Information System (GIS) to the present structure. Finally, the Database can be adapted for the World Wide Web and searched using a variety of variables such as country, desired temperature of resource, estimated power potential, and other parameters.

For immediate dissemination to the industry, the Database has been converted to a PDF file for posting on the WWW (site to be determined).[2]

[1] La Comisión Económica para América Latina (CEPAL)

[2] PDF files can be read and printed using the free Adobe® Acrobat® Reader which can be downloaded at http://www.adobe.com/prodindex/acrobat/readstep.html).

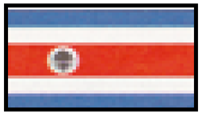
GEOTHERMAL POTENTIAL IN CENTRAL AMERICA, THE CARIBBEAN, AND SOUTH AMERICA[3]

Country	Geothermal Installed Capacity (MWe)	Geothermal Potential (MWe)	Number of Sites
Argentina	0.67	2,010	4
Bolivia	0	2,490	10
Chile	0	2,350	13
Colombia	0	2,210	5
Costa Rica	152.5	2,900	15
Dominica	0	1,390	5
Ecuador	0	1,700	5
El Salvador	160	2,210	7
Grenada	0	1,110	8
Guadeloupe	4.5	3,500	1
Guatemala	29	3,320	16
Honduras	0	990	7

3 Data on estimated geothermal potential electrical capacity in megawatts (MWe), with the exception of Jamaica, comes from the *Preliminary Report: Geothermal Energy, The Potential for Clean Power from the Earth*, Geothermal Energy Association, April 1999. The figure used is an estimate of annual electricity production using the Enhanced Technology High estimate. Data on Jamaica is from Vimmerstedt, 1998.

Country	Geothermal Installed Capacity (MWe)	Geothermal Potential (MWe)	Number of Sites
Jamaica	0	100	0
Martinique	0	3,500	0
México	751.88	6,510	20
Montserrat	0	940	1
Netherlands Antilles	0	3,000	0
Nicaragua	70	3,340	13
Panamá	0	450	2
Perú	0	2,990	12
Saint Kitts & Nevis	0	1,280	3
Saint Lucia	0	680	1
Saint Vincent & the Grenadines	0	890	1
Venezuela	0	910	3
TOTALS	**1,168.55**	**50,770**	**152**

Central America



Costa Rica

Population (millions) - July 1998	3.6
Overall Electrification (% of population)	93%
GDP (billion US$) - 1997 est.	$19.6
Real GDP Growth Rate - 1997 est.	3.0%
Inflation Rate (CPI) - 1997	11.2%
Total Installed Capacity (MWe) - 1997	1370
Electricity Consumption per Capita (kWh) - 1997	1267
Energy Demand Growth Rate	4.0%
Prices (US¢/kWh) - June 1998	
Residential	5.04
Commercial	8.97
Industrial	7.47
Estimated Geothermal Potential (MWe)	**2,900**

Power Summary

Costa Rica's total installed capacity as of December 1997 was 1,370 MWe of which Instituto Costarricense de Electricidad (ICE), the public utility company, owned 88%. The remaining 12% is owned by four cooperatives, two municipal companies, over 20 private generators, and the Costa Rican Petroleum Refinery. The majority of the energy sector remains under state control.

Costa Rica has vast hydropower resources (9,155 MWe) of which only 8% (754 MWe) are currently being utilized. The country produces approximately two-thirds of the power it consumes and imports the remainder, mostly crude oil and petroleum products (Lawrence, 1998).

Hydroelectric power dominates the country's power production accounting for over 90% of Costa Rica's total power. Thermal energy production relies on fossil fuel imports. Geothermal power produced at Miravalles supplies about 11% of Costa Rica's electrical demand.

The market for power in Costa Rica peaked in 1993 as a result of the construction of the Sandillal, Toro, and Miravalles projects. The market decreased in 1994 partly because of the Government of Costa Rica's (GOCR) fiscal problems. The GOCR froze almost every large infrastructure project in 1996 in order to cut public spending as required by the World Bank, International Monetary Fund (IMF), and IDB.

Costa Rica needs at least an additional 4,211 MWe by 2016, excluding current capacity scheduled for retirement. Of this amount, 137.5 MWe will come from geothermal sources, specifically Miravalles II (55 MWe), Miravalles III (27.5 MWe), and Tenorio (55 MWe).

Major future projects include the 177 MWe Angostura hydroelectric project expected online in 2000, Piris - 128 MWe - 2003, Los Llanos - 85 MWe - 2007, Pacuare - 156 MWe - 2008, and Boruca - 1500 MWe - 2010.

Government / Legislation

<u>Instituto Costarricense de Electricidad (ICE)</u>

Originally, ICE, the public electric utility which was created in 1949, was responsible for exploring and developing the country's geothermal resources. This changed in 1990 with the passage of Law 7200, the Independent Power Generation Act.

The investigation and development of geothermal fields falls exclusively to ICE. The private sector is only allowed to generate electricity.

<u>Laws 7200 (1990) and 7508 (1995) - Independent Power Generation Act</u>

Laws 7200 and 7508 allow private developers to build and operate geothermal power plants within the following parameters:

- 35% of the company's ownership must be Costa Rican;
- the procedure is public bidding;
- the maximum power installable per concession or public bidding is 50 MWe;
- the maximum term is 20 years;
- up to 15% of the country's total installable power can come from private sources;
- environmental impact studies are required; and
- the rate is competitively set.

No Specific Law for Geothermal

Like mineral resources, geothermal is considered the property of the State whose exploitation ICE seeks to maintain as a monopoly. All geothermal concessions belong to ICE.

The new law, which is currently under consideration by the Costa Rican Congress, is more broad minded, allowing a wider range of use for resources, but still retains ownership by the State.

Geothermal Sites / Projects

Costa Rica has an estimated 1,000-3,500 MWe of geothermal power potential.

Due to its over-reliance on hydroelectric power, Costa Rica is developing its significant geothermal resources. In 15 years, geothermal will account for 10% of Costa Rica's total installed capacity, primarily baseload. The GOCR's policy is to have 100% renewable energy production in Costa Rica by 2010 (Lawrence, 1998).

Costa Rica began exploring its geothermal resources for electrical generation in 1963. It was not until the 1973 OPEC oil embargo, however, that a major interest in developing the country's indigenous energy source materialized. Systematic studies began in 1975 at Miravalles.

ICE is interested in further developing Costa Rica's geothermal resources as an important component of its electrical generation plan. ICE's objective is to sell geothermal steam to the private sector to be used in power plants built under Build-Operate-Transfer (BOT) or similar contracts. ICE would then buy the electricity generated for the Interconnected National System.

Electricity generation using geothermal energy began at Miravalles in 1994, which in 1998 continues to be the only exploited geothermal area in Costa Rica. By the year 2000, Miravalles will produce approximately 167.5 MWe. On the basis of available data, it is probable that the development of Miravalles will reach its limit in the near

future. Consequently, ICE plans to develop other geothermal areas for electricity generation. These are Rincón de la Vieja, Tenorio, and Poco Sol Caldera.

Areas of less interest but also promising are Barva, Irazu-Turrialba, Poás, and Porvenir-Platanar, each with potential of 100-115 MWe. The least favorable areas of the country are Fortuna and Orosi-Cacao with a potential of 70 and 35 MWe respectively.

ICE defines "reserves" as the fraction of the earth's heat stored up to 2.5 km in depth, which can be commercially exploited within 10 years. "Resources" are the fraction of the earth's heat stored up to 3 km in depth, which can be commercially exploited within 25 years. Using this methodology, ICE estimates Costa Rica's reserves at 1,000 MWe; its resources at 2,250 MWe.

1. Barva
2. Fortuna-Poco Sol Caldera
3. Irazú-Turrialba
4. Miravalles Boca Pozo I
5. Miravalles Boca Pozo II
6. Miravalles I
7. Miravalles II
8. Miravalles III
9. Miravalles IV
10. Miravalles V
11. Orosí-Cacao
12. Poás
13. Porvenir-Platanar
14. Rincón de la Vieja
15. Tenorio

Barva	
LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	97-214
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).	

Fortuna-Poco Sol Caldera

LOCATION
On the Atlantic slope of the province, in the NW-SE trending Tilarán Volcanic Range where no recent volcanic activity has occurred (Alajuela Province).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	69-159
TEMPERATURE (EC)	150-240

CHRONOLOGY
1989 - Identified within the Fortuna area in the reconnaissance study.

1999 - ICE planning additional work.

NOTES
Based on boiling hot springs (98ºC) found in the area, a geothermal evaluation was included in the feasibility studies of the Peñas Blancas hydroelectric plant.

Very high geothermal gradients were observed near one of the proposed dam sites (151ºC was measured 42m below the river bed), which was interpreted to correspond to an upflow zone along calderic fractures. According to geochemical data, the hot springs arise from a 240ºC geothermal reservoir at a depth of about 1 km inside the Poco Sol Caldera (Robles, 1998).

Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).

Irazú-Turrialba

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	115-257
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES
Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).

Miravalles Boca Pozo I

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	5
POTENTIAL (MWE)	5
TEMPERATURE (EC)	-

CHRONOLOGY
1979 to 1980 - First three exploratory wells drilled.

1994 - 5 MWe backpressure wellhead unit installed. Plant factor of 80%; 80.58% in 1997.

NOTES
Includes one production and one reinjection well. Owned and operated by ICE.

Miravalles Boca Pozo II

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	10
POTENTIAL (MWE)	10
TEMPERATURE (EC)	-

CHRONOLOGY
1996 and 1997 - Under a renewable 18-month cooperative agreement between ICE and México’s CFE, two 5 MWe backpressure units were put online.

NOTES
Includes one production and one reinjection well. Owned by ICE; operated by Comisión Federal de Electricidad (CFE).

Only one of the CFE units is operating. One was shut down to supply steam to the Miravalles II plant.

Miravalles I

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	55
POTENTIAL (MWE)	55
TEMPERATURE (EC)	-

CHRONOLOGY
1976 - Prefeasibility study completed.

1985 - Feasibility study completed funded by the Inter-American Development Bank (IDB).

1994 - Start-up of first 55 MWe condensing plant. The unit has been in continuous operation since then with a plant factor of about 90%; 94.43% in 1997. This takes into account that the plant has been generating 60 MWe continuously, a level which is considered feasible and within the unit's design parameters.

NOTES
Includes 11 production and 5 reinjection wells.

Miravalles I was supplied by Fuji of Japan with 4.5% financing. Well field financed by the IDB. An Italian firm provided reservoir engineering and management; U.S. firms provided drilling services (Nabors), cementing services (Halliburton), and supply well-head equipment (A/Z Grant). Electroconsult of Italy designed the power plant.

Miravalles II

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	55
POTENTIAL (MWE)	55
TEMPERATURE (EC)	-

CHRONOLOGY
1988 - Feasibility study completed funded by the IDB.

August 1998 - 55 MWe condensing plant expected to come online (Robles, 1998). Developed and operated by ICE. Like Miravalles I, the expected generation capacity of II is 60 MWe.

NOTES
Includes 6 production and 6 reinjection wells.

Financed with a US$ 72.4 million IDB loan. Under international bidding, the contract was awarded to Ansaldo.

The specific cost of investment is US$2,279.50/kWe for Miravalles II.

Miravalles III

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Construction underway

INSTALLED CAPACITY (MWE)	27.5
POTENTIAL (MWE)	27.5-55
TEMPERATURE (EC)	-

CHRONOLOGY
1996 - 27.5 MWe BOT plant at Miravalles III put out to bid.

Spring 1997 - Competitively bid contract awarded by ICE to Oxbow/Marubeni consortium. The consortium is composed of affiliates of Oxbow Power Corporation of West Palm Beach, Florida; Tokyo-based Marubeni Corporation; Oxbow Power Services, Inc. of Reno, Nevada; and José Altmann & Compania, Ltda. of San José, Costa Rica.

Under the terms of the original tender, a second 27.5 MW unit can be awarded by ICE to the Oxbow/Marubeni consortium any time before November 18, 2000.

September 1998 - Project closed financing and began site preparation.

February 1999 - Formal ground breaking.

Spring 2000 - 27.5 MWe condensing plant expected to be online.

NOTES
A 27.5 MWe condensing plant is under construction. Builder and operator is Geoenergía de Guanacaste Ltda., a consortium of Oxbow Power Corp. and Marubeni Corp. of Japan.

Miravalles III will be Costa Rica's first BOT power project. It will sell all its electricity to ICE, the state utility, under a 15-year PPA after which ICE will assume ownership of the plant.

Estimated total cost: $70 million; $49.5 million to be financed by the IDB. The financing involves a $16.5 m loan from IDB's ordinary capital (A loan) as well as a syndicated loan of $33 m (B loan), co-arranged and underwritten by the Fuji Bank of Japan. Dresdner Bank and Credit Local de France also subscribed the syndicated loan. Geoenergía de Guanacaste Ltda, the borrower, is contributing $16.5 m in equity.

Miravalles IV

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Feasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	27.5
TEMPERATURE (EC)	160

CHRONOLOGY

NOTES
27.5 MWe condensing plant in evaluation stage.

ICE is considering calling an international competitive bid for a BOT contract for the construction of a binary cycle plant to extract energy from Miravalles's waste water which is currently being injected into the reservoir.

Interested companies will be able to define the binary cycle technology to be used and design a plant layout that will efficiently exploit the energy of these 160ºC waters (Robles, 1998).

Miravalles V

LOCATION
The Miravalles geothermal field is located in northwestern Costa Rica, SW of the Volcán Miravalles (Guanacaste Province).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	20
TEMPERATURE (EC)	160

CHRONOLOGY
NOTES A 20 MWe binary or condensing plant is in the evaluation stage.

Orosí-Cacao

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	37-81
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).	

Poás

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	103-219
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).	

Porvenir-Platanar

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	109-241
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES	

Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).

Rincón de la Vieja

LOCATION
In northwestern Costa Rica near the active Rincón de la Vieja Volcano, 17 km northwest of the Miravalles geothermal field (Guanacaste Province).

Surface manifestations include fumaroles, mud pots, thermal springs, and hydrothermally altered rocks.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	157-330
TEMPERATURE (EC)	230-240

CHRONOLOGY
1975-1976 and 1994-1995 - 17 gradient holes with depths between 52 and 379 m drilled; temperature logs are available.

1997 - ICE allocated funding from the IDB for a prefeasibility study of this area.

NOTES
The major limitation to development is that part of the geothermal system is located in the Rincón de la Vieja National Park. There is worry about possible environmental restrictions that may impede the development of the project.

The development scheme will be similar to Miravalles III and IV, e.g., BOT awarded through international public bidding.

Potential capacity (MWe) represents average values that can be fed by the "reserves" to that which can be fed by the "resources" (Cataldi, 1995).

Tenorio

LOCATION
South of the Tenorio Volcano, approximately 14 km northwest of Lake Arenal, 25 km southeast of the Miravalles geothermal field (Guanacaste Province).

The Arenal Volcano is one of Central America's most active, averaging ten minor eruptions a day. It has spewed lava down its sides only ten times since 1968.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	110-247
TEMPERATURE (EC)	230-240

CHRONOLOGY

1989 to 1995 - Prefeasibility study covering an area of 550 km², done with support of the Italian Government and the United Nations Development Program (UNDP). Indicated the presence of a geothermal reservoir at a depth of 1200-2000 m, with a temperature of 230-240ºC, and medium to low salinity fluids.

1997 to 1998 - Feasibility study started and funded by ICE. The study will include drilling three wells with support from the IDB. The field, liquid-dominated with temperatures over 230°C, is estimated to have potential of 110 MWe. The objective of this stage is to prove geothermal resources sufficient to supply steam to one or two power plants with a total capacity of 50-60 MWe.

ICE has drilled 12 gradient wells. In addition, the construction of access roads, water supply systems, and drilling pads for 4 deep exploratory-production wells has begun.

2005 - First 55 MWe plant should be online.

NOTES

Tenorio will be the next field after Miravalles, to be developed probably as a BOT. ICE will supply the steam and buy kWh from the plant.

The specific cost of investment is US$2,279.50/kWe for Tenorio.

Potential capacity (MWe) represents average values that can be fed by the “reserves” to that which can be fed by the “resources” (Cataldi, 1995).

El Salvador

Population (millions) - July 1998	5.75
Overall Electrification (% of population)	65%
GDP (billion US$) - 1997 est.	$17.8
Real GDP Growth Rate - 1997 est.	4.0%
Inflation Rate (CPI) - 1997	2.0%
Total Installed Capacity (MWe) - 1995	833
Electricity Consumption per Capita (kWh) - 1997	538
Energy Demand Growth Rate	7.0%
Prices (US¢/kWh) - June 1998	
Residential	8.19
Commercial	10.70
Industrial	11.10
Estimated Geothermal Potential (MWe)	**2,210**

Power Summary

The generation system of El Salvador is composed of hydroelectric (49%), geothermal (13%), and thermal (38%) power plants, for a total installed capacity of 900 MWe in 1996.

Large factories and industrial parks in El Salvador generally have their own backup power generating facilities. Infrastructure problems and weather conditions still interrupt service on a regular basis. Electrical generation is highly dependent on seasonal rains, because hydroelectric plants provide more than 40% of the country's generating capacity. The state-owned electric company, Comisión Ejecutiva Hidroeléctrica Del Río Lempa (CEL), aided by international financial sources, is developing additional geothermal and fuel-powered electrical plants. In addition, privately-owned generating plants, will likely reduce the number of electricity shortages in the future.

The Government of El Salvador (GOES) is moving ahead with the privatization of CEL. Four distribution companies were sold to U.S., Venezuelan, Chilean, and Central American investors in early 1998. To sell the rest of CEL will require a reorganization of the agency which is currently underway and expected to be complete by the end of 1999. It is still unknown how this privatization will take place. Some plants, i.e. geothermal and thermal may be sold, while others, i.e., hydroelectric, may be contracted under concession due to the complexity of dividing up water rights. The breakup of CEL should lead to a dramatic increase in investment in the sector over the next ten years.

There is speculation that CEL will seek to shed its generating plants in the future but that will depend on the new government which will be elected in March 1999.

After years of civil war, the resurgence of industrial output has greatly increased El Salvador's power needs following the 1992 Peace Accords. El Salvador's average annual growth of electricity demand for the last five years has been 7%. CEL is implementing a ten-year electricity generation expansion plan based on a projected 7% average annual increase in demand, as well as on meeting future demand from Guatemala and Honduras. The plan aims to increase the country's total generating capacity to 2015 MWe by the year 2010, and will require investment of more than $1 billion.

The $332 million Electric Power Sector Program, Stage II, approved in 1994 by the IDB, will provide the infrastructure needed to accommodate El Salvador's growing demand for electricity. Of the total, $215 million is coming from the IDB, $55 million from the Overseas Economic Cooperation Fund (OECF) of Japan, and $62 million from local sources.

The specific components include: (a) construction of the Berlín 55 MWe geothermal generation plant; (b) stabilization and rehabilitation of the Ahuachapán geothermal plant; (c) construction of three new 115 kV transmission lines and two 115-46 kV substations, rehabilitation of twenty 115 kV lines, and expansion of the capacity of eight existing substations; (d) an energy conservation program; and (e) institutional strengthening and staff training of CEL.

Government / Legislation

Superintendencia de Electricidad y Telecomunicaciones (SIGET)

Created in 1996, SIGET is an independent agency which regulates the transmission and distribution of electricity in El Salvador. SIGET will:

- authorize the sale of concessions for exploration and exploitation of geothermal resources;
- appoint a transactions office known as the Unidad de Transacciones (UT) which will operate the transmission system, maintain the security of the system, and assure a minimum acceptable standard for service and delivery; and
- be the point of resolution for conflicts between operators, and between operators and final consumers, but only if its services are formally requested.

Comisión Ejecutiva Hidroeléctrica del Río Lempa (CEL)

CEL, the National Electric Utility Company of El Salvador, is in the process of being privatized following the General Law of Electricity passed in 1996.

CEL's geothermal division, renamed Geothermia Salvadorena S.A., is looking for a "strategic partner" to help Geo-CEL run the geothermal plants in Berlín and Ahuachapan as well as exploit new projects. Partners currently are AES, Unocal, Calpine, Oxbow, Enron, Constellation Power, Caithness Corp., and Florida Power & Light.

CEL has evaluated future options for developing and exploiting geothermal resources, according to three schemes:

1. CEL retains ownership and management of the resource and sells the steam to an IPP, following the model set in the Philippines, Indonesia, and Costa Rica;

2. Total concession to the IPP who will completely manage the resource and the plant; and

3. A variant of 2 in which CEL participates in the capital of the local company created by the IPP.

General Law of Electricity (Decree No. 843)

The General Law of Electricity, passed October 10, 1996, established the legal framework for privatizing all aspects of electricity production, transmission, and distribution currently owned by the state organization, CEL. The time frame for complete privatization of CEL is three years. The Law also created SIGET as an independent agency to regulate the industry.

The price of electricity at generation will be market driven but the GOES will regulate the prices charged for transmission and distribution. The Wholesale Market will have two components: the Contracts Market (MC) or fixed market, and the System Regulating Market (MRS) or spot market. To participate in any phase of the fixed market (MC), valid contracts are necessary. Contracts are not necessary to participate in the spot market (MRS).

Charges for use of the transmission and distribution system will be determined by the UT based upon the costs of investment, operation and maintenance associated with each component of the system. The UT will assess

penalties on companies which do not meet their contractual obligations.

There are no restrictions on foreign ownership in the electricity sector. Transmitters and distributors will be obliged to permit use of their installation for international interconnections.

<u>No Specific Law for Geothermal</u>

According to the Salvadorean Constitution, all the country's subsurface is State property.

El Salvador has no specific law for geothermal. Companies interested in obtaining concessions for geothermal exploitation must present a written request to the SIGET which includes the following:

- Information about the company relative to its incorporation and legal capacity;
- A feasibility study which includes a descriptive narrative and blue prints;
- An environmental impact study which addresses the effects on the environment of the current project as well as any future expansions, and includes a section on all phases of the project (construction, operation, and termination). It should also include several options for dealing with any adverse effects that may result from the project.

SIGET granted its first license to a company to begin exploitation in San Vicente.

All geothermal project proposals are subject to a public offering which will be administered by SIGET. All bids must be accompanied by a guarantee equivalent to 10% of the value of the project.

Concessions will be awarded to the highest bidder except if the original bidder loses. The original bidder will be awarded the concession if they are willing to pay 85% of the price offered by the winner.

Once a concession is granted, if a company wishes to increase its capacity, it will be required to pay to the State a sum related to the real value of the original acquisition and comparable to the amount it would have paid at the time of the original acquisition had this increased capacity been included.

Upon request, SIGET will authorize for one time only, temporary permission to conduct feasibility studies for projects utilizing geothermal energy. The permission will be granted for a two-year period with one option to renew. The permission is not exclusive and merely facilitates studies conducted on state-owned property. For studies on private property, permission from the owner or administrator of that property must be obtained.

Geothermal Sites / Projects

<u>El Salvador has an estimated 2,210-4,140 MWe of geothermal power potential.</u>

Geothermal power represents the least cost generating source for base load energy for El Salvador. Each MW of geothermal power saves approximately $1,100 per day, depending on fuel cost. Consequently, geothermal power projects have a high priority.

Geothermal power currently supplies 13% of the country's total electricity demand. Ahuachapán has an installed capacity of 95 MWe; Berlín Boca Pozo I, 10 MWe. An additional 60 MWe of capacity is under construction.

By 2000, geothermal will supply about 20% of El Salvador's power. By 2010, it is estimated that there will be 380 MWe of geothermal installed capacity. To date, the GOES has invested over US$100 million in geothermal exploration and development but plans to be completely out of the geothermal development business by 2000.

El Salvador began exploring its geothermal potential in the mid 1960s. The southern Plio-Quaternary Volcanic Belt represents the principal target of exploration, with major geothermal zones, hot springs, hot wells, fumaroles, and exposures of hydrothermal activities. Most activities were halted during the Civil War (1980-1992).

Six priority areas in terms of generating power potential have been identified. Stretching across the country from west to east, they are Ahuachapán, Chipilapa, Coatepeque, San Vicente, Berlín, and Chinameca. All except Chinameca are high enthalpy, liquid-dominated fields. There is no inventory of lower enthalpy resources.

1. Ahuachapán
2. Berlín Boca Pozo I
3. Berlín II
4. Chinameca
5. Chipilapa
6. Coatepeque
7. San Vicente

Ahuachapán	
LOCATION In western El Salvador approximately 80 km west of San Salvador, 18 km east of Río Paz, and 15 km from the Guatemalan border. Studied zone in the Ahuachapán-Chipilapa geothermal field covers an area of 200 km² and is located in the counties of Santa Ana, Ahuachapán, and Sonsonate.	
STATUS Power plant(s) on site	
INSTALLED CAPACITY (MWE)	95
POTENTIAL (MWE)	95-150
TEMPERATURE (EC)	230
CHRONOLOGY 1953 - First geothermal studies conducted by the National Geologic Service and CEL. 1966 - The GOES with assistance from the UNDP assessed a good part of the country and identified Ahuachapán as an area of priority; drilled AH-1 to 1200 m. 1970 - Feasibility study concluded funded by the World Bank. 1971 - Development of the field and construction of the complex began. Plants were installed by Mitsubishi Heavy Industries, Ltd., and developed and are operated by CEL. Total of 32 wells drilled of which 11 are connected to the complex. 1975 - Single-flash unit of 30 MWe came online. 1976 - Single-flash unit of 30 MWe came online. 1981 - Double-flash unit of 35 MWe came online. 1980s - Field was over-exploited for many reasons; at one point it generated over 40% of the country's electricity causing reservoir pressure to drop quickly. 1994 - Generation stabilized at 48 MWe to maintain pressure above 19 bar.	

1995 - CEL closed financing with the IDB for the Ahuachapán Rehabilitation & Stabilization Project.

Through international bidding, Forasal was awarded the drilling contract while the consortium of SAI Engineering and Marubeni won the plant rehabilitation.

Eight of the ten wells have been drilled with an additional 33 MWe found in seven. One well now connected has 53 MWe of capacity.

NOTES
The IDB-funded Ahuachapán Rehabilitation & Stabilization Project is part of the $332 million Electric Power Sector Program, Stage II Program. It has five key components:

(1) drilling of 10 new wells to the south of the producing area;

(2) rehabilitation of the electro-mechanical equipment in the power plant;

(3) construction of a reinjection line to existing reinjection wells located in Chipilapa, 7 km away (currently the brine is dumped into the ocean via an 80-km-long canal);

(4) construction of a gathering system to connect the new wells to the plant; and

(5) rehabilitation of the canal that channels the brine to the ocean for emergency use.

Ahuachapán has 95 MWe of installed capacity (2 x 30 MWe + 1 x 35 MWe) but, as a result of over-exploitation for several reasons, is currently generating only 40-45 MWe. The purpose of the project is to increase production to at least 80 MWe.

Berlín Boca Pozo I

LOCATION
In eastern El Salvador approximately 90 km from San Salvador.

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	10
POTENTIAL (MWE)	-
TEMPERATURE (EC)	240-300

CHRONOLOGY
1966 - The GOES, with assistance from the UN, identified Berlín as an area of priority; drilled two gradient wells and one deep exploratory well.

1980 and 1981 - With funds from the World Bank, conducted a feasibility study which included drilling three slimhole wells and five deep exploratory wells. Identified a minimal area of production of 6.8 km² (a deep reserve at approximately 1,800 m with temperatures higher than 300ºC) and a the feasibility of a first unit of 55 MWe. Field work halted by the Civil War.

1987 - Production testing of wells completed.

1991 - Berlín Boca Pozo I, two 5 MWe units, came online using two existing production wells and drilling three reinjection wells. Units installed by ACEC, a Belgian company since bought by ABB.

1992 - Planta Geotérmica El Tronador, composed of two 5 MWe plants, began commercial operation. Developed and operated by CEL. Currently generation is stable at 8 MWe.

NOTES

Berlín II

LOCATION
In eastern El Salvador approximately 90 km from San Salvador.

STATUS
Construction underway

INSTALLED CAPACITY (MWE)	55
POTENTIAL (MWE)	55-150
TEMPERATURE (EC)	240-300

CHRONOLOGY
1966 - The Government of El Salvador, with assistance from the UN, identified Berlín as an area of priority; drilled two gradient wells and one deep exploratory well.

1980 and 1981 - With funds from the World Bank, conducted a feasibility study which included drilling three slimhole wells and five deep exploratory wells. Identified a minimal area of production of 6.8 km² (a deep reserve at approximately 1,800 m with temperatures higher than 300ºC) and the feasibility of a first unit of 55 MWe. Field work halted by the Civil War.

1987 - Production testing of wells completed.

1992 - With an IDB loan, conducted a study of the feasibility of two 25 MWe plants.

1993 - Completed geoscientific, engineering, and chemical studies with support from the World Bank.

November 1998 - First 25 MWe should be online.

January 1999 - Second 25 MWe unit should be online. Drilling and other activities will continue after the second unit is installed.

NOTES
The $113 million Berlín First Condensation Project is funded by a loan from the IDB and is part of the $332 million Electric Power Sector Program, Stage II Program.

Under the Berlín first condensation development, two 25 MWe plants are planned with 12 new wells -- 7 production and 5 reinjection. Six new wells have been drilled with a capacity of 30 MWe. In addition, a 6 km 115 kV transmission line will be built.

Under international bidding, contracts were awarded to the Forasal-Foraky Group (El Salvador-Belgium) for drilling and to the Sumitomo Corporation for the modular condensation units.

Construction of the steam and brine gathering system will be done by MONELCA; construction of a permanent camp by OMNI, both Salvadorean companies.

It is estimated that Berlin II will save $56,000 in fuel costs per day, including operating and financial costs.

Chinameca

LOCATION

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	5-55
TEMPERATURE (EC)	300

CHRONOLOGY
1966 - The GOES, with assistance from the UN, identified Chinameca as an area of priority.

Six deep exploratory wells were drilled, five had promising results. Of the five, three have a potential of 30 MWe; the other two, 18 MWe.

1980 - Prefeasibility study began with funding from the World Bank; study not completed.

NOTES
Prefeasibility study currently underway by CEL including additional geochemical and geophysical studies. The studies will prepare the project for field development in a private framework, possibly as a concession or an IPP.

Chipilapa

LOCATION
In western El Salvador on the northern slope of the Laguna Verde and Las Ninfas volcanoes, east of the town of Ahuachapán.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	220-230

CHRONOLOGY
1965 to 1968 - The GOES, with assistance from the UN, identified Chipilapa as an area of priority. Drilled CH-1 to a depth of 985 m with a maximum temperature of 220ºC at 300 m.

1989 to 1991 - With funds from the Central American Bank of Economic Integration (BCIE), geovolcanic, hydrological, geochemical, and geophysical studies were done. Five deep exploratory wells (from 985 to 2700 m) and one shallow thermal gradient well (450 m) were drilled in the northern slope of the Cerro Cuyanausil on a SE-NW trending line. The feasibility study was interrupted as a consequence of the results obtained by the Accelerated Development Program.

1988 to 1992 - Accelerated Development Program - Objective was to put into service two backpressure units of 5 MWe with funds received under a French-Salvadoran financial agreement. Geoscientific studies were done; and two turbine generators supplied. The project did not achieve its objective due to limited permeability and moderate temperatures (around 200-210ºC).

1990 - Instituto de Investigaciones Eléctricas of México (IIE) and CEL carried out an extensive geochemical survey of the area as well as a reservoir engineering assessment. Concluded that the explored area contains a relatively shallow (~ from +400 to -400 masl) outflow of the Ahuachapán hydrothermal system; in the past the temperatures were typically 20-40ºC higher than they are now; and below the outflow the thermal structure of the Chipilapa field reveals the presence of a deep heat source, presumably the magmatic chamber inferred by previous geovolcanological studies (Iglesias, 1995).

NOTES
Chipilapa is a high enthalpy, liquid-dominated resource.

Two alternatives for the project have arisen:

(1) Developing a pilot project with a medium-scale binary plant and utilizing the waste from the water for

other agro-industrial applications, or

(2) Using the area for reinjection to stabilize Ahuachapán.

Coatepeque	
LOCATION	
STATUS Prefeasibility study	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1991 to 1993 - Prefeasibility study completed with Italian cooperation and funds; included geovolcanic, geochemical, and geophysical studies. The project was interrupted prior to drilling an exploratory well by critics who raised issues related to the tourist interest of the area. An environmental impact study has not been done.	
NOTES High enthalpy, liquid-dominated resource	

San Vicente	
LOCATION Approximately 50 km southeast of San Salvador on the slopes of the Chichontepeque Volcano.	
STATUS Feasibility study	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	27.5-115
TEMPERATURE (EC)	230
CHRONOLOGY 1966 - The GOES, with assistance from the UN, identified San Vicente as an area of priority. One 1300 m deep well was drilled with a maximum recorded temperature of 230ºC. 1980 - Prefeasibility study funded by the World Bank. 1995 to 1998 - Feasibility study funded by a $14.6 million loan from the IDB. Project was suspended due to legal reasons. Geophysical studies, the drilling of three exploratory wells, and a feasibility study of the field remain to be completed. SIGET granted first license to begin exploitation to a	

U.S. company. 2005 - 27.5 MWe plant hoped to be online.
NOTES San Vicente is a high enthalpy, liquid-dominated resource.

Guatemala

Population (millions) - July 1998	12.01
Overall Electrification (% of population)	68%
GDP (billion US$) - 1997 est.	$45.8
Real GDP Growth Rate - 1997 est.	4.1%
Inflation Rate (CPI) - 1997	9.0%
Total Installed Capacity (MWe) - 1995	1005
Electricity Consumption per Capita (kWh) - 1997	312
Energy Demand Growth Rate	10.0%
Prices (US¢/kWh) - June 1998	
Residential	6.87
Commercial	7.86
Industrial	9.30
Estimated Geothermal Potential (MWe)	**3,320**

Power Summary

The key energy issues in Guatemala are electricity and oil. The country's consumption of energy is currently among the lowest in the world. Approximately 68% of Guatemalans have access to electricity. Outside of the capital, access falls to 30%, and in rural areas there is virtually no access. The Government of Guatemala's (GOG) goal is to increase rural electrification to 70% by 2000.

Of Guatemala's total 1005 MWe installed capacity in 1995, electricity production is almost evenly split between hydroelectric and thermal power (24% steam turbines, 49% gas turbines, and 28% diesel). In 1990, hydropower accounted for over 90% of the country's generation capacity—an over-reliance on hydropower. Guatemala estimates that it must add about 1400 MWe of new and replacement capacity by 2012 to satisfy increasing demand.

Guatemala is the only oil-producing country in Central America. However, oil reserves are concentrated in remote and inaccessible regions in the Peten basin in northeast Guatemala. With the formal end of the 36-year Civil War in 1996, however, Guatemala is pushing to develop its oil resources and granting concession for development.

Guatemala has an increasingly open power market. The country's privatization program has accelerated with the sale of Empresa de Energía de Guatemala S.A. (EEGSA), the country's largest power utility, and the proposed sale of Instituto Nacional de Electrificación (INDE), the rural power distributor in 1998-1999.

INDE has 75% of Guatemala's capacity, EEGSA 17%, and municipalities and private companies, 13%. Of the private companies' 128 MWe, Enron has 110 MWe or 86% of the total supplied by its diesel "floating generation barges."

As in the rest of Central America, Guatemala's electric sector is presently occupied with two events: the completion on schedule by 2005 of the "Sistema de interconexión eléctrica para América Central" (SIEPAC)[4] which would create a regional electricity market in Central America; and the possibility of Guatemala obtaining natural gas from México in ten years or more.

México and Guatemala have signed an accord on closer energy cooperation which, in addition to allowing Pemex to set up gas stations in Guatemala, also deals with building a natural gas pipeline between México and Guatemala.

Government / Legislation

Instituto Nacional De Electrificación (INDE)

The regulatory framework for the development of Guatemala's geothermal resources is the responsibility of INDE. INDE also channels state funds to supporting rural electrification, supplying electricity to 19 of the country's 22 provinces.

INDE will be divided into two separate entities and sold. Bidders must be recognized power company operators with bidding expected to begin in November 1998.

General Law of Electricity (Decree No. 93-96)

The General Law of Electricity (Decree No. 93-96), adopted in November 1996, ended INDE's monopoly by privatizing electricity generation and distribution in Guatemala. As a result of the Law, INDE created three distinct state companies for generation, transmission, and distribution.

The Law also created the Comisión Nacional de Energía Eléctrica (CNEE) and established the conditions for the formation of a free market-based wholesale market, the

[4] SIEPAC would create a regional electricity market in Central America by building a 230 kV transmission line connecting Guatemala, Honduras, and Panamá. (Lines currently exist between several of the countries.) The target date for completion is 2003. The IDB is providing $186.6m, over half the $346m estimated cost of the project.

IDB estimates that integrating the six electricity systems , taking into account factors like private sector involvement in building the grid, use of bigger plants, sharing plants and reserves, and optimizing water use, may save the countries as much as $10m-$20m a year.

Mercado Mayorista (MM) which was inaugurated in October 1998.

The MM will buy and sell electricity power and energy in short and long term markets, and will be headed by Energy and Mining minister Leonel Lopez Rodas. Power producers and electricity distributors with a minimum of 20,000 users will participate in the MM, as well as distribution companies handling more than 10MWe, marketers with more than 10MWe and users with a consumption of more than 100 kWh.

No Specific Law for Geothermal

The General Law of Electricity (Decree No. 93-96) revoked the existing Geothermal Law (Decree No. 126-85). According to the new Law, geothermal investment should obtain authorization (concession) from the Ministry of Energy and Mines. Renewable energy projects qualify for duty-free imports of goods that are not produced locally.

A grid-connected geothermal project in Guatemala must compete directly on the basis of price with other forms of power. According to a Hagler Bailly study, the baseload marginal cost for generation in Guatemala is 4¢/kWh (Germain, 1998).

Geothermal Sites / Projects

Guatemala has an estimated 3,320-4,000 MWe of geothermal power potential.

INDE began geothermal exploration in Guatemala in 1972 with assistance from several sources including the IDB, the Japanese Government; OPEC; OLADE; the U.S. Agency for International Development (USAID) through Los Alamos National Lab (LANL) and the U.S. Geological Survey (USGS); the International Atomic Energy Agency (IAEA); and the European Economic Community (EC).

From 1975 to 1994, the GOG spent close to $25 million in geothermal research and development, surface exploration, and exploratory drilling; $13 million in field development; and $38 million in electrical utilization, for a total of $76 million.

Guatemala has 25 volcanoes and intense volcanic activity. The volcanic highlands, where most of the geothermal resources are located, lie in the southern and southwestern parts of the country. In the 23 areas studied, estimated reservoir temperatures range from 14ºC to 300ºC. In addition to high enthalpy resources, Guatemala has significant opportunities for geothermal development in small-scale, direct use applications (Lawrence, 1998).

To date, 14 geothermal fields have been identified in Guatemala. The five most promising, with temperatures ranging from 230-300ºC, listed in order of decreasing priority, are: Amatitlán, Tecuamburro, Zúnil II, San Marcos, and Moyuta.

Second priority areas with temperatures of 130-180ºC are Los Achiotes, Totonicapán, and Ixtepeque. Palencia, Retana, Ayarza, Atitlán, and Motagua are ranked as third priority sites.

Geothermal resources currently under development include Zúnil I and Amatitlán. Orzúnil is currently building a 24 MWe BOT geothermal plant at Zúnil. It will be the country's first private geothermal plant and is expected online after 2000. A 5 MWe backpressure unit was put online in Amatitlán in 1998.

1. Amatitlán
2. Amatitlán (Geoteca)
3. Atitlán
4. Ayarza
5. Cordon and Medida, La Laguna
6. Ixtepeque-Ipala
7. Los Achiotes
8. Motagua
9. Moyuta
10. Palencia
11. Retana
12. San Marcos
13. Tecuamburro
14. Totonicapán
15. Zúnil I (Orzúnil)
16. Zúnil II

Amatitlán	
LOCATION 28 km south of Guatemala City along Laguna Amatitlán (San Marcos Department).	
STATUS Power plant(s) on site	
INSTALLED CAPACITY (MWE)	5
POTENTIAL (MWE)	5-200
TEMPERATURE (EC)	180-300

CHRONOLOGY

1972 - Preliminary exploration done by INDE with funds from the Japan International Cooperation Agency (JICA).

1977 - First investigations begun by INDE with its own funds.

1979 - Study suspended to focus on Zúnil.

1980 to 1984 - Prefeasibility study conducted covering an area of 170 km². With funding from OPEC/OLADE, INDE contracted with Electroconsult to complete the prefeasibility study including drilling two slimhole wells.

1987 - INDE and LANL began a cooperative study of field.

1989 - Electroconsult recommended a feasibility study to confirm the existence of a commercial resource.

1993 and 1994 - Resource feasibility study funded by the IDB and conducted by West Japan Engineering Inc. (West Jec). Of the four full-sized wells drilled, AMF-1 and 2 are production, AMF-3 for reinjection, and AMF-4 dry. AMF-1 and 2 showed a capacity of 12 MWe with a total resource potential estimated at 200 MWe. The temperature in the reservoir is 230-300ºC.

AMF-1 - 1581 m, 280ºC max. temp., 11 kg/cm WHP, 6 MWe estimated potential.

AMF-2 - 1502 m, 295ºC max. temp., 8 kg/cm WHP, 7 MWe estimated potential

AMF-3 - 1500 m, 231ºC max. temp., dry well.

AMF-4 - 2058 m, 240ºC temp. (at 1750 m), 35 kg/cm WHP (static wellhead pressure).

According to West Jec's mathematical model, three new production wells would amount to a potential of 25 MWe for 30 years.

1997 - Three-year contract signed for the installation of a 5 MWe plant between INDE and Ingenieros Civiles Asociados (ICA) of México; CFE will provide advice. Under the contract, INDE will supply steam to the plant and buy the electricity it generates for 3.75¢/kWh. After three years, a request for bids will be issued for the development of a 30-55 MWe plant.

ICA will install and maintain the plant, monitor the field and production wells, evaluate their capacity, and disassemble the plant after three years.

1998 - 5 MWe backpressure unit began operation.

NOTES

Beginning operation in June 1998, Amatitlán became the first geothermal power plant in Guatemala.

Initially the project was to be implemented in association with INDE and the state electric companies of neighboring countries. The project was structured as a concession in which INDE would guarantee the production of fluid and the foreign member (CEL or CFE) the supply, engineering, and construction of the plant as a Build-Lease-Transfer (BLT). Recently, however, this process was modified into an international bid in the short-term as a concession for an IPP.

Amatitlán has a probable potential of 30 MWe and an estimated of 200 MWe.

Amatitlán (Geoteca)

LOCATION

Planta Geotermoelectrica Geoteca is located in Amatitlán, 30 km from Guatemala City (Guatemala Department), 1.5 km from the national grid.

STATUS

Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	5-12
TEMPERATURE (EC)	190-200

CHRONOLOGY

1980s - Geothermal resource discovered; well B-1 drilled; supplied industrial and potable water to Bloteca S.A. (fruit dehydration) and Tubeca S.A. (concrete block drying).

1992 - Tubeca began project with a preliminary evaluation; slimhole well (B-2) intercepted a geothermal aquifer at 130 m with temperatures up to 200ºC.

1995 - With assistance from Fundación Solar (supported by USAID through Winrock International), Tubeca conducted a geologic and geophysical study of the area to locate additional sites for drilling. Concluded that the geothermal resource had a potential of 5 MWe for 25 years.

NOTES
Geoteca S.A., formerly known as Tubeca S.A., is the sole owner of the generation project with the rights to develop the geothermal resource. The company will contract for the engineering, construction, and equipment supply necessary for the plant.

Geoteca has the option to sell electricity from the project to the Empresa Eléctrica de Guatemala S.A. (EEGSA) or use it for industrial purposes.

Geoteca, has a technical assistance loan from E&Co. to support the completion of phase II of a 5 or 6 MWe geothermal project. Phase II of the project consists of drilling three new production wells, testing the productivity of the wells and making a reservoir assessment before preparing a final pre-investment report. To date, two of the three wells have been drilled.

Investment required for the construction and installation of a 5 MWe binary plant is approximately $9 million. E&Co is helping Geoteca complete the pre-investment package needed to secure project financing.

Atitlán

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1981 - Reconnaissance at the regional level. Surface geologic mapping and geochemistry conducted by INDE.

NOTES
Third priority area.

Ayarza

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY 1981 - Reconnaissance at the regional level. Surface geologic mapping and geochemistry conducted by INDE.	
NOTES Third priority area.	

Cordon and Medida, La Laguna

LOCATION	
STATUS Well(s) or hole(s) drilled	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	12
TEMPERATURE (EC)	-
CHRONOLOGY 1997- Winrock Fundacion Solar - drilling complete; received $20,000 in funding from USAID, $80,000 from private sources.	
NOTES	

Ixtepeque-Ipala

LOCATION Chiquimula Department.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1981 - Reconnaissance at the regional level.	
NOTES Second priority area.	

Los Achiotes

LOCATION Santa Rosa Department.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1981 - Reconnaissance at the regional level. Surface geologic mapping and geochemistry conducted by INDE.

NOTES
Second priority area.

Motagua

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1981 - Reconnaissance at the regional level.

NOTES
Third priority area.

Moyuta

LOCATION
In the eastern part of the country (Jutiapa Department); closest to the producing Ahuachapán geothermal field in El Salvador.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	30
TEMPERATURE (EC)	114-210

CHRONOLOGY
1972 - Geothermal investigation began by INDE covering an area of 1000 km^2.

1974 - Prefeasibility study of an area of 330 km^2 began.

1975 - Electroconsult (Italy) contracted to evaluate and complete preliminary feasibility study; 12 gradient and 2 large-diameter wells (INDE-1 and INDE-2) were drilled over an area of 10 km^2. The highest temperature found was 114°C at maximum depths of 797 and 1000 m. Concluded that the area did not offer good prospects for power generation and suggested relocation for additional studies.

1976 - Activities suspended to study more promising Zúnil field.

1987 - INDE and LANL began a cooperative study of field.

1990 and 1991 - LANL re-evaluated the resource with geochemical studies and isotopic data. Geothermal model indicated the existence of two sub-systems: one in the fault north of Moyuta Volcano with geothermometer temperatures of 210ºC; the other in the south fault with 170ºC.

NOTES
Moyuta was the first geothermal area to be explored in Guatemala. Geochemistry indicates temperatures up to 210ºC.

Moyuta will be developed as a concession for an IPP.

Palencia

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1981 - Reconnaissance at the regional level. Surface geologic mapping and geochemistry conducted by INDE.

NOTES
Third priority area.

Retana

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1981 - Reconnaissance at the regional level. Surface geologic mapping and geochemistry conducted by INDE.

NOTES
Third priority area.

San Marcos

LOCATION
250 km west of Guatemala City.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	24-50
TEMPERATURE (EC)	225-300

CHRONOLOGY
1981 - Reconnaissance at the regional level.

1993 - INDE and the European Economic Community began prefeasibility study; study conducted by Geotérmica Italian.

1995 - Prefeasibility study, including geology, geochemics, and geophysics indicated the possibility of a resource temperature of 300ºC. The continuation of the study is pending the approval of financial and technical assistance from the EC.

NOTES
Suitable for binary power generation. San Marcos will be developed as a concession for an IPP.

Tecuamburro

LOCATION
In southeastern Guatemala, 60 km southwest of Guatemala City (Santa Rosa Department). Tecuamburro Volcano has no record of historic eruptions.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	50
TEMPERATURE (EC)	165-300

CHRONOLOGY
1980 - First studies done by INDE with OLADE.

1984 to 1986 - Prefeasibility study conducted by LANL with funding from USAID. Slimhole well drilled 1 km south of Laguna Ixpaco (808 m) encountered a maximum temperature of 235ºC. Geochemistry indicates up to 300ºC. Test wells indicated two fields; one with temperature of 300ºC centered below Laguna Ixpaco, the other with a temperature of 165ºC. Estimated minimum potential of 50 MWe.

NOTES
Will be developed as a concession for an IPP.

Totonicapán

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	265

CHRONOLOGY
1993 - Identified as a priority area with the cooperation of IAEA.

1996 and 1997 - Geochemical study conducted; isotopes analyzed in Vienna by IAEA.

NOTES
Estimated potential capacity pending further study with support from IAEA.

Zúnil I (Orzúnil)

LOCATION
200 km west of Guatemala City; west of the Samalá River (San Marcos Department).

STATUS
Construction underway

INSTALLED CAPACITY (MWE)	24
POTENTIAL (MWE)	24-50
TEMPERATURE (EC)	250-300

CHRONOLOGY
1973 to 1977 - Preliminary exploration done by INDE with funds from JICA.

1977 - INDE conducted a prefeasibility study which included drilling 18 slimhole wells in an area covering 310 km²; discovered a high enthalpy reservoir (287ºC) at 1130 m.

1979 - Selected an area of 4 km² for feasibility study.

1980 and 1981 - INDE funded drilling of six deep exploratory wells, four of which were productive. Contracted with Electroconsult for feasibility study of a 15 MWe plant.

1983 - Electroconsult feasibility study concluded that the resource could support a 15 MWe plant for 20 years; suggested drilling three additional wells to maintain steam flow. Study did not estimate resource's total potential.

1987 - INDE and LANL began a cooperative study of field.

1987 to 1991 - MK-Ferguson drilled three directional wells (1500 to 2000 m) to evaluate the deep reservoir; funded by the IDB. High enthalpy liquid-dominated resource with a maximum measured temperature of 300ºC demonstrated a capacity of 24 MWe.

1988 to 1990 - Geoscientific studies conducted, e.g., geotectonics, gravity and SEV interpretation, fluid inclusions, and mercury soil samples.

1992 - INDE invited interested companies to submit bids for the construction and operation of a geothermal plant.

1993 - INDE reached a contractual agreement with Orzúnil S.A. (Ormat) to exploit the field through the construction of a 24 MWe binary plant. INDE will produce the steam; Orzúnil will generate electricity.

April 1999 - Hybrid plant (flash steam and binary) to be online.

NOTES

Orzúnil (Zúnil I) will be Guatemala's first private geothermal power plant, serving as a model for the future development of private geothermal power in the country. Ormat International is the project developer. Orzúnil will buy steam from INDE and sell electricity to INDE.

Initially, the plant was to be put into service in 1995. Construction was delayed, however, due to financing and bureaucratic problems which have since been overcome.

Financing was arranged by Ormat with assistance from the International Finance Corporation (IFC). IFC will invest $14.3 million in the project ($12 million debt and $2.3 million in equity). In addition, IFC also arranged a $15-million syndicated loan for the project.

Zúnil II

LOCATION

198 km west of Guatemala City; 2 km east of Zúnil I; east of the Samalá River; 5 km from the grid (San Marcos Department).

STATUS

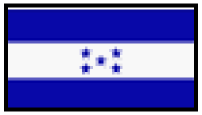
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	40-50
TEMPERATURE (EC)	244-280

CHRONOLOGY

1992 - Prefeasibility studies covering an area of 16 km²

and funded by the IDB were finished by West Jec. Included drilling three slimhole wells and two wells with larger diameters (6.5"). Large diameter well Z-21A (757 m) had a measured temperature of 244ºC and produced dry steam at a rate of 35 t/h with 6 bar abs. separation pressure. The well found a "steam cap" which is probably associated with the deep geothermal system. The potential estimated by the study is 40 to 50 MWe. Production cannot be tested until the exploration and development drilling is completed.
NOTES Resource similar to Zúnil I but shallower and cooler. Will be developed as a concession for an IPP.



Honduras

Population (millions) - July 1998	5.86
Overall Electrification (% of population)	50%
GDP (billion US$) - 1997 est.	$12.7
Real GDP Growth Rate - 1997 est.	4.5%
Inflation Rate (CPI) - 1997	15.0%
Total Installed Capacity (MWe) - 1995	721
Electricity Consumption per Capita (kWh) - 1997	403
Energy Demand Growth Rate	16.0%
Prices (US¢/kWh) - June 1998	
Residential	6.93
Commercial	10.82
Industrial	9.09
Estimated Geothermal Potential (MWe)	**990**

Power Summary

Honduras's current installed electric power generation capacity is approximately 720 MWe, out of which 430 MWe is hydroelectric and 290 MWe is thermal. The country's main hydroelectric facility is the Francisco Morazan Dam, which was commissioned in 1985. The plant has an installed capacity of 300 MW, which represents 70% of the country's total hydroelectric power generation capacity. The country's electrical power system is composed of four hydroelectric plants, five thermal plants, and two private power generators. Demand for electricity has increased significantly over the past few years. Honduras imports 25% of its primary energy.

With Honduras's energy demand growing 16%, the country is considering incentives to increase energy generation with renewable resources, decrease high fuel consumption in thermoelectric plants, and diversify energy production.

Hurricane Mitch hit Honduras hard in October 1998. Over 9,000 people died; over 9,000 were missing; nearly 13,000 wounded; there were over 456,000 people in shelters; and 1 million people were evacuated within Honduras. Four out of every six Hondurans were affected by Hurricane Mitch.

The economic cost of the disaster has yet to be calculated. According to President Carlos Flores, Hurricane Mitch destroyed two generations of efforts to build infrastructure, and robbed hundreds of thousands of Honduran families of their possessions. In the short-term, the storm wiped out about 67% of Honduras's GNP. Officials in Honduras calculate the long-term damage caused by the hurricane at $4 billion, twice the government estimate and more than the country's annual gross domestic product. GDP could witness zero growth or even contract in 1999 according to IMF officials.

Preliminary assessments conducted by the IDB found that the damage to the electricity sector in the region has been minor compared to the damage to roads, schools, bridges and homes. Some parts of the grid are destroyed as well as the road to the Cajon Dam. The cost of fixing the damage is estimated to be $6-10 million.

Extra funds will be released for the Government of Honduras (GOH) to invest in reconstruction, and debt repayment has been suspended for three years. The Paris Club also offered to write off 67% of Honduras's total debt once an IMF-backed reform plan is in place. In addition, the World Bank announced an interest-free US$1 billion loan for both Honduras and Nicaragua, and the IMF approved a US$67 million emergency loan for Honduras at 0.5%, repayable over 10 years with a 5.5 year grace period (Latin American Monitor, January 1999).

IDB officials believe Hurricane Mitch could spur SIEPAC, asserting that the need for economic integration in Central America is now more urgent than ever as countries have to work together to overcome the disaster (Power in Latin America, January 1999).

Government / Legislation

<u>Empresa Nacional de Energía Eléctrica (ENEE)</u>

ENEE has suffered from technical and financial shortcomings which have diminished its operating potential. The enactment of a framework law on the electrical subsector created the National Electrical Energy Commission, allowed the generation of energy by the private sector and permitted the adjustment of electricity tariffs in accord with costs. Nevertheless, energy distribution continues to be inefficient, with losses of 25% in the distribution system.

ENEE has a favorable legal framework in place for the development of resources with a public bidding process for a PPA or Build-Own-Operate (BOO) contracts likely. In 1999, the GOH plans to allow participation of the private sector in the distribution of electricity throughout the country. No date has been set for the privatization of ENEE.

<u>Ministerio de Energía y Minas</u>

The new function of the Ministry of Energy and Mines' Electricity Subsector, is to plan and normalize the sector.

<u>Energy Subsector Framework Law (1994)</u>

Approved on November 3, 1994, the Energy Subsector Framework Law regulates the generation, transmission, distribution, and commercialization of electric power in Honduras, allowing the private sector to participate in the generation and distribution of electric power.

Framework Law of the Electricity Sub-Sector (1996)

Honduras approved legislation to encourage investors into raising the country's renewable energy generation. Firms coming into the sector will be able to build a plant without paying sales tax on any of their materials for 15 years. Another 10-year tax break frees them from income tax.

The new law covers energy produced from biomass or alcohol, solar, tidal or wave power, as well as geothermal and hydro energy.

A development fund of $11m will be set up and used by ENEE, the state electricity company, for such renewable energy projects. The law passed by the national assembly at the end of March 1998 is also aimed at creating rural jobs.

No Specific Law for Geothermal

The specific incentives which benefit generation activities by renewable energy for private investment consist of the exemption of the rights of the duty for the import of generation equipment (Power in Latin America, April 1998).

Geothermal Sites / Projects

Honduras has an estimated 990 MWe of geothermal power potential.

ENEE began exploring Honduras's geothermal resources in the 1970s with a field survey of Pavana undertaken by Geonomics. The survey was terminated early due to financial problems. In 1979, a nationwide reconnaissance program identified 128 thermal manifestations and took water and gas samples at 111 and 11 sites respectively.

In 1980, GeothermEx, funded by the UN, identified six sites of interest: Pavana, Sambo Creek, El Olivar, San

Ignacio, Azacualpa, and Platanares. The World Bank provided $900,000 for geothermal exploration in 1982.

In the mid-1980s, the UNDP and the Italian Government funded two Italian companies at $3 million, Geotermica Italiana srl and Dal, to assess the potential of central Honduras (Comayagua, Santa Bárbara-Sula, San Ignacio, and Azacualpa).

Working in cooperation with the UNDP, in 1985 and 1986 LANL and the U.S. Geological Survey, funded by USAID and the U.S. Department of Energy (DOE) under the "Central American Energy Resources Project," helped ENEE evaluate the country's geothermal power generation potential, and prioritize the previously identified six sites. (The $10.2 million-Central American Energy Resources Project also covered Costa Rica, El Salvador, Guatemala, and Panama.)

Platanares, San Ignacio, and Azacualpa (in that order) were selected as the three best geothermal sites for power generation using binary cycle plants. Platanares has potential of 10-110 MWe. Several firms from the U.S. and Italy have approached ENEE regarding development of this site (Lawrence, 1998).

Honduras's geothermal resources are located in off-grid, rural areas, and geothermal could contribute to the country's rural electrification program. Geothermal development in Honduras has stagnated, however, due to a lack of adequate financing, technical capability, and institutional inertia.

1. Azacualpa
2. El Olivar
3. Isla del Tigre
4. Pavana
5. Platanares
6. Sambo Creek
7. San Ignacio

Azacualpa	
LOCATION In central Honduras; part of the Central Geothermal Zone; on the Río Jaitique along the east side of the north-trending Santa Barbara graden; approximately 100 km northwest of Tegucigalpa (Departamento de Comayagua).	
STATUS Well(s) or hole(s) drilled	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	13-36
TEMPERATURE (EC)	129-190

CHRONOLOGY
1985 - Geology and hydrogeochemistry investigated by LANL, Tennessee Technological University, and ENEE as part of the Central American Energy and Resource Project.

1985 to 1987 - Studies done by Geotérmica Italiana and Dal Intexa through the UNDP Fund. Included geochemical exploration, geology, geophysics, and drilling slimhole exploratory wells. The two wells found a temperature of 115ºC at depths of 650 and 500 m. Maximum measured temperature is 129ºC. Suitable for binary cycle generation.

NOTES
Azacualpa has good potential, less than Platanares but equal to San Ignacio, for development as an electrical power source (Eppler et al, 1987).

The site, which consists of several hot springs, is heavily forested and has canyons up to 100 m deep. Access is by rough dirt roads from Zacapa to the village of Azacualpa. The earth's crust appears to be highly fractured and thinned making it similar to sites in the western United States (Eppler et al, 1987).

Calculated base temperature of 180-190ºC (Goff et al, 1988). Suitable for binary cycle generation.

El Olivar

LOCATION
Approximately 20 km north of Lago de Yojoa in northern Honduras; 50 km south of San Pedro Sula; thermal springs are located in Sula Valley which is one of the most productive agricultural areas in Honduras

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	1.3
TEMPERATURE (EC)	120

CHRONOLOGY
1985 to 1986 - Geology and hydrogeochemistry investigated by LANL, Tennessee Technological University, and ENEE as part of the Central American Energy and Resource Project.

NOTES
Due to low temperature (120ºC) and flow rate (200 l/min), compared to other sites, El Olivar is the least promising for geothermal power generation. The total power output for both hot spring systems is only 1.3 MWe.

Isla del Tigre

LOCATION
On a small island in the Gulf of Fonseca.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES
The GOH through the Ministry of Energy and Mines has expressed an interest in evaluating the resource with the aim to small-scale power generation.

El Tigre has the potential to replace diesel in supplying the population of Amapala with electricity. Pollution caused by the diesel power is a serious environmental problem. Converting the diesel to geothermal would also allow direct use applications related to the local fishing industry.

The data does not yet exist to evaluate the geothermal resource's assets.

Pavana

LOCATION
In the southwestern part of the country, near the Gulf of Fonseca; 3 km southeast of Pavana; ~200 km from the intersection of the Río Agua Caliente and the Pan-American Highway (Departamento de Choluteca).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	11
TEMPERATURE (EC)	150

CHRONOLOGY
1970s - Site studied by Geonomics, Inc. including photogeologic mapping and limited follow-up field checking. Preliminary report suggested three calderas; due to bankruptcy, company was unable to complete the project.

Mid 1970s - Geologic mapping by the UNDP and stream sampling by GeothermEx, Inc..

1985 to 1986 - Studied by LANL and the U.S. Geological Survey as part of the Central American Energy and Resource Project. Main thermal area has a minimum natural outflow of about 3000 l/min of 60ºC. Geothermometry suggests a reservoir base temperature of 150ºC.

NOTES
Superficial studies of preliminary geochemical and geology have been done. Calculated base temperature of 150ºC (Goff et al, 1988), substantially lower than other fields in Honduras. May be suitable for binary power generation.

Pavana is located near power lines, a major paved highway, and agricultural projects where its water could be used for processing.

Oxbow has expressed an interest in obtaining a concession for power generation. The geographic situation of Pavana, which is near the border with Nicaragua and closer in relation to the Active Central American Volcanic Cadera where several high enthalpy geothermal fields are located, is of great interest and potential.

Platanares

LOCATION
In west-central Honduras in the Quebrada Agua Caliente; 30 km east of the Guatemalan border, 16 km west of Santa Rosa de Copán; 2 km east of the San Andrés gold mine; 710-740 masl (Departamento de Copán).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	10-110
TEMPERATURE (EC)	225-240

CHRONOLOGY
1985 to 1986 - Studied by LANL, the U.S. Geological Survey, and ENEE; included extensive geologic exploration, geochemistry, and geophysics studies.

1986 and 1987 - LANL drilled three slim core holes to depths of 650 m (PLTG-1), 401 m (PLTG-2), and 679 m (PLTG-3). PLTG-1 and -3 intercepted fractures. Bottom hole temperatures of 160 to 165ºC, initial flow rates of 356 l/min and 563 l/min for, and maximum power of 3.12 MW(t) and 5.12 MW(t) for core holes PLTG-1 and -3 respectively. The downhole fluids are relatively dilute (< 1200 mg/kh TDS) and slightly alkaline and are not expected to be corrosive in any geothermal applications (Goff et al, 1991).

Sulfate isotope and geothermometers indicate temperatures of 225-240ºC at depths of 1200-1500 m.

Preliminary evaluations indicate the possibility of obtaining 10 MWe from the shallow reservoir. LANL recommended six wells, five production and one reinjection, approximately 600-700 m deep.

NOTES
The Platanares geothermal site was determined by LANL to be the best geothermal prospect in the country due to its high geothermometric temperatures (225ºC), high discharge volume (>3000 l/min), and large estimated reservoir volume (assuming porosity of 10%, estimated maximum is 16 km³) (Goff et al, 1986).

Preliminary evaluations done by LANL and USGS indicate the possibility of obtaining 10 MWe from the shallow reservoir using six wells, five production and one reinjection, approximately 600-700 m deep, and a binary cycle.

Platanares could be a good pilot project for cascading use, e.g., power generation as well as industrial and agricultural direct applications.

The San Andrés gold mine is a potential buyer of power produced at Platanares.

Sambo Creek

LOCATION
In northern Honduras; approximately 1.5 km south of the village of Sambo Creek (Departamento de La Ceiba).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	15-17.6
TEMPERATURE (EC)	155

CHRONOLOGY
1977 - Geonomics investigated.

1980 - GeothermEx investigated.

1985 to 1986 - Studied by LANL and the U.S. Geological Survey as part of the Central American Energy and Resource Project.

NOTES
Since no geophysical studies of Sambo Creek exist to assess the reservoir, it would cost more to develop than

the Pavana field (which has an equivalent temperature(.

Power output is 17.6 MWe assuming a reservoir temperature of 155ºC, an ambient temperature of 30ºC, and an estimated discharge rate of 2000 l/min.

San Ignacio

LOCATION
In central Honduras; part of the Central Geothermal Zone; 3 km northwest of Barrosa village; 8 km northwest of the town of San Ignacio; hot springs issue from the northern side of the broad Valle de Siria at the southern edge of a ridge of the Montañas de la Flor; ; ~100 km north of Tegucigalpa; 750-1000 masl (Departamento de Francisco Morazán).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	14
TEMPERATURE (EC)	160-230

CHRONOLOGY
1977 - Geonomics investigated.

1980 - GeothermEx investigated.

1985 to 1986 - Studied by LANL and the U.S. Geological Survey as part of the Central American Energy and Resource Project; mapped four spring areas.

1985 to 1987 - Geotermica Italiana srl and Dal under the UNDP surveyed site; studies included geochemical exploration, geology, geophysics, and drilling a slimhole exploratory well to 500 m.

NOTES
After Platanares, San Ignacio (La Tembladera) is considered the second most promising site for power generation by binary cycle. This conclusion is based on chemical and isotopic geothermometry (185-230ºC), natural discharge volume (600-1200 l/min), and widespread sinter (> 1km²).

Access to the site is excellent; it is located near a main road. The site has moderate relief with little vegetation and has around 50 hot springs (Goff et al, 1986).

México

Population (millions) - July 1998	98.55
Overall Electrification (% of population)	95%
GDP (billion US$) - 1997 est.	$694.3
Real GDP Growth Rate - 1997 est.	7.3%
Inflation Rate (CPI) - 1997	15.7%
Total Installed Capacity (MWe) - 1995	41071
Electricity Consumption per Capita (kWh) - 1997	1247
Energy Demand Growth Rate	6.0%
Prices (US¢/kWh) - June 1998 Residential Commercial Industrial	 4.87 11.06 4.20
Estimated Geothermal Potential (MWe)	**6,510**

Power Summary

Mexican power output reportedly increased 6.5% in 1997. In 1996, México generated 154,000 gigawatt-hours of electricity from 36 gigawatts (GW) of electric generating capacity. According to México's Energy Minister Tellez, the country will require 6 GW more capacity over the next six years. México is a major non-OPEC oil producer and has the world's sixth largest oil company (Pemex). Of the country's current installed capacity, hydrocarbons account for 54%, hydropower 28.8%, coal 6%, geothermal 2.4%, and nuclear power 2.1%. Under the country's industrial energy policy, a significant percentage of México's thermoelectric plants are slated for conversion to natural gas by 2005.

The Comisión Federal de Electricidad (CFE) owns most of México's installed electric generating capacity, however, this is beginning to change as CFE lacks the funds needed to meet México's soaring electric power demand.

In August 1998, México's energy secretariat published a seven-year plan for its energy sector. It must meet a projected increase in electricity demand of 3.9% to 6% a year until 2006. This will require more than 12-13 GW of additional generating capacity representing $25 billion in investment. Private investors are expected to provide the extra capacity to meet the increase in demand by funding 51% of the $25 billion investment.

Low oil prices have also led to increasing privatization of México's power sector; oil revenues account for about 40% of government income. The price of Mexican crude oil dropped to a record low of US$6.95 a barrel in

December 1998. For every dollar it drops, the Government of México (GOM) loses 1% of total revenue. In late March 1998, the GOM was forced to slash federal spending by $1.1 billion due to lower-than-expected oil prices. Recent budget cuts may force CFE to loosen its grip on the country's power sector and allow more privatizations. The GOM's inability to disengage itself from dependency on oil revenue has left the country vulnerable as oil prices drop.

The most common form of participation in the construction of independent power producers (IPP) has been through Build-Lease-Transfer (BLT) contracts. In the IPP process, the CFE generally picks the lowest bid per kilowatt-hour to provide electricity.

Under a BLT structure, private companies finance the construction of the power plant based on turnkey contracts with respectable contractors. The plant is then leased to CFE for operation for a term sufficient to provide return on investment. At the end of the term, CFE takes ownership of the plant.

Ambitious plans are underway to develop México's power industry under a Build-Own-Operate (BOO) structure but BLT arrangements continue to dominate the development the power projects. The 100 MWe Cerro Prieto geothermal plant awarded to Mitsubishi in October 1997 is a BLT. Project structures are assessed on a case-by-case basis.

CFE opened the bidding for three IPPs totaling 1,350 MWe in October 1998, including a 10 MWe geothermal plant at Las Tres Vírgenes and Monterey III, a planned geothermal and combined-cycle plant.

Private firms are already allowed to build and operate IPPs but opening up the distribution and sale of energy requires a change in the Mexican constitution.

In February 1999, Mexican President Ernesto Zedillo sent bill to Congress which would allow private investment in electricity generation, distribution, and sales. The Energy Ministry proposed selling off generation plant clusters, tendering concessions for regional distribution and control of a national transmission grid, and establishing a free electricity commodity market. The proposal specifies that nothing would be implemented until after the 2000 elections, thereby taking it out of the political arena. The Mexican Congress is scheduled to begin debate on CFE's privatization in March 1999.

While the government fiercely denied any immediate plans to invite greater private participation in the oil sector, analysts said the electricity overhaul could be a litmus test to see how Mexican society would accept a similar process for Pemex.

Government / Legislation

Comisión Federal de Electricidad (CFE)

CFE controls the generation, distribution, and transmission system of México. Pressure to privatize the country's power sector stems from the CFE's financial constraints following recent budget cuts. Despite the pressure, the country's switch to privatized power is still uncertain.

Secretariat of Energy

Article 27 of the Constitution gives exclusivity to the state in electricity and petrochemical markets on the basis that they are of strategic importance. Amendments to the Constitution state that generation of electricity less than 30 MWe can be private; over 30 MWe remains the State's responsibility but concessions are allowed. Also, the Mexican Government slowly but steadily is removing its tariff subsidies, the co-generation and other self-supply projects (generally of up to 30 MW) which have been allowed since 1992 will become more attractive, creating an additional source of demand.

México operates under Roman Law which prohibits what it does not permit.

Electric Power Law of 1975 — 1992 Amendment

In 1992, an amendment to the Electric Power Law of 1975 was adopted, allowing domestic and foreign private sector investment in generation in areas not related to the supply of power to the public in general. These areas are self-generation, co-generation, independent power production, and small production. Small-scale production is defined as projects with a capacity less than 30 MWe, self-supply for rural or off-grid communities up to 1 MWe, or exportation up to 30 MWe.

Independent production is the generation of electric power provided by a plant with a capacity of more than 30 MWe intended exclusively for sale to the CFE or for export.

Geothermal is under Water Laws

The geothermal division of CFE, the Gerencia de Proyectos Geotermoeléctricos (GPG), was transferred in October 1997 to the Generation area (Subdirección de Generación). This transfer included the fields of Cerro Prieto, Los Azufres, and Los Humeros, all which are part of GPG.

CFE is directly responsible for the exploration, development, and commercial use of geothermal energy to produce electricity, although development, construction, and operation of geothermal projects by private companies are already permitted.

CFE retains control of all geothermal projects. The development of geothermal resources currently comes under Mexican water law.

Geothermal Sites / Projects

México has an estimated 6,510-8,000 MWe of geothermal power potential.

Geothermal energy accounts for 2.6% of México's power generation with an installed capacity of 753 MW, five plants and 28 units and the potential to grow to 2,000 MW by the year 2010. México is the world's third largest producer of geothermal electricity.

México is estimated to have 8,000 MWe of geothermal resources, second in the world only to Indonesia. The country's first geothermal well was drilled at Pathé El Grande in Tzipathé, Hidalgo in 1954, and the National Commission of Geothermal Energy created the following year. The first commercial geothermal plant in Latin America, a 3.5 MWe unit, began its 14 years of operation at Pathé in 1959.

By 1987, 545 thermal localities had been identified which grouped around 1380 individual hot points including hot springs, hot water shallow wells, hot soils, fumaroles, etc.

The GOM will stop investing in geothermal development which accounted for $70 million in 1997. Five plants—Cerro Prieto IV, Tres Vírgenes I, Los Azufres II, Los Humeros II, and La Primavera I—will be developed as BLTs or BOTs. Several U.S. geothermal companies, e.g., CalEnergy, Caithness Energy, Calpine Corporation, and Ormat International, are active in México.

CFE categorizes geothermal applications as the following:

- Large central plants (100 MW, 300ºC) - compete with thermoelectric, oil, and gas plants, 2 to 4 ¢ US/kWh;
- Medium central plants (5 MW, 200ºC) - compete with diesel, 7 to 10 ¢ US/kWh;

- Small plants (0.5 MW, 150ºC) - isolated areas; and
- Micro plants (20 kW, 80ºC) - individual use.

México plans to increase it base of geothermal energy in one of three ways depending on the resource:

1. For projects > 10 MWe — CFE will call for open bids from EPC contractors to develop under BLTs. CFE will have two contracts: one for steam production and one for power generation. These will be six-year agreements. CFE expects to develop 100 MWe this way.

2. For projects of 300 kW in remote areas — CFE will purchase and install equipment using its own funds. A plant of this size can supply a population of 2,000 and can be used for domestic use, water wells, and small industrial applications.

   Approximately 150 t/h of water at 120ºC can produce 1 MWe. The plant costs approximately $750,000; the economics depend primarily on the well (Le Bert, 1997). CFE has to date installed four 300 kW units.

3. For extremely remote areas — CFE will initiate a program of installing 20 kW turbines to use warm surface water from rivers. CFE currently has a patent pending on this technology.

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1. Acoculco Caldera
2. Araró
3. Bahía Concepción
4. Cerro Prieto
5. Cerro Prieto Biphase Turbine Project
6. Domos de Zitácuaro
7. El Ceboruco-San Pedro
8. El Centavito
9. La Primavera
10. La Soledad
11. Laguna Salada
12. Las Derrumbadas
13. Las Tres Vírgenes
14. Los Azufres
15. Los Humeros
16. Maguarichic
17. Ojinaga
18. Pathé

19. Puertecitos
20. Santa Rita

Acoculco Caldera

LOCATION
In Central México at the extreme eastern part of the Transmexican Volcanic Belt (CVT); 110 km NE of México City (between the States of Puebla and Hidalgo).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	274-307

CHRONOLOGY
1981 - Regional reconnaissance study carried out (Romero).

1982 - Geothermal interest confirmed when high ratios of magmatic significance were measured (Polak et al).

1986 - Geological exploration continued; described extensive zones of hydrothermal alteration accompanied by cold acid springs and observed dead animals around gas emissions similar to "Kaipohans" features found in the Philippines (Castillo and De la Cruz).

1995 - CFE drilled well EAC-1 to 2000 m; temperature of 274ºC measured at the bottom of the well; no permeable productive zones were found.

1998 - IIE conducted environmental studies; investigation included mapping of hydrothermal alteration zones using remote sensing (Rodríguez, 1998).

NOTES
"Low permeability seems to be the general condition at production depths in this zone, so it is advisable to schedule the next exploratory phase based on directional wells, to have a better chance to target permeable zones. Attempts to define the geometry of the thermal anomalous area and the feasibility of its commercial exploitation will be done simultaneously" (Lopez-Hernandez and Castillo-Hernandez, 1997).

Araró

LOCATION
Michoacán State

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0

POTENTIAL (MWE)	-
TEMPERATURE (EC)	26-118

CHRONOLOGY
1990 to 1994 - Detailed stratigraphy and geophysical studies conducted.

1991 - Six exploratory and thermal gradient wells drilled; 123 m to 1350 m; found temperatures of 26ºC to 118ºC.

NOTES
Exploration stopped because Araró seems to be a fossil hydrothermal system, now extinct, as shown by its present low temperatures and its intense high temperature hydrothermal alteration at depth (Quijano-León and Gutierrez-Negrín, 1995).

Bahía Concepción

LOCATION
27.0 Lat., 112.0 Long. (Baja California Sur State).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1990 to 1994 - Detailed mapping done.

NOTES

Cerro Prieto

LOCATION
In the northwestern part of the country in the Mexicali Valley between the southeast end of the Imperial Fault and the northern end of the Cerro Prieto Fault; 30 km SE of Mexicali, close to the mouth of the Colorado River; between 115º12' and 115º18' longitude west and 32º22' and 32º26' latitude north (Baja California México State).

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	620
POTENTIAL (MWE)	620-1000
TEMPERATURE (EC)	305-350

CHRONOLOGY
1958 - First reconnaissance studies began.

1964 - Four deep exploratory wells drilled; found temperatures up to 300ºC.

1967 - 14 more wells drilled.

1973 - First two 37.5 MWe units of CP-I came online.

1979 - Second two 37.5 MWe units of CP-I came online.

1981 - 30 MWe unit of CP-I came online.

1981 to 1987 - CP-II and CP-III installed; each with two 110-MWe units.

1989 - Reinjection of waste brine began; up to 40% of waste fluid is now being injected.

GeothermEx estimated energy stored at the reservoir's present exploitation area at 2E16 kJ, representing an energy stock of 1,800 MWe/year (figure includes the subtraction of the energy that had been extracted to date).

1990 - CFE signed a contract with CP Latina (now Latina-Calpine) for their steam supply for a period of approximately 10 years at 800 t/h.

1996 and 1997 - Workovers performed showed that wells produce from zones deeper than average traditional feeding zones. Results showed that recovery can be greater than 100% in some cases using an appropriate workover technique (Ocampo et al, 1997).

February 1997 - Workshop held at Cerro Prieto to discuss drilling a 6 km deep well in the eastern part of the field to test the economic potential of deeper production zones as well as conflicting ideas about what lies beneath the Cerro Prieto geothermal field.

October 1997 - CFE selected Mitsubishi to build and operate the 100 MWe (four 25 MWe condensing units housed in a single power house) CP-IV project under a BLT.

Mitsubishi offered a $797/per installed kW and a levelized generating cost of 2.81¢/kWh.

Once the plant is built, CFE will take possession of it, have the right to operate it, and pay a quarterly rent for 15 years to meet credit amortizations. When the leasing period ends, CFE will own the plant.

1998 - CP-IV reached financial closing in April. Issued call for bids to supply 1,000 t/h of steam for CP-IV project; steam will be supplied by 20 wells drilled in the Ejido Nuevo León area to an average depth of 2800-3000 m.

2000 - CP-IV expected to be online by July 30.

NOTES

Cerro Prieto, the second largest geothermal field in the world, has nine units operating in three geothermal power plants (CP-I, CP-II, and CP-III). The total installed capacity of the field is 620 MWe—180 MWe from CP-I and 220 MWe from both CP-II and CP-III. All three are part of the Baja California Electrical System of CFE.

Theoretically, CP-I, II, and III can supply a maximum capacity of 906 MWe (Oropeza, 1998). More than 240 wells have been drilled in the field which covers an area of 15 km².

Cerro Prieto's 1996 capacity factor was 83.4%. In 1997, CFE and CP Latina (Constructora y Perforada Latina) operated an average of 129 wells, 101 and 28 respectively with an average production per well of 36.5 t/h. Since late 1995 Calpine Corporation has been a partner with Latina (Beall et al, 1997).

Four additional 25-MWe units are under construction as part of CP-IV. CP-IV is the first geothermal project to be constructed in México since 1994. It will increase Cerro Prieto's installed capacity 16% and the country's capacity 13% (Hiriart-Le Bert, 1998).

CP-V, to supply an additional 100 MWe, is under assessment.

On of CFE's main efforts for 1998 is to improve steam production in the Cerro Prieto field, e.g., the repowering of CP-I which is designed to save 115 t/h of steam.

Additionally, a geothermal-gas combined cycle plant project is being studied. The project would have a 14 MWe gas turbine and 25 MWe geothermal turbine. The latter would be designed to operate with saturated or superheated steam created by heat extracted from the gas turbine exhaust and could thus generate 30 MWe at peak hours.

Finally, a geothermal-combined cycle plant with geothermal pre-heating project is in the prefeasibility stage. This would consist of the construction and installation of a 440 MWe combined cycle plant. To lower the summer temperature peaks, a thermal inertia pond could complement the cooling tower.

Cerro Prieto Biphase Turbine Project

LOCATION
In the northwestern part of the country in the Mexicali Valley between the southeast end of the Imperial Fault and the northern end of the Cerro Prieto Fault; 30 km SE of Mexicali, close to the mouth of the Colorado River; between 115º12' and 115º18' longitude west and 32º22' and 32º26' latitude north (Baja California México State).

STATUS

Construction underway	
INSTALLED CAPACITY (MWE)	4.178
POTENTIAL (MWE)	4.178-60
TEMPERATURE (EC)	-

CHRONOLOGY

1996 - E&Co. lent $125,000 to Douglas Energy Co. (DECO) and Biphase de México (BIMEX).

1997 - Biphase power plant installed; minor modifications needed to address a problem of chemical scaling. Flow from Well No. E-15 added to increase power output to 4060 kW.

Well survey indicated the potential for three additional 20 MWe installations.

1998 - Turbine expected to be installed; full operation of plant.

NOTES

DECO and BIMEX designed project to generate power from wasted steam and brine flow energy.

The turbine project will generate 4.178 MWe of power. Roughly one-quarter of this will derive from the centrifugal separation of the steam and brine (geothermal water) mixture that flows from Well No. 103, while the balance of over 3 MWe will be produced by passing the separated steam through a small turbine attached to the biphase unit before it flows to the existing main steam turbine in the power plant. The biphase thus capitalizes on the steam and brine that would otherwise be lost in a conventional cyclone separator. The increase in energy produced from the well under consideration will be of the order of 45%.

This system has been tested on earlier geothermal fields with positive results. The Cerro Prieto biphase will further showcase its commercial capacity by generating power for CFE. With success, the project is due to precipitate duplicate initiatives in the Cerro Prieto field and in other geothermal areas, and to confirm that geothermal is both clean and profitable energy.

E&Co's investment played a critical "but for" role in the biphase project's evolution, enabling Douglas Energy to advance its negotiations with other financing sources and present itself as bankable to investors in future projects.

The biphase power plant was installed in late 1997 and has undergone minor modifications to address a problem of chemical scaling. The steam turbine unit has been fabricated and is expected to be installed in the next few months and be in full operation by the end of 1998.

The project is jointly supported by DOE and the

California Energy Commission (CEC) under the geothermal loan program. Additional support was received from E&Co.

CFE will purchase the power generated by the plant. The revenue will be used to pay O&M and repay the CEC and E&Co. loans.

CFE has stated its intention to install additional biphase power plants when the first unit is successfully demonstrated. The optimal installation increment appears to be 20 MWe.

The installed cost, including electrical transmission lines, is estimated to be $11 million or $523/kWh. The effective steam rate is 51 lb/kW (Cerini et al, 1997).

Domos de Zitácuaro

LOCATION
19.5 Lat., 100.0 Long. (Michoacán State).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE) 0

POTENTIAL (MWE) -

TEMPERATURE (EC) -

CHRONOLOGY
1990 to 1994 - Detailed mapping done.

NOTES
Exploration stopped due to existence of an outcropping metamorphic basement whose fracturing and probable permeability seem to be very low (Quijano-León and Gutierrez-Negrín, 1995).

El Ceboruco-San Pedro

LOCATION
21.0 Lat., 105.0 Long. (Nayarit State).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE) 0

POTENTIAL (MWE) -

TEMPERATURE (EC) 23-180

CHRONOLOGY
1990 to 1994 - Hydrology, tectonics, volcanology, and geophysical studies conducted.

1992 to 1994 - 10 exploratory and thermal gradient wells drilled; 124 m to 2801 m; temperatures 23ºC to

180ºC.
NOTES

El Centavito

LOCATION Baja California Sur State	
STATUS Power plant(s) on site	
INSTALLED CAPACITY (MWE)	0.3
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES 300 kW plant used for irrigation.	

La Primavera

LOCATION Jalisco State.	
STATUS Well(s) or hole(s) drilled	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	95
TEMPERATURE (EC)	305
CHRONOLOGY 1980s - Eight wells drilled in La Primavera, detecting a reservoir in fractured igneous rocks with temperatures up to 305ºC (Hernandez-Galán, 1988). 1989 - CFE planned to install 5 MWe wellhead unit. 1998 - Primavera I obtaining licenses. December 2000 - 75 MWe Primavera I expected online.	
NOTES Primavera II - 20 MWe under assessment.	

La Soledad

LOCATION Jalisco State.	
STATUS	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-

TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES	

Laguna Salada

LOCATION
32.5 Lat., 113.5 Long. (Baja California State).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	112-125

CHRONOLOGY
1990 to 1994 - Geophysical studies conducted.

1994 - Three exploratory wells drilled from 1777 to 2396 m; temperatures of 112ºC to 125ºC.

NOTES

Las Derrumbadas

LOCATION
Puebla State

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1994 - Exploratory well drilled.

NOTES

Las Tres Vírgenes

LOCATION
In the Ecological Reserve of Desierto de Vizcaino, home to the bighorn sheep and other unique endemic species; 35 km NE of Santa Rosalía; area for development is limited to 7,500 m²; access to the area is by an 18-km long gravel road; 720 masl (Baja California Sur State).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0

POTENTIAL (MWE)	25
TEMPERATURE (EC)	245-280

CHRONOLOGY

1984 to 1993 - Geological, geohydrology, geophysics, geochemistry, and petrography studies conducted by CFE; exploratory boreholes drilled.

1997 - Drilled seven wells to depths of 1291 to 2500 m; four wells are producing at 25-30 t/h steam and 50-80 t/h water, three are injection. The water is alkali chloride (sodium-chloride); geothermometer temperatures have reached 280ºC.

1997 - International bidding opened for 10 (2 x 5) MWe Las Tres Vírgenes I as a BLT.

1998 - Las Tres Vírgenes I due for award at end of year.

2000 - First Stage (Tres Vírgenes I); Two 5 MWe plants expected to be online. The first unit will be built near wells LV-1 and 5, the second near LV-3 and 4. Steam consumption required is 24 kg/s.

2001- Second Stage (Tres Virgenes II); an additional 15 MWe expected to be online.

NOTES

The Las Tres Vírgenes field has different characteristics compared to México's other geothermal resources, e.g., reservoir located in the basement, low permeability, low pressure, and located in an ecological preservation area.

Present knowledge indicates that the geothermal reservoir is of small size with limited fluid recharge (Lopez et al, 1995).

Due to the location of the field in an ecological preserve, CFE has decided that 5 MWe condensing units are appropriate. A binary cycle would also be possible but only if it uses steam (CFE has already bought small capacity plants to use the separated water). The estimated useful life of the resource is 25 years.

Las Tres Vírgenes will supply electricity to the small, isolated Santa Rosalía grid where the maximum present demand is 6 MWe supplied by diesel generators at high cost. A large increase in demand is expected.

The approximate cost of a 5MWe plant with two wells including exploration is $13 million or 4¢ US/kWh (Le Bert, 1997).

Los Azufres

LOCATION

In central México in the Sierra de San Andrés, 220 km

NW of México City; covers approximately 11,100 hectares in a national forest protection zone; located in the Mexican Volcanic Belt (MVB) between the 19º45'30"-19º50'30" north latitude parallels and the 100º38'30"-100º43'00" west longitude meridians; 2800 masl (Michoacán State).	
STATUS Power plant(s) on site	
INSTALLED CAPACITY (MWE)	88
POTENTIAL (MWE)	88-610
TEMPERATURE (EC)	280-340

CHRONOLOGY

1950s - CFE initiated geophysical, geological, and geochemical exploratory studies.

1972 - Exploration renewed.

1977 - First production wells drilled.

1982 - First five 5-MWe backpressure units (25 MWe) went online.

1988 - 50 MWe condensing unit began commercial operation at Tejamaniles.

1989 - 5 MWe backpressure unit (U-8) began operation.

1990 - 5 MWe backpressure unit (U-9) began operation.

1991 - Marítaro project, to install two 20 MWe condensing units, was bid on but not signed.

1993 - 5 MWe backpressure unit (U-10) and two 1.5 MWe binary Ormat units began operation.

1996 - Two 5-MWe backpressure units transferred to Miravalles in Costa Rica.

March 1997 - CFE held a seminar in Morelia to discuss possible geothermal projects.

1997 to early 1998 - Unit 7 (50 MWe) down due for generator repair. Marítaro project canceled.

1998 - Encouraged by contract received on Cerro Prieto-IV, CFE prepared bid for 100 MWe Los Azufres II project as a BLT. Estimated total project costs is $116 million for field and plant investment. O&M costs of Field and Plants is 13¢/kWh and 45¢/kWh respectively. Additional assumptions: 8% interest for 12 years. Cost of generated energy is 2.4¢/kWh and the IRR is 12.7% (Taboada, 1998).

1999 - Bid expected from CFE for four 25-MWe units (100 MWe) at Los Azufres III.

2000 - 100 MWe of Los Azufres II expected online by July.

2003 - Bid expected from CFE for two 25-MWe units at Los Azufres IV.

NOTES

After Cerro Prieto, Los Azufres ("The Sulphurs") is the second most important geothermal power project in México. The field has ten plants with an installed capacity of 88 MWe—seven 5-MWe backpressure units, one 50-MWe condensing unit, and two 1.5-MWe binary units. Of the total, 63 MWe are located in the field's southern zone (Tejamaniles), 25 in the northern (Marítaro).

An average of 19 wells (out of a total of 67) were in production in 1997, all operated by CFE. Average annual flow rate was 830 t/h. Los Azufres's capacity factor is 93.6%.

The development strategy is to install condensing units on sites where there is more knowledge of the reservoir and move the backpressure units to sites where more information is needed.

CFE is increasing the generation capacity of the field to 188 MWe with the installation of four 25 MWe condensing units under the Los Azufres II project (El Chino I and II).

An additional 100 MWe at Los Azufres III and 50 MWe at Los Azufres IV are also under assessment.

According to CFE, recent mathematical studies concluded that the water table has a potential of 470 MWe—350 in the northern sector and 120 in the southern. Volumetric assessments of the resource indicate that the Tejamaniles sector can sustain an energy production capacity of 230 MWe and the Marítano sector a capacity of 480 MWe (Taboada, 1998).

Environmental effects due to geothermal production were observed...Leaking evaporation ponds, discharging pipelines and overflowing reinjection wells represent the principal contamination sources in Los Azufres (Birkle and Merkel, 1998).

After 16 years of continuous operation, the reservoir pressure has decreased due to the large amount of geothermal fluids extracted...The average pressure drop in the south is 0.71 bar/year, and 0.33 bar/year in the north...The steam production has been stable or in some cases increased, while the brine production has decreased considerably (Torres-Rodriguez, 1998).

In addition, Los Azufres has been the site of the Geothermal Training Center since 1995 where CFE trains personnel from throughout Latin America in geothermal exploration, engineering, operations, small-scale plants (10-400 kW), and small-scale direct uses.

CFE is pursuing the development of several direct use projects at Los Azufres including, in order of priority, wood drying, fruit dehydration, and aquaculture.

Los Humeros

LOCATION
Within the Los Humeros Caldera (a Quaternary Caldera) in the eastern portion of the Mexican Volcanic Belt, 200 km east of México City (between Puebla and Veracruz States).

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	35
POTENTIAL (MWE)	35-80
TEMPERATURE (EC)	300-400

CHRONOLOGY
1968 - CFE carried out exploration studies.

1981 - H-1 well drilled to 1458 m confirmed the existence of a geothermal reservoir.

1990 - Unit 1 began operation.

1993 - Unit 7, last of seven 5 MWe backpressure units, began operation.

1993 - The Geothermal Energy New Zealand Limited (GENZL) completed assessment using the MULKOM reservoir simulator; estimated that the reservoir has an electrical generation capacity of 80 MWe for 25 years, using a single porosity model.

1995 - Field studied to find out the possibility of incorporating new turbo-generators in strategic locations.

2001 - 15 MWe at Humeros II expected online by December.

NOTES
Wells in Los Humeros boast the highest recorded temperatures in México—400ºC. Los Humeros has seven 5 MWe backpressure units for a total installed capacity of 35 MWe. In 1997, an average of 20 wells were in production with an average production of 27 t/h. Los Humeros's capacity factor is 112%. CFE operates all the wells.

There are plans to increase the field's production to 50 MWe with the installation of 15 MWe under Los

Humeros II. In addition, 25 MWe under Los Humeros III is under assessment.

In addition, an edible mushroom growing plant, using heat from well H-1, has operated at Los Humeros since 1992. The replacement of fossil fuels and/or electricity by geothermal steam has lowered production, incubation, and pasteurization costs.

Maguarichic

LOCATION
Chihuaria State

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	0.3
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES
Maguarichic has 600 inhabitants and 150 houses. The power produced by the 300 kW plant is used for domestic uses.

Ojinaga

LOCATION
Chihuaria State

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	0.3
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES
300 kW plant used for domestic uses.

Pathé

LOCATION
Hidalgo State

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	3.5
POTENTIAL (MWE)	-

TEMPERATURE (EC)	-

CHRONOLOGY
1954 - First geothermal production well drilled in México.

1959 - First commercial geothermal plant in Latin America, a noncondensing 3.5 MWe unit, began operation.

1973 - Unit taken offline due to steam supply problems.

1990 to 1994 - Tectonics studies conducted.

1994 - Exploratory well drilled.

NOTES

Puertecitos

LOCATION
Baja California State

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	0.3
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES
300 kW plant used for tourism.

Santa Rita

LOCATION
20.5 Lat., 102.5 Long. (Jalisco State).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	160

CHRONOLOGY
1990 to 1994 - Detailed mapping done.

NOTES
Exploration stopped because all rhyolitic domes were much older than anticipated (Quijano-León and Gutierrez-Negrín, 1995).

Nicaragua

Population (millions) - July 1998	4.58
Overall Electrification (% of population)	48%
GDP (billion US$) - 1997 est.	$9.3
Real GDP Growth Rate - 1997 est.	6.0%
Inflation Rate (CPI) - 1997	11.6%
Total Installed Capacity (MWe) - 1995	430
Electricity Consumption per Capita (kWh) - 1997	313
Energy Demand Growth Rate	6.1%
Prices (US¢/kWh) - June 1998	
Residential	14.19
Commercial	15.85
Industrial	12.45
Estimated Geothermal Potential (MWe)	**3,340**

Power Summary

Nicaragua has the lowest per capita electricity consumption and the least efficient energy production in Central America. Only 48% of the population has access to electricity. Nicaragua currently has nine power plants on the national grid: two thermal, two gas, one geothermal, two hydro, and two mini-hydro. Many of the plants are well over 20 years old and little maintenance has been done since 1979.

Nicaragua is a net importer of petroleum, spending US$44 million per year; 60% of the country's installed capacity is thermal power. The balance of Nicaragua's installed capacity is 5% gas, 11.5% geothermal, and 22.5% hydroelectric.

In order to satisfy the growing demand for electricity under the Plan of Expansion, 1997-2015, projections indicate the necessity of putting into operation an additional 1,159 MWe which includes retiring 280 MWe. Of this total, 185 MWe would be from geothermal power, specifically: 20 MWe from Momotombo, 50 MWe at San Jacinto-Tizate, and 70 MWe at El Hoyo-Monte Galán. Rural electrification is another priority of the Government of Nicaragua (GON).

The GON hopes to attract private investment over the next few years to help fill its immediate energy needs, focusing on projects with short completion dates. The state utility, Empresa Nicaragüense de Electricidad's (ENEL), ability to attract investment will be affected by its weak financial position and losses, estimated as high as 6% of GDP, which are further undercut by the GON's large balance of payments deficit. Debt relief following Hurricane Mitch, plus ENEL's efforts to cut losses and increase tariffs, may promote additional foreign investment.

Nicaragua's long-term plans focus on developing its significant geothermal resources. Also in the long-term, Nicaragua anticipates being a net exporter of energy to SIEPAC, the Central American interconnected grid.

Although not to the extent in Honduras, Hurricane Mitch caused substantial damage in Nicaragua. The country estimates its economic damage from the hurricane at $1 billion, 47% of its annual GDP. Mud slides caused by excessive rain killed more than 1,500 people near the Casita Volcano and completely destroyed the towns of El Porvenir and Rolando Rodríguez.

In the power sector, Hurricane Mitch brought down more than 500 electricity poles, 150 transformers, and 37,000 meters of transmission lines mainly in the Matagalpa, Jinotega, Madriz and Somotillo Departments. The damage caused ENEL's generation capacity in Managua to drop from 57.4MWe to 37.4MWe at the Santa Barbara Hydropower Plant (50 MWe) where some of the reservoirs were filled. The IDB estimates that $6m will be needed to repair the electricity sector in Nicaragua.

The GON launched an economic reform, pro-business and pro-trade program in 1990 following elections held after the Sandinista's 12-year dictatorship. The Chamorro Administration privatized 351 state enterprises, lowered inflation from 13,500% to 12%, and cut foreign debt in half. President Aleman was elected in 1994.

Government / Legislation

Empresa Nicaragüense de Electricidad (ENEL)

ENEL, the state utility, handles the exploitation, transport, and distribution of the electricity produced by any type of plant. The GON plans to sell-off the generation and distribution assets of ENEL in 1999 but retain the company's transmission divisions in state hands. Pricewaterhouse Coopers is conducting a study of ENEL in the lead-up to privatization.

Instituto Nicaragüense de Energía (INE)

The energy sector of Nicaragua was nationalized by the Sandanistas in 1979 and all municipal power companies and rural electric cooperatives were absorbed by INE. In early 1995, INE's business functions of supplying electricity to the public were transferred to ENEL.

INE is responsible for regulating, supervising, and controlling Nicaragua's energy sector and for applying the energy policies set by the Comisión Nacional de Energía

(CNE). It is expected that INE will be privatized within the next few years.

El Deparamento de Recursos Geotérmicos of INE is responsible for geothermal development in Nicaragua.

Law No. 272 - Electrical Industry Law (April 1998)

The new Electrical Industry Law establishes that the privatization of the country's generation, distribution, and commercialization activities will occur two years after the Law's enactment. The Law also establishes the legal regulations for the generation, distribution, commercialization, and import and export of electricity.

The Law gives the GON the authority to privatize generation and distribution, including the privatization of ENEL within two years of passage of the Law. Transmission will remain with the State. (BOO and BOT contracts were allowed for private generation companies prior to the passage of the Law.)

Electrical industrial activities must adhere to the following objectives:

- Quality, continuity and security in electrical service,
- Minimization of the cost of electrical service, based on the efficient use of energy resources,
- Promotion of an effective competition and attract private capital,
- Promotion of the efficient use of electricity, and
- Provide electrical service following rules for environmental protection and industrial and personal safety.

In addition, the Law establishes a spot and forward market for electricity, allows for the free import and export of electricity, provides a three-year tax moratorium on imported machinery and equipment used in energy generation and distribution, and guarantees an indefinite tax break on all kinds of fuel used in electricity generation.

Finally, the Law created the Comisión Nacional de Energía (CNE). CNE is in charge of forming the objectives, policies, strategies, and general guidelines for the country's energy sector.

Ante-proyecto de Ley de la Industria Geotérmica (Draft Geothermal Law)

The Draft Geothermal Law provides a legal framework which is designed to protect the country's interests while encouraging the development of geothermal resources and establishing a regime for the private-sector development of those resources.

The Draft Law defines two types of concession: exploration and exploitation. It outlines three steps for developing a project: acquiring an exploration concession, acquiring a PPA, and acquiring a foreign permission document. Additionally, the project developer must post a bond equal to 25% of the total project cost. The core concepts of the Draft Law are:

- Geothermal resources are the property of the State.
- All activities related to exploring and exploiting geothermal resources are of national interest.
  - For all legal purposes, geothermal resources are declared for public use and rational exploitation.
  - The granting of an exploitation concession is given on the approval of INE that:
    1. the soliciting company presents a Development Plan for the project, and
    2. first draft of a contract for buying and selling the steam between the concession and ENEL or its successor.
- Incentives to private investment.

The U.S. geothermal industry, through the Geothermal Energy Association (GEA) and DOE, has commented on the Draft Law. The area limitations on concession size was identified as one of the more problematic provisions in the Draft Law which were limited to 100 km² for exploration and 20 km² for exploitation. GEA also recommended that the requirement that steam be sold to the State at an established price be eliminated. The complex and restrictive regulations may put Nicaragua in a less competitive position vis-à-vis other countries and dissuade foreign investment.

To date, Nicaragua's approach to geothermal development has been to grant exploitation permits to private companies on a negotiated basis. Once the resource has been identified, the GON will put the project out to bid, offering a preference to the company that conducted the initial resource assessment.

The GON cannot offer any pricing incentives; geothermal prices must be competitive with those of thermal and other power projects. It is estimated that geothermal can be priced at 6.5¢/kWh at El Hoyo-Monte Galán while Enron is offering to sell residual oil to offshore barge plants for power generation at 5.5¢/kWh.

The Tax Law (Ley de Justicia Tributaria)

The Tax Law exempts all equipment and machinery earmarked for electricity generation for public use. Companies are also exempt from taxes until they recover their investments.

General Law of Environmental and Natural Resources No. 217-96

The Law assigns geothermal concession under the framework of laws which regulate natural resources, fundamentally, handles geothermal as a mining resource.

Geothermal Sites / Projects

Nicaragua has an estimated 2,000-4,000 MWe of geothermal power potential.

The GON has as a priority the development of geothermal power and sees its role as facilitator rather than developer or operator. The GON's goal is to have 200-300 MWe of geothermal installed capacity by 2001.

On October 11, 1994, the GON presented a plan to the U.S. to develop 500 MWe of geothermal capacity over the next 12 years; the plan was discussed at the Summit of the Americas (Lawrence, 1998).

Nicaragua annually spends US$44 million to import oil for electric generation. The installation of geothermal power plants for base load could rapidly displace thermal plants and help the country's trade balance. The development of Nicaragua's geothermal resources would not only solve the energy crisis of the country, but would make it an exporter of energy to the rest of Central America through SIEPAC.

With SIEPAC, Nicaragua could develop more of its geothermal resources to sell as baseload to the region while importing peak load capacity. Without SIEPAC, Nicaragua would develop only those geothermal resources it can use domestically or export as baseload to its immediate neighbors.

Nicaragua is endowed with large geothermal potential due to the presence of volcanoes of the Marrabios range along the Pacific Coast. Geothermal investigations began in 1966 with a study by the Italian company, Electroconsult. In June 1969, the GON signed a contract with Texas Instruments Inc. to carry out a geothermal research program in western Nicaragua. Completed in 1971, the studies identified two sites with high enthalpy potential: Momotombo and San Jacinto-Tizate. Following the catastrophic earthquake of December 1972 which leveled Managua, the GON cut the program.

The commercial exploitation of Momotombo started in 1983, when the first unit of 35 MWe was put in operation. The second unit of 35 MWe was installed in 1989. Geothermal energy accounted for 11.55% of Nicaragua's electricity generation in 1997. Due to poor maintenance of its steam wells and over-development of the reservoir, Momotombo was only producing 12 MWe as of Summer 1998. The GON has issued two bids for field reclamation.

Geothermal investigations identified ten areas of greatest interest: Cosigüina Volcano, Casita-San Cristóbal Volcano, Telica-El Ñajo Volcano, San Jacinto-Tizate Volcano, El Hoyo-Monte Galán Volcano, Momotombo Volcano, Managua-Chiltepe, Tipitapa, Masaya-Granada-Nandaime, and Isla de Ometepe. With the exception of Ometepe, all of the zones are high enthalpy.

Currently, one project is in development (San Jacinto-El Tizate), one in the study stage (Masaya-Granada-Nandaime), and three with concessions (El Hoyo-Monte Galán, El Ñajo-Santa Isabel, and Triton Mining Corporation). In addition, Nicaraguan authorities are undertaking a study to identify 60 rural, small-scale geothermal sites. Twelve have been identified to date (Germain, 1998).

1. Casita-San Cristóbal
2. Cosigüina
3. El Hoyo-Monte Galán
4. El Ñajo-Santa Isabel
5. Geothermal Energy Master Plan
6. Isla de Ometepe
7. Managua-Chiltepe
8. Masaya-Granada-Nandaime
9. Momotombo
10. Nagrote-La Paz Centro
11. San Jacinto-El Tizate
12. Tipitapa

13. Triton Mining Corporation

Casita-San Cristóbal	
LOCATION Volcán Casita is located within the Cordillera Los Marrabios, a 70 km long volcanic chain that extends from the northern shore of Lake Managua to Chinandega, 1405 masl.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY October 1998 - Hurricane Mitch triggered a deadly avalanche and breakout flow of Volcán Casita. The mud slides killed more than 1500 people, displaced hundreds more, destroyed several towns and settlements, and disrupted the Pan American Highway at numerous bridges. The towns of El Porvenir and Rolando Rodriguez, combined population of approximately 2000, were completely destroyed. The disaster was produced by the coincidence of two discrete events: an avalanche on the southern flank of Volcán Casita, and extraordinarily heavy rains. Normal October rainfall is 328 mm. October 1998 rainfall totaled 1984 mm, more than six times normal.	
NOTES	

Cosigüina	
LOCATION Located in the extreme north of the Cordillera Los Marrabios near the Gulf of Fonseca in Chinandega, close to the Pacific Coast.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES Volcán Cosigüina has been selected to be a pilot project	

for rural electrification and direct use of a low enthalpy geothermal resource. The area is predominantly an agriculture zone, and low-enthalpy geothermal fluids could be used intensively to dry grains, in fish farming, and in greenhouses. The project site would be located off-grid and power generated by the plant would serve the local rural population.

This site is in the very beginning stages of development. Geothermal potential is not known.

El Hoyo-Monte Galán

LOCATION
Within the Cordillera Los Marrabios in western Nicaragua, 50 km north of Managua.

STATUS
Exploration concession

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	150-200
TEMPERATURE (EC)	200-250

CHRONOLOGY
1980 - OLADE with funding from the Italian Government, conducted a prefeasibility study.

1985 - French company, SPEG, made a magneto-telluric study of area.

1994 - Agreement in Principle signed by the GON and Trans-Pacific Geothermal Corporation (TGC).

December 1995 - INE granted a geothermal exploration concession to TGC to determine the possibility of generating 50-150 MWe using geothermal fluids.

January 1996 to February 1997 - TGC performed several geologic and geophysical investigations including analyses of satellite and aerial photo imagery, microearthquake studies, ground magnetic (GM) survey, self potential (SP) survey, MT/CSAMT survey, one-meter temperature survey, geologic mapping and gas geochemistry. The GM, SP, MT/CSAMT, and one-meter temperature surveys, data integration, and final report were funded in part by the U.S. Department of Energy.

The studies identified various anomalies indicating a large geothermal resource characterized by shallow seismicity, fumarole activity, surface fractures, and high subsurface temperatures.

Eight preliminary slimhole drill sites were chosen to test the following four areas: upper regions of the El Royo and Picacho Volcanoes, east-northeast base of the El Hoyo Volcano, Cerro Colorado, and the ring fracture system of Monte Galán Caldera.

Based on volumetric calculations and an integrated analysis of geoscientific data, the potential of the TGC concession is estimated at 120-150 MWe for 30 years at El Hoyo, and 40-50 MWe for 30 years at Cerro Colorado.

TGC signed a Joint Venture Agreement with Calpine Corporation.

Present - TGC-Calpine negotiating a PPA with ENEL; arranging a drilling permit for eight slimhole wells. Drilling will begin upon signature of a PPA with ENEL.

NOTES
The objective is to install 105 MWe in three 35 MWe modules. The estimated price is 6.5¢/kWh.

The cost of a 50 MWe plant, including all capital costs, interest during construction, insurance, start-up costs, and contingencies is estimated at $135 million; for the total 105 MWe, $260 million.

El Hoyo-Monte Galán has been approved under the U.S. Initiative for Joint Implementation (USIJI). USIJI gives certificates to projects which reduce or avoid CO2 emissions. Yet to be resolved is the worth of these certificates; how they can be "commercialized."

Assuming 105 MWe at 95% availability, the project would prevent the emission of 527,7890 metric tons per year or 18.5 million metric tons total of CO2 over 35 years. Using a value of $15/ton (the Nevada Public Service Commission value in 1992 dollars), the CO2 offset would equal $8 million per year.

E&Co. provided investment support to assist TGC during the final negotiations of the three agreements necessary to advance to financing: the PPA with ENEL, the exploration concession, and the investment contract with the GON.

El Ñajo-Santa Isabel

LOCATION
Located adjacent to San Jacinto-El Tizate, east of León.

STATUS
Exploration concession

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	60
TEMPERATURE (EC)	235-265

CHRONOLOGY
August 1997 - Unocal Geotérmica Nicaragua S.A., a subsidiary of Unocal Geothermal International, received

an exploration concession for 100 km² in August with a proposal to install a 60 MWe plant.

Unocal carried out the following activities in the last quarter of 1997: geological mapping, geochemistry studies, geophysical surveys, and satellite image interpretation. Gas geochemistry data indicate temperatures of 235ºC and 265ºC.

Present - Unocal is negotiating a PPA with ENEL.

NOTES

Geothermal Energy Master Plan

LOCATION
Countrywide

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	NA
POTENTIAL (MWE)	NA
TEMPERATURE (EC)	NA

CHRONOLOGY
1982 to 1983 - Reconnaissance funded by IECO and OLADE.

1998 - Geothermal Energy Master Plan funded by the IDB. GeothermEx selected by international bid.

NOTES
The Master Geothermal Energy Plan's main objective is to reevaluate and classify Nicaragua's geothermal resources in terms of electrical generation potential, and to plan for the exploration and development activities that will follow.

Funded by the IDB, the Master Plan will also help establish limits and concession conditions for private or state companies, serving at the same time as a document to present and promote the geothermal areas of the country. For each area identified, the Plan will include the following information:

(1) General description and geographic limits,
(2) Description of available scientific data,
(3) Additional geoscientific investigations,
(4) Data synthesis and reinterpretation,
(5) Development of a preliminary geothermal model,
(6) Preliminary evaluation of the resource, in terms of electrical power,
(7) Evaluation of environmental aspects,
(8) Specification of studies needed to reach the feasibility stage, and.
(9) Estimation of the costs to reach the feasibility stage.

Isla de Ometepe

LOCATION
An island located in Lake Nicaragua, approximately 120 km from Managua and 17 km from the nearest mainland.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1980 to 1981 - Identified during reconnaissance.

1998 - $100 million IDB program to include interconnection via an underwater cable to the island under consideration.

NOTES
Ometepe has been selected to be a pilot project for rural electrification and direct use of a low enthalpy geothermal resource. A barge loaded with diesel fuel makes a weekly run across Lake Cocibolca, which hosts unique species, to the island generating station. The risk of an accident is high. The plan is to construct an underwater cable from the mainland to the island. Development of geothermal power on the island could replace this expensive investment.

The GON has targeted the island of Ometepe for tourism development. In 1997, less than 20,000 tourists visited the island which presently has 90 hotel rooms. The German aid agency, GTZ, is assisting in the development of a tourism plan for Ometepe.

Managua-Chiltepe

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES

Masaya-Granada-Nandaime

LOCATION

STATUS Prefeasibility study	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1980 - OLADE conducted a prefeasibility study with Italian cooperation; identified area as having great prospects for geothermal development.

NOTES
The GON has asked the European Union to fund a feasibility study.

This project is not included in the Geothermal Energy Master Plan due to its early development stage.

Momotombo

LOCATION
On the southern slope of the Momotombo Volcano, 1200 masl, in the Cordillera Los Marrabios.

STATUS
Power plant(s) on site

INSTALLED CAPACITY (MWE)	70
POTENTIAL (MWE)	-
TEMPERATURE (EC)	220-300

CHRONOLOGY
1966 - First information from the government related to geothermal activity in Nicaragua.

1969 - First systematic investigations were begun with support from the United Nations; objective was to identify installing a 30 MWe plant in either Momotombo or San Jacinto.

1971 - Report identified Momotombo as an area which had characteristics appropriate for exploitation.

1974 - GON contracted Electroconsult and other companies to drill four exploratory wells and conduct a feasibility study; showed the feasibility of a 35 MWe plant.

1975 to 1978 - GON hired Energéticos and CalEnergy to complete the first phase of drilling; 28 wells drilled to depths between 320 and 2250 m.

1982 to 1984 - Second phase of drilling carried out; six wells drilled.

October 1983 - First Ansaldo 35 MWe unit came online.

1989 - Second Ansaldo 35 MWe came online.

1998 - Two units' combined production was 12 MWe from six wells as of June.

1998 - ENEL issued a request for a public bid for field reclamation and plant rehabilitation; pre-qualified four international geothermal development companies (Oxbow, Bufete Industrial, Caithness, and Ormat). Of the four companies, only Ormat submitted a bid and, due to Nicaraguan law, the bidding process was voided and a second request for bids issued.

The program proposed is a 15-year development, operation, and maintenance concession and PPA. ENEL will keep title to the plant, well field, etc.

NOTES

Formally known as the Central Geothermal "Patricio Argüello R." Plant, Momotombo has two 35 MWe single-flash units which have been online since 1983 and 1989 respectively. The field, including 43 wells, was developed and is operated by ENEL.

Momotombo has an installed capacity of 70 MWe but, due to reinjection and over-development problems, is currently producing only 12 MWe. Of its 43 wells, only 6 are operating.

The field principally is producing from a shallow reservoir of less than 1000 m. All geothermal fluids have been discharged into Lago Managua; there is no reinjection.

Due to the overexploitation of the field and a total lack of reinjection during the 1980s, the power output at Momotombo has declined significantly. As of June 1998, the plants' combined production was 12 MWe.

Geological studies indicate that both intermediate (1000±m) and deep (2500m) geothermal reservoirs exist at Momotombo. There is sufficient evidence to verify the existence of at least 35+ MWe of geothermal steam and a very strong possibility of bringing the field back to the full 70 MWe or more (Dick, 1998).

Under the Stabilization Project implemented with funds from the Investment Fund of Venezuela (FIV), ENEL directed the drilling of three production replacement wells (MO-41, MO-42, and MO-43) of which only MO-42 was successful, producing 3 MWe in stable production ENEL has issued two bids in 1998 for field reclamation and plant rehabilitation.

The price for electricity produced at the Momotombo Power Plant is very high, 4.8-5.3¢/kWh compared to 3.5-4.0¢/kWh for hydro-power. Plants on the fields under development will have prices comparable to those found

in other Central American countries, 5.0- 5.5¢/kWh.

Nagrote-La Paz Centro

LOCATION Located on the banks of Lake Managua immediately to the south of the Momotombo field.	
STATUS Concession	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES Caithness was awarded an exploration concession.	

San Jacinto-El Tizate

LOCATION	
STATUS Concession	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	25-120
TEMPERATURE (EC)	200-289

CHRONOLOGY

1971 - Report identified San Jacinto-El Tizate as an area which had characteristics appropriate for exploitation.

1980 - OLADE, with funding from the Italian Government, conducted a prefeasibility study.

May 1993 - Intergeoterm, a consortium composed of ENEL and the Russian company, Burgazgeoterm (22.2% and 77.8% ownership respectively), received an exploration concession from INE; initial plan to install 115 MWe.

1993 to 1995 - Intergeoterm drilled seven exploration-production wells at depths between 724 and 2335 m; last well (SJ-7) was not finished due to financial problems; encountered temperatures of 264ºC to 289ºC; well tests indicated cumulative capacity of wells SJ-4, SJ-5, and SJ-6 is 25 MWe.

Present - In order to continue the development activities at San Jacinto-Tizate, Intergeoterm is searching for a financially strong partner.

NOTES

The plan is to construct seven power units with a total capacity of 120 MWe and a total cost of $250 million, beginning with two 2.5 MWe units.

The basic equipment, e.g., turbines, generators, separators, and fittings for the first stage of the 51 MWe facility (2 x 2.5 + 2 x 23) has been manufactured in Russia. The advanced civil works on the steam field are completed (Povarov, 1998).

SC Kaluga Turbine Plant (KTZ) has manufactured two geothermal power plants of unit container type which will be shipped assembled. The prototypes for these turbines were units manufactured by KTZ that have been used for a long time for driving feed pumps at nuclear power stations with VVER reactors of 1000 MWe capacity. These turbines have an exceptionally efficient flow path and are very reliable. During the last 20 years of operation, no blades or rotors have failed and there were no other accidents (Povarov, 1998).

The project is stalled due to lack of financing. Intergeoterm is currently talking to several potential partners, including Daimler-Benz, in order to obtain the financial capability to continue the field's development. Once a partner is found, ENEL will cease its involvement in the project.

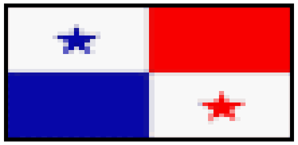
Tipitapa

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES	

Triton Mining Corporation

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	5
TEMPERATURE (EC)	-
CHRONOLOGY Triton is arranging permits with the Ministerio del Ambiente y Recursos Naturales (MARENA) and INE for	

its proposal.
NOTES Due to the high cost of energy in the area which Triton is exploring, the private Canadian company has proposed a concession of an area with geothermal potential for the installation of a small 5 MWe unit.



Panamá

Population (millions) - July 1998	2.73
Overall Electrification (% of population)	67%
GDP (billion US$) - 1997 est.	$18.0
Real GDP Growth Rate - 1997 est.	3.6%
Inflation Rate (CPI) - 1997	1.2%
Total Installed Capacity (MWe) - 1995	985
Electricity Consumption per Capita (kWh) - 1997	1213
Energy Demand Growth Rate	6.0%
Prices (US¢/kWh) - June 1998	
Residential	12.05
Commercial	11.86
Industrial	9.96
Estimated Geothermal Potential (MWe)	**450**

Power Summary

Panamá has considerable potential for hydroelectric generation which currently accounts for 61% of the country's total installed capacity. Thermal makes up the remaining 39%.

Investment in new electrical generation projects has been low over the last few years with IRHE devoting significant resources to the maintenance of existing plants which were not properly maintained during the final years of the Noriega regime. This policy, along with the upgrading of the Fortuna hydroelectric plant, has enabled the country to meet its current demand. New investment is needed, however, to meet future anticipated demand which is growing by approximately 45 MWe per year.

Because the state power company. Instituto de Recursos Hidraulicos y Electrificación (IRHE) does not have the financial resources to undertake the investment required to meet future demand, the Government of Panamá (GOP) decided on privatization. IRHE's generation costs are among the highest in the region—10-12¢/kWh.

IRHE is awaiting bids for the 130 MWe Esti hydroelectric project; another tender is open to purchase energy from a 100 MWe thermal plant to be installed and operated by the private sector. Additionally, the 120 MWe Gualaca hydroelectric project is scheduled for completion in 2005.

The IDB approved a $79 million loan to further Panamá's electricity reforms, help overcome bottlenecks in infrastructure, and advance SIEPAC.

The Panamá Canal is important to world energy markets as a major transit center for oil shipments and a potential choke point . Control of the canal will revert from the United States to Panamá at noon on December 31, 1999.

Government / Legislation

Instituto de Recursos Hidraulicos y Electrificación (IRHE)

Panamá is restructuring its electricity sector. IRHE, the state power company which was created in 1961, has been divided into four generation companies, three distribution companies, and one transmission company for sale.

Fifty-one percent of the shares of the distribution companies have already been sold; 39% will be retained by the government, and 10% will be sold to the unionized IRHE workers. The GOP will retain 49% of the shares in the four generation companies, 49% will be sold, and the remaining 2% will be transferred to the workers.

The GOP will retain control of the transmission company which will act as the main buyer, acquiring power from the private generators for delivery to the distributors, with the exception of large buyers who can purchase directly from the generators.

The IFC is guiding IRHE in the privatization process, including preparation of tender documents.

Law No. 6 (February 1997)

The new electricity law promotes competition, allows private investment in generation, and provides for service improvements in the electricity sector by splitting IRHE into eight new companies. All but the transmission companies will be privatized.

The Law establishes a maximum of 20% of the national installed capacity for any individual private project or company. Additionally, the total participation of private generation is limited to 45% of the country's total installed capacity.

Panamá imposes no restrictions on the import of electric power equipment.

No Specific Law for Geothermal

Geothermal Sites / Projects

Panamá has an estimated 450 MWe of geothermal power potential.

Panamá has low enthalpy geothermal resources suitable for the construction of binary power plants. The two main fields currently under development are Cerro Pando and El Valle de Antón.

As part of the "Central American Energy Resource Project," funded by USAID, LANL worked with IRHE to evaluate four thermal sites: Chitré-Calobre, Pueblo Nuevo, El Valle de Antón, and Olá. The study concluded that the only area in Panamá that may possess significant geothermal potential and warrants additional studies is El Valle de Antón (Shevenell, 1989).

The IDB is currently funding a $1.1 million program to conduct a feasibility study of El Valle de Antón.

1. Cerro Pando
2. El Valle de Antón

Cerro Pando	
LOCATION South of the continental divide in western Panamá, 800 to 3000 masl (Chiriqui Province).	
STATUS Well(s) or hole(s) drilled	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	7
TEMPERATURE (EC)	27-67
CHRONOLOGY 1976 to 1980 - Supported by the Overseas Development Administration of the U.K., 11 boreholes drilled and sampled; measured temperatures of 27ºC to 67ºC; found strong evidence that the springs are diluted by cold ground water before discharging at the surface; concluded that there is a uniform reservoir of thermal solution at depth (Bath, 1983).	
NOTES Spring temperatures reach maximum values of 66ºC at Los Pozos on the Colorado River, 67ºC at Cotito, and 41ºC at Catalina. Flow rates are low, ranging up to 1.5 l/s. Total heat output is estimated at 7 MWe from calculations incorporating measured spring discharges with river bed discharges inferred from stream	

conductivity anomalies. Some seasonal variation of temperature and flow rate has been observed, indicating the probable mixing of thermal discharge with shallow cool ground water (Bath, 1983).

El Valle de Antón

LOCATION
502º Latitude, 949º Longitude.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	150-160

CHRONOLOGY
1989 - Funded by USAID, LANL worked with IRHE to conduct hydrogeochemical investigation of the site; geothermometer temperatures range from 150ºC to 160ºC; concluded that site was the only area in the country that may possess significant geothermal potential.

1998 - IRHE has a $1.1 million IDB project to finance basic studies and pre- investment activities for the Valle de Antón geothermal field; deep exploration well planned for late 1998.

NOTES
IDB loan approved in 1996 to contract for consultancy and drilling services to conduct advanced prefeasibility studies in this field.

To accomplish this objective, some 3000 m of exploratory geothermal wells will be drilled. The first 2000 m will seek to penetrate the permeable resistive layers. Once a depth of 800-1000 m is reached, the electrically conductive layer, which is inferred to be the formation sealing the reservoir, will be entered and thermal-gradient and heat-flow measurements will be taken. The remaining 1000 m of drilling will deepen the first two wells with a view to intercepting the geothermal deposit. Rock samples will be taken during the drilling operations for geoscientific studies.

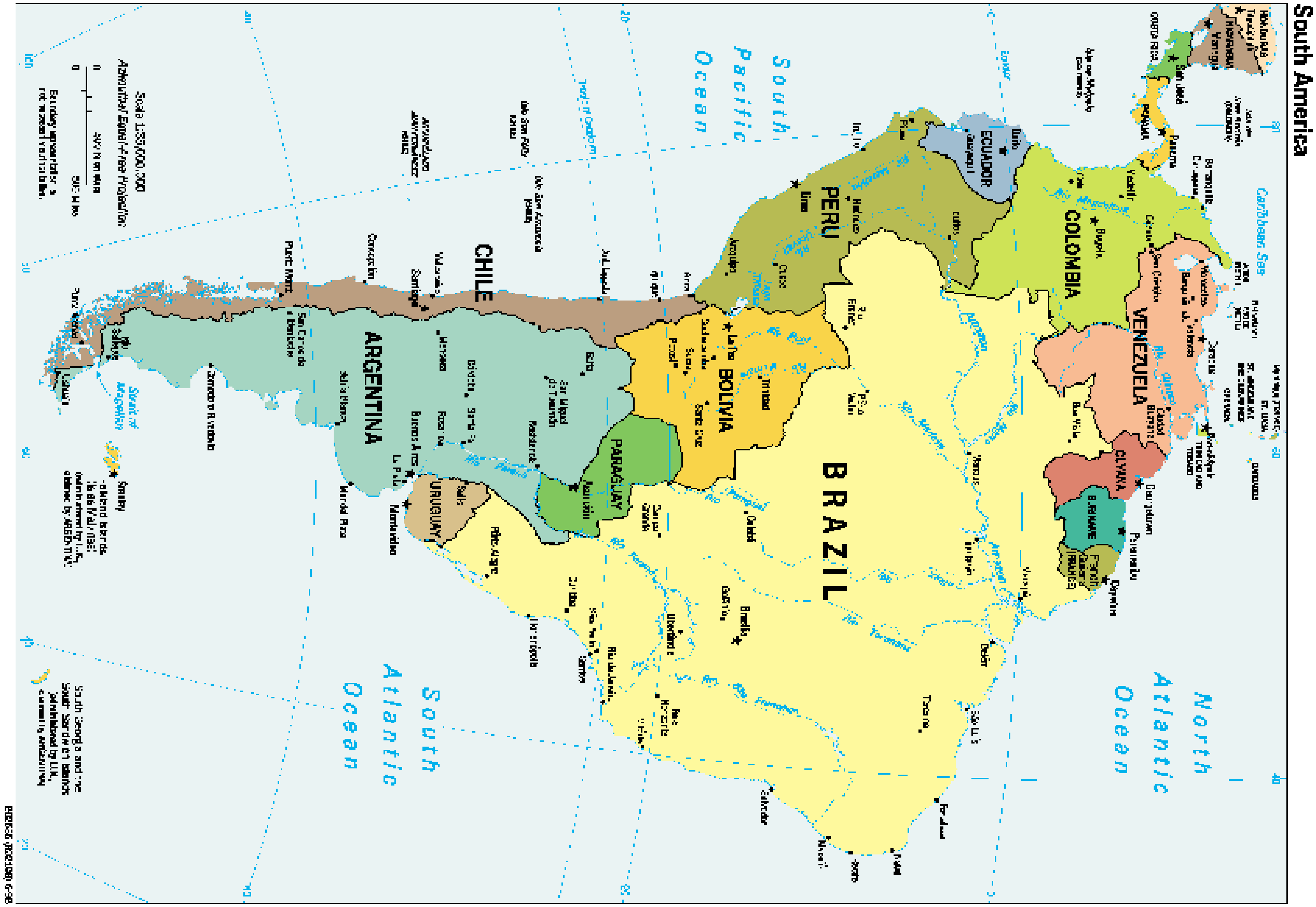
When drilling is completed the wells will be tested; if they are capable of maintaining production for a reasonable length of time, studies will then be conducted on the geothermal reservoir. The findings from the various disciplines will be analyzed and interpreted in order to prepare the prefeasibility report.
A consulting firm will be hired to conduct a national geothermal reconnaissance survey and a prefeasibility study in the geothermal field, in addition to contracting and supervising the drilling of the wells. This same firm,

together with an expert advisory group, will assess the environmental impact of the program. Individual consultants will be hired for updating of specifications and bidding documents for well drilling, consolidating reports on Chitre-Calobré and El Valle de Antón, and forming an expert advisory group.

A drilling contractor will be hired (by the consulting firm) to drill the wells.

Central America and the Caribbean

The Caribbean


South America
Caribbean Sea
North Atlantic Ocean
South Atlantic Ocean
South Pacific Ocean
COLOMBIA
VENEZUELA
GUYANA
SURINAME
ECUADOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY
PANAMA

The Caribbean

The islands of Saba and Saint Eustatius (Statia) of the Netherlands Antilles, Saint Kitts[5] and Nevis, Montserrat, Dominica, Saint Lucia, Saint Vincent and the Grenadines, and the French territories, Guadeloupe and Martinique, form part of the of the active volcanic arc of the Caribe Oriental and the Lesser Antilles.

From Saba in the north to St. Vincent in the south, active volcanoes and surface hydrothermal manifestations exist on each of the islands. In the cases of Dominica and St. Lucia, intense surface hydrothermal activity marks the presence of high enthalpy geothermal systems—230EC at Wotten Waven in Dominica, and 300EC at La Soufrière-Qualibou in St. Lucia.

The thermal energy available in these volcanic islands makes them of interest for geothermal exploration. The majority of electricity on the islands is produced with diesel generators, and, as a result, costs for electricity are relatively high. Electrical needs are growing on the islands as light industry and tourism grow, and use of an indigenous resource would decrease the cost of importing diesel fuel (Huttrer, 1998).

Since 1982, Republic Geothermal Inc. staff, U.S. Geothermal Industries Corporation (USGIC), Dr. D. E. Michels and J. Renner, have conducted prefeasibility studies on Dominica, Grenada, Saba, Statia, St. Kitts and Nevis, and St. Vincent.

As part of the ongoing efforts of the U.S. Department of Energy (DOE) to determine the potential of developing small geothermal production facilities, the Idaho National Engineering & Environmental Laboratory (INEEL) with Geothermal Management Company, Inc. (GMC) prepared preliminary assessments of the potential for the development of geothermal resources of Saba and Statia, St. Kitts and Nevis, and St. Vincent.

The geologic work was limited to a general geologic reconnaissance, collection of samples from hot springs, and analysis of available literature, and aerial photography. The DOE-sponsored team also visited with the island governments to determine the interest in developing geothermal energy and the status of the electrical system on each island.

5 Also known as Saint Christopher.

Although geothermal resources are abundant on several of the islands, apart from Guadeloupe which has a 4.5 MWe binary plant, geothermal development is still in the early stages for several reasons:

1. Geothermal development is not a priority in the energy policies of the island governments.

   Traditionally, the islands have depended on diesel generation, with the exception of Dominica which has hydroelectric power.

2. None of the countries have geothermal laws; many do not have laws for the regulation of the electricity sector in particular.

3. Limited financing and the high cost of geothermal exploration has held back the projects in the feasibility stage.

4. There are no economic incentives for geothermal development.

5. The population, and consequently the markets, of the islands, are small.

While none of the utility companies have an accurate accounting of their real costs, it seems very likely that geothermally generated power could be provided for a lower cost than the utilities now pay in-house. In many countries, O&M- caused brownouts or power outages are all too common and are reportedly on the increase (Huttrer, 1998). For example, Dominica reported 50 outages in 1997; Grenada, 11 to 50; Jamaica, 10 to 50; St. Kitts & Nevis, 10; St. Lucia, 10 to 50; and St. Vincent & the Grenadines, 11 to 25 (Vimmerstedt, 1998).

Some negative aspects or obstacles regarding initiation of Caribbean small geothermal power projects are:

1. The difficulty in financing small (<$50 million) projects.

2. The relatively low rate of return likely on small Caribbean geothermal power projects and the associated need to minimize exploration expenditures which unavoidably will increase the risk level perceived by potential investors.

3. The speckled history of fiscal responsibility on the part of the governments of several of these islands and their consequent low international credit ratings.

4. The marginal solvency of many of the national utility companies and the inability or

unwillingness of the national governments to guarantee payments by their utilities for power purchased.

5. The common occurrence of destructive hurricanes in the region and the recent experiences with damage due to the volcanic eruptions on Montserrat (Huttrer, 1998).

Huttrer ranks the islands, in order of development potential, as follows:

1. Guadeloupe
2. St. Lucia
3. Dominica
4. St. Vincent
5. Nevis
6. Saba
7. St. Kitts
8. Grenada
9. Martinique
10. Montserrat
11. Statia

Geothermal power could almost surely be sold to the utilities for less than the 12-15¢/kWh cost of generation now estimated by the various utility companies, and the prospect of initiating significant savings is appealing to government officials as well as the citizens-on-the-streets (Huttrer, 1998).

Dominica

Population (millions) - July 1998	0.07
Overall Electrification (% of population)	95%
GDP (billion US$) - 1997 est.	$0.2
Real GDP Growth Rate - 1997 est.	3.7%
Inflation Rate (CPI) - 1997	1.7%
Total Installed Capacity (MWe) - 1995	15
Electricity Consumption per Capita (kWh) - 1997	8000
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997	
Residential	20
Commercial	22
Industrial	NA
Estimated Geothermal Potential (MWe)	**1,390**

Power Summary

Dominica's total installed capacity in 1995 was 14.796 MWe, which was almost evenly divided between hydroelectric and thermal power. The transmission system, 11 kV, is predominately situated in the coastal area where the population is concentrated. DOMLEC has serious problems with losses in the transmission system and guaranteeing potential.

In 1989, the Dominican Government launched a plan to achieve energy independence. Since then, Dominica Electricity Services, Ltd. (DOMLEC) has expanded its grid and now services 95% of the population, up from 55% in 1989 (Lawrence, 1998).

Government / Legislation

<u>Dominica Electricity Services, Ltd. (DOMLEC)</u>

DOMLEC is responsible for the generation of electricity and was privatized at the end of March 1997. The private English company, U.K. Commonwealth Development Co. (CDC), owns approximately 40% of DOMLEC with the balance owned by the state.

<u>Ministry of Civil Works, Communications, and Housing (MCWH)</u>

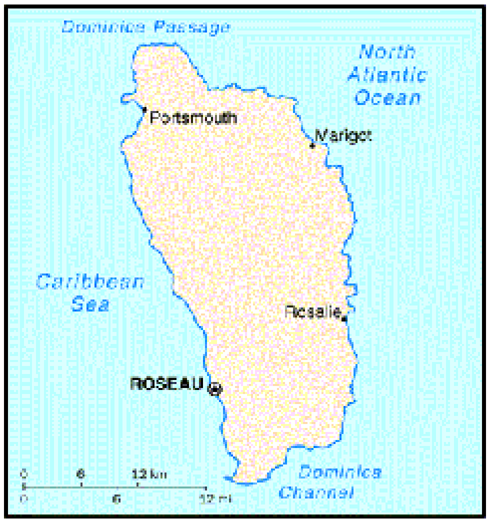
The MCWH is responsible for Dominica's energy sector.

Geothermal Sites / Projects

<u>Dominica has an estimated 1,390 MWe of geothermal power potential.</u>

Geothermal development is important as a substitute for diesel generation and to supply Dominica's increasing base load demand.

The French institute of geological investigations and mines, Bureau de Recherches Géologiques et Minières (BRGM), began the first integrated exploration of Dominica's geothermal resources in 1977, identifying three areas of interest: Wotten Waven, Boiling Lake, and Soufrière.



Morne Diablotin and Morne au Diable, two active volcanic complexes, are located in the northern part of the island but are considered of lower priority. BRGM began an expanded exploration program in 1982 with a focus on Boiling Lake and Wotten Waven.

INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of Dominica under a DOE-sponsored program.

1. Boiling Lake
2. Morne au Diable
3. Morne Diablotin
4. Soufrière
5. Wotten Waven

Boiling Lake	
LOCATION Located in Desolation Valley.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY	

1977 - BRGM identified as an area of interest.
NOTES Despite spectacular surface activity, Boiling Lake was ruled out for further study due to difficulties in accessing the site.

Morne au Diable	
LOCATION In the north of the island. Active volcano.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1977 - BRGM identified as an area of interest.	
NOTES Considered lower priority area.	

Morne Diablotin	
LOCATION In the north of the island. Active volcano.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1977 - BRGM identified as an area of interest.	
NOTES Considered lower priority area.	

Soufrière	
LOCATION In the south of the island.	
STATUS Prefeasibility study	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-

TEMPERATURE (EC)	-
CHRONOLOGY 1977 - BRGM identified as an area of interest.	
NOTES	

Wotten Waven

LOCATION
Located in Roseau Valley.

STATUS
Concession

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	10
TEMPERATURE (EC)	230

CHRONOLOGY
1977 - BRGM identified as an area of interest.

1982 - BRGM expanded exploration program, considering the site the area of highest priority due to its proximity to the capital, Roseau. Exploration indicated the probable existence of a geothermal system with temperatures on the order of 230ºC at an estimated depth of 800-1500 m. Identified the location of exploratory wells.

1991 to 1992 - BRGM in conjunction with the UN Department of Technical Cooperation for Development (UN/DTCD) confirmed the site's priority; proposed a feasibility study to the local government which was not pursued.

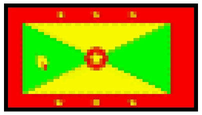
1994 - Negotiations between Caribbean Power Enterprise, Ltd. and the Government of Dominica began.

1995 - Concession assigned to a private joint venture company, Dominica Geothermal Power Co. (DGPC), composed of 51% ownership by Caribbean Power Ltd. and 49% Dominican ownership.

DGPC obtained the complete concession for geothermal resources and all their possible applications.

1998 to 2004 - Development planned.

NOTES
Project, to develop four modules of 2.5 MWe each, is stalled apparently due to financial problems.



Grenada

Population (millions) - July 1998	0.01
Overall Electrification (% of population)	90%
GDP (billion US$) - 1997 est.	$0.3
Real GDP Growth Rate - 1997 est.	3.1%
Inflation Rate (CPI) - 1997	3.2%
Total Installed Capacity (MWe) - 1995	17
Electricity Consumption per Capita (kWh) - 1997	946
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997	
Residential	19.26
Commercial	20.37
Industrial	16.30
Estimated Geothermal Potential (MWe)	**1,110**

Power Summary

Grenada is dependent upon imports for the bulk of its domestic energy needs.

Government / Legislation

Grenada Electricity Services, Ltd. (Grenlec)

(GRENLEC) is owned and operated by the Government of Grenada (GOG) and is the sole provider of electricity on the island.

Geothermal Sites / Projects

Grenada has an estimated 1,110 MWe of geothermal power potential.

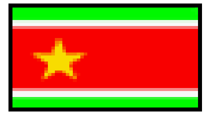
OLADE observed a possible resource of high enthalpy in the area of Mount Saint Catherine in 1981 which was later confirmed in 1992 as part of the UN/DTCD program.

Prefeasibility studies have revealed one small solfatara on Mount Saint Catherine, several small thermal springs in ravines radial to the central volcano, and numerous relatively young phreatic explosion craters. Additionally, the sub-sea volcano “Kick-em-Jenny” lies only five miles off Grenada’s north coast suggesting that the zone between it and central northeastern Grenada may be geothermally prospective (Huttrer, 1998).

INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of Grenada under a DOE-sponsored program.

1. Adelphi-Saint Cyr
2. Castly Hill
3. Chambord
4. Clabony-Mount Hope
5. Hermitage-Peggy's Whim
6. Mount Saint Catherine
7. Plaisance-Red River
8. St. Georges

All eight sites in Grenada are in the preliminary / identification report stage.



Guadeloupe

(overseas department of France)

Population (millions) - July 1998	0.42
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1995 est.	$3.7
Real GDP Growth Rate - 1997 est.	NA%
Inflation Rate (CPI) - 1997	3.7%
Total Installed Capacity (MWe) - 1995	39
Electricity Consumption per Capita (kWh) - 1995	2483
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997 Price range	10-12
Estimated Geothermal Potential (MWe)	**3,500**

Power Summary

Guadeloupe's target for 2000 is to generate 25% of its energy consumption from renewable energy sources (Lawrence, 1998).

Geothermal Sites / Projects

<u>Guadeloupe has an estimated 3,500 MWe of geothermal power potential.</u>

Guadeloupe has the only geothermal power plant in the Caribbean, a 4.5 MWe double flash power plant at Bouillante which came online in 1984 and supplies the leeward coast of Basse-Terre with electricity. The plant has been generating at an average rate of 4.7 MWe.

The Bouillante plant had intermittent problems caused by relatively high amounts of noncondensable gases and associated H_2S0_4, which seem to have been mitigated by Compagnie Française de Géothermie (CFG) (Huttrer, 1998).

There are plans to expand the Bouillante plant and set up another in Martinique.

1. Bouillante

Bouillante	
LOCATION	
STATUS Power plant(s) on site	
INSTALLED CAPACITY (MWE)	4.5
POTENTIAL (MWE)	4.5-25
TEMPERATURE (EC)	220-245
CHRONOLOGY 1969 and 1970 - Three wells drilled. Bouillante 1 reached 800 m and 220ºC; not capable of great production. Bouillante 2 encountered a highly productive drain at 338 m with pressure higher by 14 bars than hydrostatic pressure and with a temperature of 242ºC. Bouillante 3 drilled to 445 m, crossed a sandy layer at 410-440 m with temperature close to 240ºC; layer subsequently proved capable of producing only a few tons/hour of steam and water. 1971 - Bouillante 2 subjected to a long-duration production test. During six months, the well produced a flow of steam-water mixture tending to become stabilized at 30 t/h of steam and 120 t/h of water. The	

surface separation at 5 bars provides 20% steam and 80% water. The steam contains 0.4% by weight of noncondensable gases consisting basically of carbonic gas (90%) with traces of H2S (1%).

1972 and 1973 - Metallurgical campaign MT-5 EX started.

1974 - Bouillante 2 retested. Drilling restarted: Bouillante 3 deepened to 850 m. No evidence of considerable production between 450 and 850 m. Bouillante 4 drilled to 1200 m. No marked productivity at any level.

Seismic reflection profile shot at sea along the western coast of the island to determine the thickness of the tuff formation in which the drill holes have stopped. The propagation speed of the seismic waves in these tuffs seems to be between 3200 and 3500 m/sec (D'Archimbaud, 1975).

1984 - 4.5 MWe double flash condensing plant commissioned at a cost of 110 million French francs.

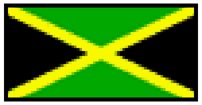
1994 -The company Géothermie Bouillante was created; aims for a progressive increase in the energy exploited (Jaudin, 1994).

2003 - 20 MWe proposed to be online.

NOTES

Guadeloupe is a French colony. The site was explored and developed by EURAFREP S.A. and Electricité de France.

For a proposed 25 MWe, projected annual capital charges and operational costs are about 4,000 and 700 French francs per kW respectively (Lawrence, 1998).

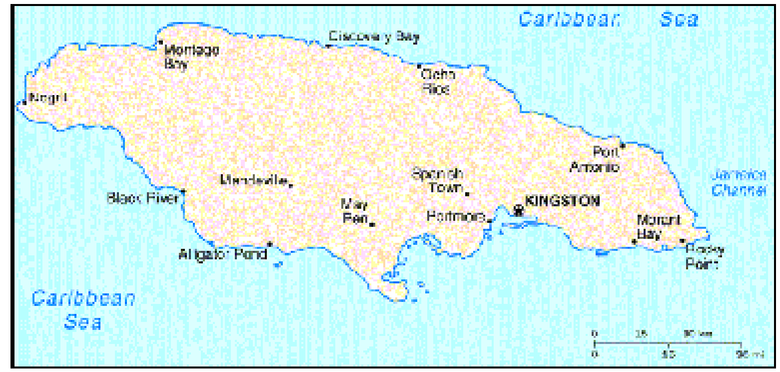


Jamaica

Population (millions) - July 1998	2.63
Overall Electrification (% of population)	64%
GDP (billion US$) - 1996 est.	$9.5
Real GDP Growth Rate - 1996 est.	-1.4%
Inflation Rate (CPI) - 1996	17%
Total Installed Capacity (MWe) - 1995	1182
Electricity Consumption per Capita (kWh) - 1995	1503
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997	
Residential	11.8
Commercial	10.8
Industrial	9.1
Estimated Geothermal Potential (MWe)	**100**

Power Summary

Jamaica's domestic energy sources include biomass (firewood and bagasse) which accounted for 98.3% of non-fossil fuel energy in 1992, and hydropower, which accounted for the remaining 1.7% (Lawrence, 1998).

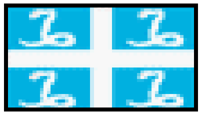


Geothermal Sites / Projects

Jamaica has an estimated 100 MWe of geothermal power potential.

Jamaica's geothermal resources are comparable to that of the other Caribbean islands—300 billion tons of oil equivalent (BTOE) of both thermal and electric quality resources combined.

No specific geothermal site data has been found for Jamaica.



Martinique

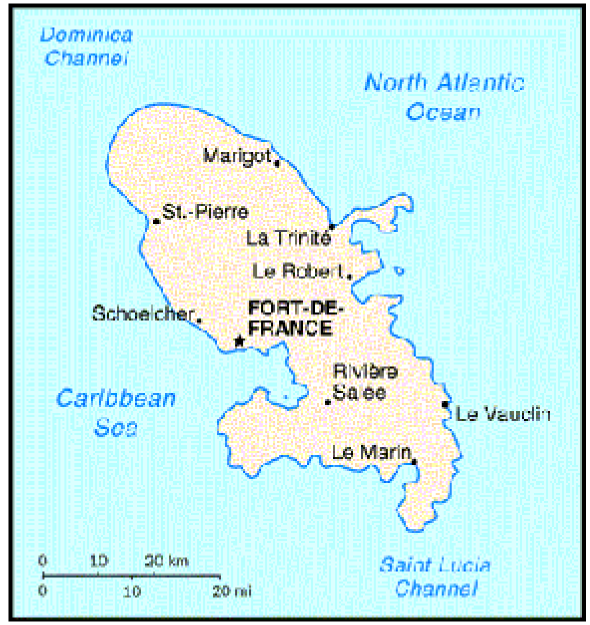
(overseas department of France)

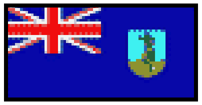
population (millions) - July 1998	0.41
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1997 est.	$4.0
Real GDP Growth Rate - 1997 est.	NA%
Inflation Rate (CPI) - 1997	3.9%
Total Installed Capacity (MWe) - 1995	115
Electricity Consumption per Capita (kWh) - 1995	2280
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997 Price range	10-12
Estimated Geothermal Potential (MWe)	**3,500**

The very active Mt. Pele comprises an obvious locus for geothermal resources. There are solfataras, hot springs, earthquake epicenters nearby and well developed fracture systems (Huttrer, 1998).

<u>Martinique has an estimated 3,500 MWe of geothermal power potential.</u>

There are plans to set up a geothermal plant in Martinique (Lawrence, 1998).





Montserrat

(dependent territory of the UK)

Population (millions) - July 1998	0.01
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1996 est.	$0.043
Real GDP Growth Rate - 1996 est.	-20.2%
Inflation Rate (CPI) - 1996	6.2%
Total Installed Capacity (MWe) - 1995	5
Electricity Consumption per Capita (kWh) - 1995	1178
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997	
Resident	18
Commercial	20
Industrial	17
Estimated Geothermal Potential (MWe)	**940**

Geothermal Sites / Projects

Montserrat has an estimated 940 MWe of geothermal power potential.

Even before the 1995 eruptions, the southwestern flank of the Soufrière Hills volcano was the site of solfataric activity and of numerous thermal springs. There was also significant seismic activity and several well developed fracture systems transecting the volcano (Huttrer, 1998).

1. Soufrière Hill

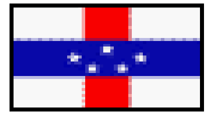
Soufrière Hill	
LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0

POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

1992 - Possible high enthalpy resource observed at area west of Soufrière Hill under UN/DTCD program.

NOTES



Netherlands Antilles

(part of the Netherlands Kingdom)

Population (millions) - July 1998	0.21
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1997 est.	$2.4
Real GDP Growth Rate - 1997 est.	1.3%
Inflation Rate (CPI) - 1997	3.6%
Total Installed Capacity (MWe) - 1995	20
Electricity Consumption per Capita (kWh) - 1997	4128
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997 Price range (St. Martin)	17-20
Estimated Geothermal Potential (MWe)	**3,000**

The Netherlands Antilles is made up of the three Windward Islands of the Dutch Caribbean—Saba, St. Eustatius (Statia), and St. Maarten.

Geothermal Sites / Projects

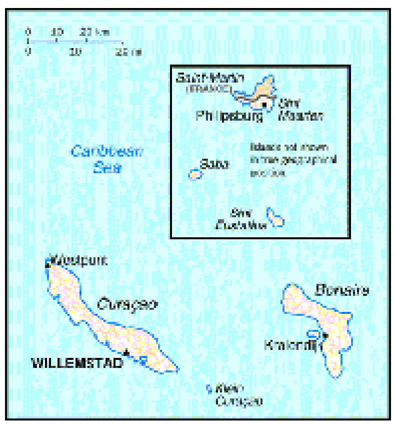
The Netherlands Antilles have an estimated 3,000 MWe of geothermal power potential.

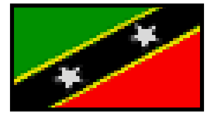
Saba is a small island comprising a central volcano with at least 15 andesitic domes on its flanks. There is a record of volcanic eruption(s) less than 1000 years ago and there are numerous hot springs along the shoreline and just off shore. The island is highly fractured, some hot springs temperatures have risen in the last 40 years.

INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of Saba and Statia under a DOE-sponsored program.

While some heat probably remains beneath The Quill on Statia as evidenced by reported occurrences of thermal waters in two wells drilled for drinking water, there are no known hot springs or paleo-thermal areas on the island (Huttrer, 1998).

No specific geothermal sites have been identified for Saba and Statia.





Saint Kitts & Nevis

Population (millions) - July 1998	0.04
Overall Electrification (% of population)	100%
GDP (billion US$) - 1997 est.	$0.2
Real GDP Growth Rate - 1997 est.	5.8%
Inflation Rate (CPI) - 1997	3.1%
Total Installed Capacity (MWe) - 1995	16
Electricity Consumption per Capita (kWh) - 1997	1976
Energy Demand Growth Rate	NA%
Prices (US¢/kWh) - 1997	
Residential	11.8
Commercial	12.6
Industrial	12.6
Estimated Geothermal Potential (MWe)	**1,280**

Power Summary

An expansion project to increase electricity capacity is underway with assistance from the Caribbean Development Bank (CDB).

Government / Legislation

Department of Electric and Light

Utility was privatized in 1995.

No Specific Laws for Electricity or Geothermal

St. Kitts and Nevis do not have laws which regulate the use of geothermal resources or the electric sector.

Geothermal Sites / Projects

St. Kitts and Nevis have an estimated 50 MWe of geothermal power potential.

INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of St. Kitts and Nevis under a DOE-sponsored program.

There are encouraging geothermal indicia at five places on Nevis. On Nevis's western and southern sides, there are two solfataras, numerous thermal wells, and a large area of hydrothermal alteration. Also, strong earthquakes with hypocenters very near Nevis occurred in 1951 and 1961. On St. Kitts, though there are moderately large areas of steaming ground in the crater of Mount Liamuiga, as well as thermal springs along the western shoreline, the geothermal indicia are less well-defined than on the other islands (Huttrer, 1998).

1. Basseterre
2. Brimstone Hill
3. Nevis Peak

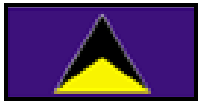
Basseterre	
LOCATION St. Kitts.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1992 - Possible high enthalpy geothermal resource identified under UN/DTCD program.	
NOTES	

Brimstone Hill

LOCATION St. Kitts.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1992 - Possible high enthalpy geothermal resource identified under UN/DTCD program.	
NOTES	

Nevis Peak

LOCATION Nevis.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1992 - Possible high enthalpy geothermal resource identified on western flank of Nevis Peak under UN/DTCD program.	
NOTES	



Saint Lucia

Population (millions) - July 1998	0.15
Overall Electrification (% of population)	87%
GDP (billion US$) - 1997 est.	$0.6
Real GDP Growth Rate - 1997 est.	0.8%
Inflation Rate (CPI) - 1997	-2.3%
Total Installed Capacity (MWe) - 1995	45
Electricity Consumption per Capita (kWh) - 1997	705
Energy Demand Growth Rate	9.0%
Prices (US¢/kWh) - 1997 Price range	22-28
Estimated Geothermal Potential (MWe)	**680**

Power Summary

Saint Lucia's total installed capacity in 1995, 44.5 MWe, consisted of thermal power generated by imported diesel fuel. Although the size of St Lucia's petroleum import bill is not yet critical, the total dependence on imported petroleum fuels to satisfy commercial energy requirements is a matter of concern (Barthelmy, 1990). Of the total 44.5 MWe, 25 MWe are plants that are more than 30 years old. The island's energy demand is growing 8-10% per year, largely as the result of the creation of the tourist industry.

Prospects for economic growth will depend on diversification of the productive base of the economy and the continued expansion of the physical infrastructure. In particular, the development of the geothermal resource shall provide a secure indigenous source of energy that is likely to stimulate investment, economic growth, and employment (Barthelmy, 1990).

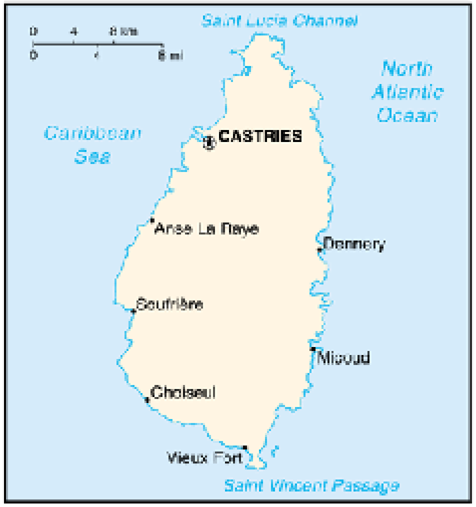
Government / Legislation

St. Lucia Electricity Services, Ltd. (LUCELEC)

LUCELEC, the institution responsible for the generation of electricity, is actually a company of mixed economic control: 43% by the British company, U.K. Commonwealth Development Co. (CDC), 18.7% by the Mayoralty of Castries, 12.4% by the Government, 12% by Social Insurance, and the remaining 13% by the private sector.

The process of privatizing the electric company is identical to that which occurred in Dominica and the private majority is the same British company.

Like Dominica, privatization was realized in St. Lucia without a legal or regulatory framework for the electric sector in place.



Ministry of Planning, Development, and Environment

The energy sector and environment are under the purview of the Ministry of Planning, Development, and Environment.

No Specific Laws for Electricity or Geothermal

St. Lucia does not have laws which regulate the use of geothermal resources or the electric sector.

Geothermal Sites / Projects

St. Lucia has an estimated 680 MWe of geothermal power potential.

A least cost power development program for St. Lucia must incorporate geothermal energy (Barthelmy, 1990).

Evaluation of St. Lucia's geothermal potential began in 1951 with a field study mission by the late Gunnar Bodvarsson of the Sulphur Springs area. An initial comprehensive geothermal resource exploration program was started 20 years later by the United Kingdom's Ministry of Overseas Development in the early 1970s followed by engineering testing in the late 1970s.

In the 1980s, Aquater (Italy), Los Alamos National Laboratory (funded by USAID), and the UN Revolving Fund for Natural Resources Exploration (UN/RFNR) and USAID conducted prefeasibility studies which included drilling production-size exploratory wells.

The second of two wells drilled by a team led by Italian geothermists found what appeared to be an economically exploitable resource. Unfortunately, this well suffered mechanical failures and the produced steam was never harnessed to generate power.

More recently, INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of St. Lucia under a DOE-sponsored program.

Geothermal indicia on St. Lucia comprise a very large solfatara near the village of Soufrière, thermal springs nearby and very recent volcanic activity including both phreatic and pyroclastic eruptions (Huttrer, 1998).

1. La Soufrière-Qualibou Caldera

La Soufrière-Qualibou Caldera

LOCATION
In the southwestern part of the island. St. Lucia belongs to the Windward Islands in the Lesser Antilles (West Indies); within 13º43' and 14º07' N and 61º05' W; island is 25 miles long and up to 12 miles wide; made up almost entirely of products of volcanic origin.

Geothermal site is the Qualibou Caldera, the Belfond area, and Sulphur Springs Valley, in the southwestern part of the island. The Qualibou Caldera lies on a NE-SW regional tectonic alignment.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	10-30
TEMPERATURE (EC)	200-350

CHRONOLOGY
1951 - Investigation began with a field study mission by the late Gunnar Bodvarsson of the Sulphur Springs area.

1974 to 1976 - First systematic investigations by the UK Ministry of Overseas Development when the island was a British territory. Merz and McLellan drilled seven wells to depths of 116 to 725 m; four wells were productive.

1982 - Aquater S.p.A. of Italy began extensive geological, geophysical, and geochemical surveys after St. Lucia became independent with funding from the European Investment Bank (EIB). Identified five sites for exploratory drilling to verify the nature of the fluid and reservoir.

1983 to 1984 - Los Alamos National Laboratory conducted geological, geophysical, hydrochemical, and engineering investigations with funding from USAID. Postulated the existence of a three-layer geothermal system: an upper condensing zone, an intermediate vapor-dominated or two-phase zone, and a lower boiling brine zone. Put preliminary estimate of field's potential at 30 MWe.

1987 to 1988 - UN/RFNR and USAID jointly funded prefeasibility study which included drilling production-size exploratory wells.

Two deep wells drilled (SL-1 at Belford, SL-2 at Sulphur Springs); only SL-2 (1413 m) was productive with a flowing enthalpy of 2900 kJ/kg and a flow rate of 9.3-17.5 kg/s. Fluids from SL-2 had a high gas/steam ratio (up to about 25% in weight), high H_2/H_2S ratio, HCl in the condensed steam, and high acidity (pH of 2.8). Estimated electrical output potential of SL-2 is 3 MWe.

The most significant geological information obtained from the drilling cores and cuttings is that the formations crossed by the wells SL-1 and SL-2 indicate an almost complete lack of juvenile pyroclastic products. This leads to the consideration that the area under exploration may not be the center of a strong pyroclastic activity (Barthelmy, 1990).

Results were not judged satisfactory due to high cost of drilling and lack of supervision. Total investment: $5.5 million.

1988 - Oxbow Geothermal Corporation submitted proposal to develop a 10 MWe geothermal facility.

1990 - Feasibility study begun with support from UN/RFNR and USAID for a 10 MWe plant.

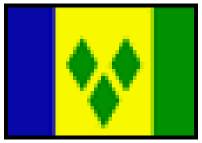
1992 - UN/DTCD integrated the evaluation of existing geothermal activities in St. Lucia in the context of a regional project which would comprise other islands with geothermal potential.

The Government completed an economic evaluation of installing two units of 5.2 MWe each in Soufrière. Due to lack of production in the existing wells, however, the project has stalled.

NOTES
The Belfond area, located 1.5 km southeast of Sulphur Springs, is the primary target for additional exploration. The main geothermal reservoir at 250ºC is thought to be located at a depth of 1000 m.

Due to the environment of mistrust created as a consequence of the lack of concrete results obtained in this project, LUCELEC has not considered the offers of the private companies that are involved in Dominica and Grenada.

Development of plant will be through an international bid or concession.



Saint Vincent & the Grenadines

Population (millions) - July 1998	0.12
Overall Electrification (% of population)	95%
GDP (billion US$) - 1997 est.	$0.3
Real GDP Growth Rate - 1997 est.	1.0%
Inflation Rate (CPI) - 1997	3.6%
Total Installed Capacity (MWe) - 1995	14
Electricity Consumption per Capita (kWh) - 1997	545
Energy Demand Growth Rate	5.0%
Prices (US¢/kWh) - 1997	
Residential	22.0
Commercial	25.2
Industrial	20.0
Estimated Geothermal Potential (MWe)	**890**

Power Summary

St Vincent's electricity needs are met with diesel and hydropower. Oil imports are needed to meet 90% of the islands' primary energy needs. In 1995, St. Vincent imported 940 barrels/day of oil to satisfy its energy needs. Cane Hall, a diesel plant located about three miles outside the capital, Kingstown has triggered complaints of noise pollution.

St. Vincent Electricity Services, Ltd. (VINLEC), currently has seven generating plants—three diesel sets which were commissioned from 1972 to 1993, and four small hydropower stations. Power sales are reportedly increasing at 5% per year.

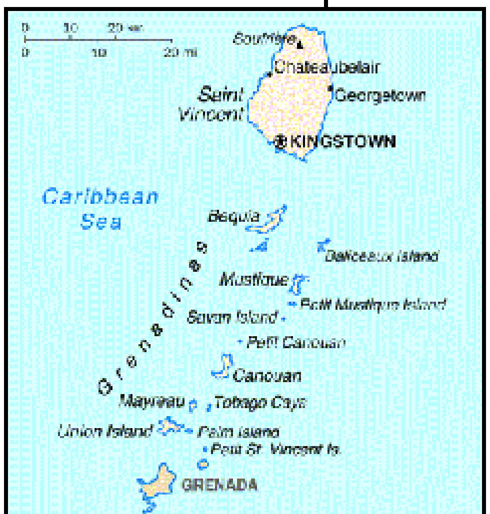
The country requires another 3.6 MWe of electricity in 1999 into Cane Hall and a new generating site developed at Lowmans Bay by the year 2003. This will bring St Vincent's capacity to 17.5 MWe.

In an effort to diversify its economy from heavy dependence on banana exports, St. Vincent is improving its electricity sector to attract a range of new businesses, mainly financial services and information processing.

Supported by an $8.8m loan from the European Investment Bank (EIB), the Government of St. Vincent (GOSV) is expanding and improving its power sector to become competitive in attracting new investments. The EIB loan will provide partial funding, with the government securing the rest.

Using the island's indigenous geothermal power would decrease the country's reliance on imported fuel and increase the output of salable goods, thereby improving the country's balance of payments and decreasing its national deficit.

Government / Legislation



Ministry of Communications and Works

The Ministry of Communications and Works is responsible for the country's energy including geothermal. The Ministry, in consultation with Central Planning, the Prime Minister, and the Cabinet, can issue concessions for energy-related projects deemed beneficial to the national interest.

Drilling permits come from this Ministry and may be included in the Concession Agreement. If not included in the agreement, they could take 3-6 months to be issued.

St. Vincent Electricity Services, Ltd. (VINLEC)

VINLEC is a quasi-state utility company. Assuming VINLEC remains unprivatized, a private geothermal developer would have to execute a power sales agreement with VINLEC as a precondition to the acquisition of a loan. In this case, there would have to be assurances that VINLEC could and would be able to pay for power received.

No legislative changes are necessary for the development of private power (Lawrence, 1998).

No Specific Laws for Electricity or Geothermal

St. Vincent and the Grenadines do not have laws regulating the use of geothermal resources or the electric sector.

The GOSV supports the concept of private development of its indigenous geothermal resources. There are no insurmountable legal, regulatory, or institutional barriers to the development of St. Vincent's geothermal resources once their economical production is confirmed (Huttrer, 1995).

The Central Water and Sewerage Authority (CWSA)

The CWSA controls all aspects of water-related matters on St. Vincent.

Geothermal Sites / Projects

St. Vincent and the Grenadines have an estimated 890 MWe of geothermal power potential.

St. Vincent's geothermal potential has not been formally studied.

INEEL, GMC, and USGIC prepared a preliminary assessment of the potential for the development of geothermal resources of St. Vincent under a DOE-sponsored program.

La Soufrière volcano has erupted three times since 1902, there is a steaming resurgent dome in the crater and there are numerous hot springs in river valleys on the western side of the volcano (Huttrer, 1998).

Of additional interest are three N25E striking features near Wallibou Beach, in an area locally known as "Hot Waters," and a circular feature near Morgans Wood near Trinity Falls (Huttrer, 1995).

Capital Growth Holdings, a U.S. firm is currently exploring on St. Vincent and intends to drill an exploration well in 1999.

1. Soufrière Volcano

Soufrière Volcano

LOCATION
Soufrière Volcano is located in the northern part of St. Vincent; 60º56' W, 13º15' N.

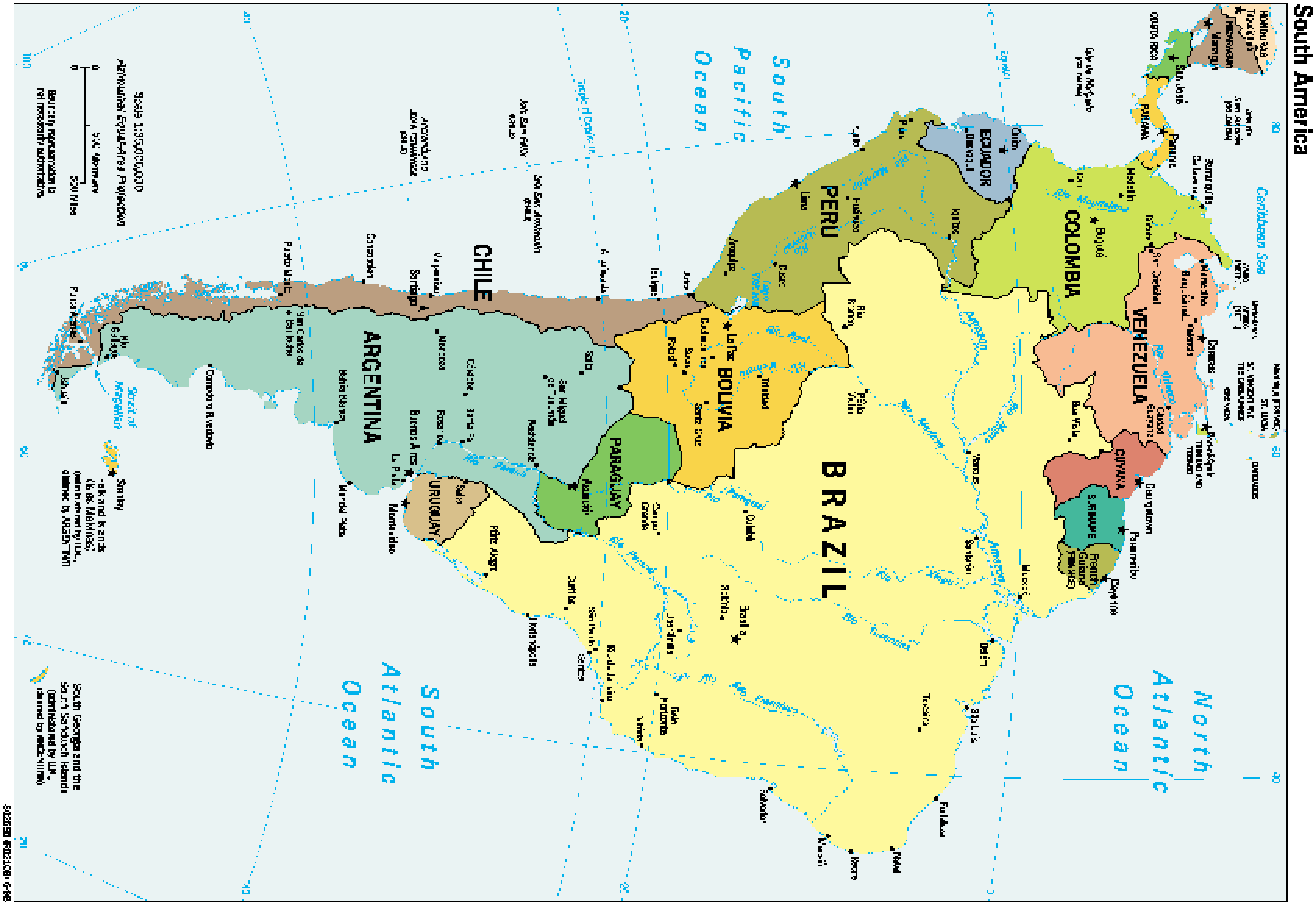
STATUS
Feasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	8-10
TEMPERATURE (EC)	155-190

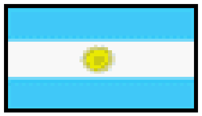
CHRONOLOGY
1995 and 1996 - Prefeasibility studies conducted by Geothermal Management Corporation with support from DOE and USAID. Geothermometer analysis of fluid samples show temperatures of 155-190ºC. Study confirmed that the northwestern quadrant of St. Vincent on the flanks of the Soufrière Volcano may be favorable for the discovery of commercially exploitable geothermal resources.

1997 and 1998 - Growth Capital Holdings (GCH), project developer, signed MOU with Government of St. Vincent; conducted geologic studies and selected drilling target. Hired drilling engineer, ThermaSource, Inc.

1999 - Exploration well to be drilled. Unconfirmed reports that the project was suspended due to financing problems.
NOTES The Soufrière Volcano is the youngest on St. Vincent and one of the most active in the entire Caribbean island arc, having erupted in 1902, 1971, and, most recently, 1979. Numerous fumaroles are visible, primarily on the southeastern and western sides of the dome and also near its summit.


South America
Caribbean Sea
South Pacific Ocean
North Atlantic Ocean
South Atlantic Ocean
COLOMBIA
VENEZUELA
GUYANA
SURINAME
ECUADOR
PERU
BRAZIL
BOLIVIA
PARAGUAY
CHILE
ARGENTINA
URUGUAY

South America



Argentina

Population (millions) - July 1998	36.26
Overall Electrification (% of population)	92%
GDP (billion US$) - 1997 est.	$348.2
Real GDP Growth Rate - 1997 est.	8.4%
Inflation Rate (CPI) - 1997	0.3%
Total Installed Capacity (MWe) - 1995	20207
Electricity Consumption per Capita (kWh) - 1997	1670
Energy Demand Growth Rate	7.7%
Prices (US¢/kWh) - June 1998	
Residential	14.2
Commercial	14.6
Industrial	8.2
Estimated Geothermal Potential (MWe)	**2,010**

Power Summary

Argentina's electric power sector has been privatized and deregulated, with separate markets created for generation, transmission, and distribution. A decade ago the country's power sector was characterized by shortages, breakdowns, and high costs. Since 1992 and economic reforms, however, total generating capacity in the country has increased more than 40% and more than $7 billion has been invested in the sector. Since 1996 alone, the price of energy in the country´s spot market has declined 18% according to analysts at the Banco General de Negocios (BGN) in Buenos Aires.

Both demand and supply are expected to continue growing. Recent additions to capacity have been mainly hydroelectric plants. The Government of Argentina (GOA) plans to issue an international call to tender for the contract to complete, operate, and maintain Yacyreta—the 3200 MWe joint Argentine-Paraguayan hydroelectric dam and station located on the banks of the Parana River—in the first quarter of 1999.

In its annual Energy Prospective completed at the end of 1997, Argentina's Secretary of Energy predicted that even under relatively modest assumptions for economic growth, demand will increase 60% by the year 2010. Under more optimistic assumptions, demand would more than double.

In addition to domestic growth, possibly the most important recent event in the electricity sector is the August 1997 agreement between Argentina and Brazil to integrate the two countries' electricity markets with guaranteed free competition among generators, the banning of all state subsidies, and the requirement that pricing be based solely on costs. Exports to Brazil could reach 5,000 MW in the medium term.

Rich in natural gas, Argentina can transport gas to Brazil and Chile where the fuel can be used to generate electricity or it can turn gas into electricity at home using highly efficient combined cycle generating technologies and export the electricity produced.

Argentina requested $46.5 million financing from the World Bank and $14 million from the Global Environment Fund (GEF) for a program to supply energy to rural areas using renewable resources where feasible. It will support the transfer of the operation of the rural power sector from the government to the private sector, and strengthen the regulatory function of provinces. The commercial delivery mechanism is based on a unique concession system where rights to a whole province are awarded in open bidding to the company that asks for the lowest subsidy. Negotiations have been postponed at the request of the GOA (Development Business, February 1999).

Government / Legislation

Public Law No. 24.065 — Electric Law (January 1992)
The Electric Law enacted in January 1992, established a legal structure for restructuring and privatizing the electricity industry. The federal government intended for the Electric Law to reduce electricity rates and improve service. The restructuring that preceded privatization was designed to lead to competition between the soon-to-be-privatized electricity companies and was modeled after earlier restructuring by Chile and the price-cap regulation of the United Kingdom.

Two further legal changes occurred during 1993. A 1993 amendment to the Foreign Investment Law more explicitly addressed the question of foreign investment. This amendment removed restrictions that applied only to foreign investors, freeing them of the need to receive prior approval for most investment.

Later in 1993, the measures of the 1989 Economic Emergency Law, the 1989 Reform Law, and the 1993 amendment to the Foreign Investment Law were combined in an act called Decree 1853, which removed most of the remaining restrictions on foreign investment.

No Specific Law for Geothermal

Provincial Governments are responsible for geothermal exploration and direct uses. Increasing numbers of foreign companies are investing in Argentina's provinces. For the past six years, the IDB has financed provincial reforms to reduce the size of the public sector, privatize public services, and allow the provinces to use their competitive advantages.

At the National level, there are no specific legislation or initiatives for geothermal power generation. The legal framework differs depending on whether the geothermal resource to be exploited is steam or hot water.

There is no National code for the use of hot water geothermal resources. Their use is subject to the Provincial laws which regulate the use of water. Legislation varies from province to province.

Law No. 22.259 (July 30, 1980)

Governs use of "indigenous vapors" and modifies the old Mining Code. Steam is considered the property of the State—National or Provincial—depending on in which political jurisdiction it is found. It is granted in concession to whomever proves sufficient technical and economic solvency.

Geothermal Sites / Projects

Argentina has an estimated 2,010 MWe of geothermal power potential.

Since the early 1990s, due to low fossil fuel prices, the emphasis of Argentina's geothermal program has shifted from exploration and development of high temperature resources for electricity generation to the use of lower temperature resources in direct applications (Pesce, 1998).

The generation of electricity from geothermal power is not currently economical. The price of electricity is $0.09/kWh; the cost of generation just $0.02/kWh and falling (NRECA; March 1998).

Prefeasibility studies have been completed in 19 geothermal areas; 90% of the high-enthalpy areas and 75% of the low-enthalpy areas.

High-enthalpy areas include Copahue-Caviahue, Domuyo, Tuzgle, and Valle del Cura. Low-enthalpy areas are Cerri, Médanos, Carrindanga, Caimancito, La Quinta and El Palmar, Río Valdez, Santa Teresita, Suriyaco, Colón, Villa Elisa, Larroude, Telsen, and Gan Gan.

Two provinces are actively promoting geothermal development, Neuquén and Jujuy, but primarily for balneotherapy and heating related to tourism. No potential is seen in Neuquén Province for the installation of small electric plants because the province has an extensive electric grid and adequate capacity.

1. Copahue-Caviahue
2. Domuyo
3. Tuzgle
4. Valle del Cura

Copahue-Caviahue

LOCATION
On the eastern slopes of the Andes, near the border with Chile, at 37°50'S, 71°05'W; 1170 km WSW from Buenos Aires, and 360 km NW of Neuquén, the provincial capital. Located on the western edge of a 15- to 20-km diameter megacaldera near the 2977-m high Quaternary Copahue Volcano (Neuquén Province).

STATUS
Power plant on site; currently offline.

INSTALLED CAPACITY (MWE)	0.67
POTENTIAL (MWE)	30
TEMPERATURE (EC)	171-270

CHRONOLOGY
1974 - Geothermal survey and drilling in the field begun by the Comisión Nacional de Estudios Geotérmicos.

1976 - COP 1 exploratory well drilled to 954 m.

1979 - Study begun by the Consejo de Planificación para el Desarollo (COPADE).

1980 - Japan International Cooperation Agency (JICA) continued study of Copahue and Domuyo. Objective was to evaluate the sites for power generation.

1981 - Prefeasibility study conducted by the Secretary of State of Copahue and Latinconsult, Electroconsult (Italy).

1981 - COP 1 deepened to 1451 m; maximum temperature 250ºC; between 850 and 1000 m found a productive zone with an initial flow of 17 tons/hr of dry steam; supplies 670kWe ORMAT binary pilot plant which is currently off-line. A 33kV-line now connects Copahue with the provincial grid.

1986 - COP 2 drilled to 1241 m deep; maximum temperature 235ºC; 2876 kJ/kg; well showed inferior conditions of permeability with initial flow less than that of COP 1.

1988 - 670kWe ORMAT binary pilot plant using COP 1 came online in April. The plant has been off-line since 1996.

1991 - COP 3 drilled to 1065 m deep; maximum temperature 240ºC; JICA drilled and studied.

1997 - Provincial government hired the Empresa Neuquina de Servicios de Ingeniería (ENSI) to design a snow melting pilot project to keep streets to Villa Copahue clear during the winter; test project used COP 2.

1997 - COP 4 drilled to 1256 m for the Villa Thermal Copahue Heating Project; static pressure 40 bar at wellhead; 235ºC reservoir temperature.

1998 - 45 km of piping laid for snow melting system; 1.5 m of snow can be melted in 2.5 hours.

NOTES

Includes five geothermal manifestations of importance (fumaroles and hot springs) covering an area of approximately 1.2 km², four of which are located in Argentina. They are TERMAS DE COPAHUE, LAS MAQUINAS, LAS MAQUINTAS, and ANFITEATRO. (The fifth, CHANCHO-CO, is located in Chile.)

The Copahue Volcano corresponds to the last episode of the Copahue-Caviahue Effusive Complex whose activity began during the Pilocene and continued into the Quaternary. The volcanic materials are mainly lavas; pyroclastics are less abundant. They are predominantly calc-alkalic basalts, andesitic-basalts and andesites and, in smaller proportion, latites (Pesce, 1995).

Copahue means "sulfur place" in the local language, Araucara.

According to the geothermal model, Copahue is a vapor-dominated geothermal field to a depth of 1300 m. The existence of a main reservoir at an estimated depth of 1800 m has yet to be confirmed.

Villa Thermal Copahue Heating Project - Melts snow to keep resort town accessible year round.

Other current uses: balneotherapy.

Domuyo

LOCATION
In the northern part of the province at 36°40'S, 70°40'W (Neuquén Province).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	186-230

CHRONOLOGY
1982 - Prefeasibility studies begun by the Group of Volcanology Work of the Secretary of Mining with support from the Japanese International Cooperation Agency (JICA).

1984 - Thermal gradient well drilled to depth of 1000 m and a multi-purpose exploratory well to 376 m.

The resulting model indicates the presence of a reservoir at 650 to 750 m. The geothermal fluids originate in a system that changes gradually from vapor-dominated (218-226 ºC) to liquid-dominated (186-190 ºC).

A zone of low resistivity has been detected at 800 to 1200 m.

NOTES
At present, Domuyo's geothermal resources are being exploited for space heating and for supplying hot water to a small tourist complex, Villa Aguas Calientes.

Prefeasibility studies have been completed and the location for a deep exploratory well has been selected. Also, elaboration of a model for the geothermal systems which establishes the main geothermal field characteristics has been concluded.

Field displays fumaroles, hot springs, and gas emanations. Associated with Quaternary shoshonitic volcanism. Detailed surveys covered about 600 km² around Cerro Domo Volcano, the largest manifestation of Quaternary volcanism in the area. The studies delimited a thermal anomaly probably related to magma bodies in the upper levels of the crust that are related to tensional structures (Pesce, 1995).

Tuzgle

LOCATION
In the Altiplano of Salta and Jujuy at 23°55'S; 66°30'W (Jujuy and Salta Provinces). An area of about 900 km²

has been studied in detail.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	132-142

CHRONOLOGY
1977 - Reconnaissance studies began.

1980 - Prefeasibility study began covering an area of 900 km²; seventeen (17) thermal gradient wells planned; eleven (11) drilled.

The wells have found a superficial reservoir whose base is located at a depth of 400-500 m, and which indicates in some points the presence of a second reservoir.

The preliminary geothermal model postulates the existence of a shallow reservoir which may be fed from deeper levels where two hydrothermal cells are interconnected by fractures. The geothermal fluids would be located in old fractured extrusive rocks and their upward flow controlled by vertical structures (Pesce, 1995).

NOTES

Due to its distance from electrical distribution centers, the potential for development of Tuzgle will likely increase with a growing energy demand. It is reported that this resource is used for mining.

Valle del Cura

LOCATION
San Juan Province

STATUS
Prefeasibility study

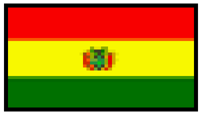
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	130-200

CHRONOLOGY
1986 - First phase of prefeasibility studies conducted by Hydro projects S.A.-Setec S.R.L.-Cepic S.C..

Observed geochemical and isotopic anomalies suggest the existence, at drillable depths, of a boiling reservoir with temperatures above 200 ºC, as well as 130-150 ºC secondary shallower reservoirs.

NOTES
Thermal anomaly is related to subvolcanic bodies

associated with the neighboring Tórtolas volcano



Bolivia

Population (millions) - July 1998	7.83
Overall Electrification (% of population)	64%
GDP (billion US$) - 1997 est.	$23.1
Real GDP Growth Rate - 1997 est.	4.4%
Inflation Rate (CPI) - 1997	7.0%
Total Installed Capacity (MWe) - 1995	805
Electricity Consumption per Capita (kWh) - 1998	370
Energy Demand Growth Rate	8.0%
Prices (US¢/kWh) - June 1998	
Residential	6.58
Commercial	13.17
Industrial	7.36
Estimated Geothermal Potential (MWe)	**2,490**

Power Summary

Bolivia's electricity sector is made up of a National Interconnected System (NIS) and three main isolated systems. NIS accounts for nearly 90% of the country's consumption and approximately 77% of its installed capacity. Of the electricity generated in the NIS, 60% is thermoelectric and 40% is hydroelectric.

In June 1995, the government of Bolivia announced the capitalization of Empresa Nacional de Electricidad's (ENDE) three main electricity generation companies to three U.S. power companies, Dominion Energy, Energy Initiatives, and Constellation Energy, for $140 million. The Bolivia Power Company (COBEE) was purchased by another U.S. company, NRG Energy. (Capitalization differs from traditional privatization in that money paid by the new partner(s), who also assumes management of the company, goes not to the national treasury but into the company as direct investment.) The four generating companies are working to increase Bolivia's generating capacity for both domestic consumption as well as to export, primarily to Brazil.

Bolivia's per capita electricity consumption, 370 kWh in 1998, is the fourth lowest in the region, higher only than Haiti, Guatemala, and Guyana. Increasing demands for fuel, which has grown 8% per year rather than the estimated 4-5%, caused serious shortages in the capital La Paz in late 1998. Bolivia's state oil company YPFB will take measures to deal with the fuel scarcity, including the expansion of the Cochabamba-La Paz multi-purpose pipeline, which should come on-stream by the end of 1999.

Government / Legislation

The Bolivian Government has completely overhauled the structure of the electric industry. While the Government previously held direct control of the State enterprises involved, the State's role now is limited to that of a regulatory agency.

Superintendency of Electricity

The Superintendency of Electricity, the entity with national jurisdiction, is responsible for regulating the activities of the electric industry. The Superintendency of Electricity, on behalf of the Bolivian State, grants concessions to a legal entity to generate, distribute, or transmit electricity. The maximum term of a concession is forty (40) years.

Law No. 1604 (December 21, 1994)

The Electricity Law stipulates that "The activities related to the Electric Industry shall be governed by principles of efficiency, transparency, quality, continuity, adaptability and neutrality."

The Electricity Law removed day to day operation of the electric industry from the Government bureaucracies and instituted a framework for private initiative to fill the expected needs of the sector. The Government retained regulatory control of the sector.

In addition, the Electricity Law fundamentally overhauled the tariff structure. The new structure allows generators to use a marginal cost pricing system. Tariffs will directly reflect costs related to location and peak/off-peak periods. Subsidies to low income consumers will be eliminated over a five year period.

Article 5 of the law stipulates that the exploitation of renewable resources for the production of electricity are regulated by this law.

Article 10 states that to engage in the activities of the electric industry, foreign companies must form Bolivian subsidiaries.

No Specific Law for Geothermal

The Electricity Law has not been enough to bring in private investment. A geothermal law is needed to outline the rules of the game, and to increase private investment in developing Bolivia's geothermal resources.

Geothermal Sites / Projects

Bolivia has an estimated 2,490 MWe of geothermal power potential.

The objectives of the Bolivian Government vis-à-vis geothermal development, are to encourage private investment, promote regional development, expand and diversify energy exports, and increase the use of the country's renewable resources.

Bolivia's geothermal resources are primarily located in the Cordillera Occidental of the Western Andes Mountains that constitutes the border with Chile, and in the Altiplano. The area is arid and dry with an altitude of 4000-5000 masl. The area is sparsely populated and poor and the principal economic activity is small-scale mining.

Since the 1970s, Bolivia has identified geothermal energy as an important and complementary source of energy, from a geographic point of view, to strengthen the southern part of the NIS. Looking at local energy supply, geothermal sources are the most economical for the southwestern corner of Bolivia. Additionally, Bolivia's resources are well situated to supply the ever-increasing market in northern Chile. Forty-two (42) principal thermal manifestations have been identified.

In 1976, ENDE and the Ministries of Energy and Hydrocarbons and of Mining and Metallurgy, with funds from the UNDP and assistance from the ENI Group of Italy, began evaluating Bolivia's geothermal potential. Seven primary areas of geothermal interest were identified:

Volcán Sajama, Empexa, Salar de la Laguna, Volcán Ollague-Cachi Laguna, Laguna Colorada, Laguna Verde, and Quetana. Of the seven, three are considered most important: Laguna Colorada, Sajama, and Valle de Río Empexa. These are located along the Occidental Cordillera of the Andes which runs north-south along the border with Chile.

The area of primary geothermal interest coincides with the shortage of primary energy alternatives. Due to the distance to transport and distribution systems of commercial energy, geothermal energy is greatly appreciated to be competitive and complementary with other primary resources.

To date, $16.5 million has been spent on evaluating the country's geothermal resources primarily on the Laguna Colorada project.

1. Capachos
2. Castilla-Huma
3. Laguna Colorada
4. Pazña
5. Poopo
6. Sajama
7. Sorocachi
8. Urimiri
9. Valle de Río Empexa
10. Vichas-Lupe

Capachos

LOCATION

STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	80-135

CHRONOLOGY
1997 and 1998 - Sample collected by NRECA; analysis done by Fraser Goff, Los Alamos National Laboratory.

There are chemical indications of thermal character (As, B, Cs, Li, Rb) but low silica. These waters also have relatively high Ca + Mg suggesting a mixing of reservoir water with cooler groundwater. "Best estimate" (BE) temperature is #135ºC, probably closer to 80ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).

Castilla-Huma

LOCATION

STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	75-160

CHRONOLOGY
1997 and 1998 - Sample collected by NRECA; analysis

done by Fraser Goff, Los Alamos National Laboratory.

Some chemical indications of thermal character but high Ca + Mg and low silica. Mixing of reservoir and near-surface waters is indicated. BE temperature is #160ºC, probably closer to 75ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).

Laguna Colorada

LOCATION
In the Cordillera Occidental in the southwestern corner of the Potosí department near the border with Chile; 340 km south of the city of Uyuni; 200 km south of Empexa; and east of the Tatio geothermal field located in Chile. At 67º40'W, 22º30'S; altitude ranges from 4300 to over 5000 masl.

Site composed of three fields: SOL DE MAÑANA, APACHETA-AGÜITA BRAVA, and HUAYLLAJARA.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	150-400
TEMPERATURE (EC)	250-260

CHRONOLOGY
1970s - Site identified under the UNDP Energy Resources Evaluation Program.

1976 to 1977 - Reconnaissance studies begun with assistance from the Italian Government and ENI of Italy. Work done by the company, Aquater.

1978 to 1980 - Prefeasibility study done by ENDE with the Italian Government and the Andean Development Corporation (CAF).

1982 - Technical-economic evaluation done of the installation of a 30 MWe plant in Laguna as part of the NIS.

1985 - Feasibility study begun.

1987 to 1989 - Five wells drilled to depths of 1180 to 1601 m. Two stages of developed were defined: (1) the installation of a backpressure plant of 4-10-MWe for the local markets (mining, mineral processing plants, and rural electrification), and (2) the drilling of additional wells with the objective being to ascertain the potential necessary for plants of greater capacity for the supply of electricity to NIS and export to Chile.

1990 - ENDE obtained US$8.5 million from the Italian Government to install a pilot plant in Sol de Mañana composed of two 4 MWe units and a transmission line for the local market.

1991 to 1992 - ENDE deepened reinjection well SM-4 from 1474 to 1726 m, and drilled SM-5 (1705 m).

Six wells have been drilled to an average depth of 1500 m in the Apacheta and Sol de Mañana fields. Five are production, one is reinjection. Two production wells, SM-2 and SM-5, have potentials of 6.5 MWe and 6 MWe respectively.

The wells' production fluctuates between 350 and 370 t/h of geothermal fluid (vapor and water), with pressures of 30-48 bar, and reservoir temperatures of 250-260 ºC.

1993 - Due to domestic corruption, the Italian Government canceled its promised financing and the project was halted.

Following an invitation to international experts, ENDE contracted with the Engineering Services of CFE of México to define exactly the geothermal resources and the potential for their technical and economic development.

CFE's study confirmed the minimum potential of the field at 100 MWe, outlining the following as a plan for its development:

(1) Immediately utilize the vapor of the present wells by installing one or two 5 MWe backpressure units whose construction would take 1 to 1.5 years,

(2) Install two condensing plants of 60 MWe each for a total of 120 MWe, for connection to the NIS and export to northern Chile, which would take 2.5 to 3 years.

CFE certified that the potential of Laguna Colorada is 120 MWe (2 x 60 MWe) for 25 years. Under this scheme, 20 production wells are required to provide steam to the power plants, and 7 reinjection wells to dispose of approximately 4400 t/h of residual water (Delgadillo, 1998).

Possible markets are mining centers, SIN, and SING. The total investment necessary for SIN (connecting to the Telamayu substation) is US $159 million; for SING (connecting to the Calama substation) is US $145 million. The price to sell the energy is for SIN, US

$35.1/MWh; for SING, US $33.4/MWh. Estimated price is 3.5¢/kWh (Amez, July 1998).

NOTES
Energy Initiatives purchased the Laguna Colorada geothermal rights for $50,140.

The potential of the Sol de Mañana field is estimated as follows. Minimum potential: 20-30 MWe; probable potential: 150-180 MWe; possible potential: 350-400 MWe.

To date, $16.5 million has been invested in the Laguna Colorada project.

Pazña

LOCATION

STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	90-180

CHRONOLOGY
1997 and 1998 - Sample collected by NRECA; analysis done by Fraser Goff, Los Alamos National Laboratory.

These fluids have some thermal characteristics but high Ca + Mg and low silica. Mixing of reservoir and near-surface waters is indicated. BE temperature is #180ºC, probably closer to 90ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).

Poopo

LOCATION

STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	75-170

CHRONOLOGY

1997 and 1998 - Sample collected by NRECA; analysis done by Fraser Goff, Los Alamos National Laboratory.

Some chemical indications of thermal character but high Ca + Mg and high SO4 (nearly 400 ppm). Mixing of reservoir and near-surface waters is indicated. BE temperature is #170ºC, probably closer to 75ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).

Sajama

LOCATION
To the west of the Sajama Volcano, approximately 250 km from La Paz.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	240-250

CHRONOLOGY
1970s - Site identified under the UNDP Energy Resources Evaluation Program.

1976, 1988, and 1990 - Evaluations of site by ENDE with support from the UNDP, the Italian Government, and the IAEA. Studies indicated the existence of a high enthalpy resource.

1992 and 1993 - Additional studies done by CORDEOR and GEOBOL. (national institutions).

NOTES
Proposed uses: rural electrification, to supply the National Interconnected System (NIS), and for other direct uses with a social character.

Reservoir temperatures estimated at 240-250ºC at a depth of 800-1200 m.

The next stage should be the drilling of deep exploratory and production wells.

The existence of a paved road, which is the international route running to Arica, Chile, will facilitate the development of the Sajama project.

Sorocachi

LOCATION

STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	90-140

CHRONOLOGY
1997 and 1998 - Sample collected by NRECA; analysis done by Fraser Goff, Los Alamos National Laboratory.

There are chemical indications of elevated reservoir temperature (a little As, Cs, Rb; good B and Li) but relatively low $SiO2$. Either the deep reservoir water has re-equilibrated during flow to the surface or the deep fluid has mixed with cool near-surface groundwater. BE temperature is #140ºC, probably now closer to 90ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).

Urimiri

LOCATION

STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	75-180

CHRONOLOGY
1997 and 1998 - Sample collected by NRECA; analysis done by Fraser Goff, Los Alamos National Laboratory.

Some chemical indications of thermal character but high Ca + Mg and low silica. Mixing of reservoir and near-surface waters is indicated. BE temperature is #180ºC, probably closer to 75ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler

near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).

Valle de Río Empexa

LOCATION
In the Cordillera Occidental west of the Salar de Uyuni River; covers an area of more than 10,000 km².

Site includes two fields: EL DESIERTO and FUNETE DE TOWA.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	230-340

CHRONOLOGY
1970s - Site identified under the UNDP Energy Resources Evaluation Program.

1976 to 1977 - Reconnaissance studies begun with assistance from the Italian Government and ENI of Italy. Work done by the company, Aquater.

1977 to 1980 - Prefeasibility study conducted by ENDE with the cooperation of the UNDP, CAF, and the Italian Government. The study included the drilling of six thermal gradient wells to depths of 150-165 m.

The study estimated that the reservoir has temperatures of 230-240ºC at depths of 800-1000 m.

NOTES
Resource estimated to have reservoir temperatures of 230-240ºC at depths of 800-1000 m and produce 30 t/h of vapor with an enthalpy of 1400 kJ/kg at 7 bars of pressure. Chemical geothermometers indicate 230-340ºC reservoir temperatures.

Despite the favorable characteristics of the Río Empexa field, development was not pursued because Laguna Colorada was evaluated to be more economically feasible.

Proposed industrial uses: mineral extraction of sulfur, borox, and other minerals. Also local rural electrification. Río Empexa is adjacent to Salar de Uyuni where geothermal power could be used in the exploitation and transformation of salts (lithium, potassium, borox, and magnesium) and other minerals. In order to develop this site, it is important to ascertain that financial resources are available. Moreover governmental support in promotional work is needed as well as methods to attract private participation through contracts which divide risk.

Vichas-Lupe

LOCATION

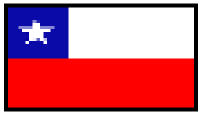
STATUS
Reconnaissance

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	100-160

CHRONOLOGY
1997 and 1998 - Sample collected by NRECA; analysis done by Fraser Goff, Los Alamos National Laboratory.

Water from this site has some species of thermal character but low silica, fairly high Ca + Mg and high HCO (> 1000 ppm). It is probably a mixed water and may have a close association with carbonate-bearing rocks. BE temperature is #160ºC, probably closer to 100ºC (Goff, 1998).

NOTES
The site does not have obvious electrical geothermal potential unless there is an obvious nearby volcanic heat source and some geologic/hydrologic evidence for mixing of a deep reservoir component and cooler near-surface groundwaters. On the other hand, direct use applications may be excellent depending on flow rate and chemical scaling/corrosion considerations (Goff, 1998).



Chile

Population (millions) - July 1998	14.79
Overall Electrification (% of population)	97%
GDP (billion US$) - 1997 est.	$168.5
Real GDP Growth Rate - 1997 est.	7.1%
Inflation Rate (CPI) - 1997	6.0%
Total Installed Capacity (MWe) - 1995	5946
Electricity Consumption per Capita (kWh) - 1997	1996
Energy Demand Growth Rate	8.0%
Prices (US¢/kWh) - June 1998	
Residential	10.3
Commercial	9.2
Industrial	5.91
Estimated Geothermal Potential (MWe)	**2,350**

Power Summary

Chile has limited indigenous energy resources, and looks to international partners and imports to help it meet the country's rapidly increasing domestic energy demand.

Hydroelectric power supplies about 60% of the country's electricity needs with the balance coming from coal (which is being phased out due to environmental concerns) and natural gas. Chile's historic dependence on imported energy has prompted the Government of Chile (GOC) to substitute hydro, coal, geothermal, and other renewable technologies for imported petroleum.

A significant portion of Chile's increased energy needs goes to powering the country's mining sector in the northern part of the country, and to the large urban areas, such as Santiago (which alone accounts for 40% of the country's total energy demand).

Chile's energy demand has been doubling every six or seven years; new cross-border trade agreements between Chile and Argentina will facilitate more imports of oil, gas and eventually electrical power.

Chile's energy consumption is projected to rise 15% in the north and 8.5% in the south-central zone. Empresa Nacional de Electricidad (ENDESA), the leading private power generator in Chile, forecasts that between the year 2002 and 2012, an additional supply of 21,000 MWe—equivalent to $8 billion—is needed just to meet the foreseen demand.

Power generation in Chile is organized around 4 grid systems: 1) the Northern Grid, which accounts for around

19% of national generation; 2) the Central Grid, accounting for 68.5% of national generation and serving 93% of Chile's population; 3) the Aysen Grid (0.3% of total generation); and 4) the Magallanes Grid (0.8% of total generation). Approximately 1 million people in rural areas do not have access to the grid. By 2005, however, President Frei is committed to extending electric supply to the entire rural population.

In addition to the 4 grids, "self producers" account for 11.6% of national generation. Electricity transmission and distribution takes place through the 4 grids, as well as 36 electricity distribution companies.

In late September 1998, Chile switched to summer time three weeks early in an effort to conserve energy following a long drought which affected the Central Grid. The drought cut hydroelectric output significantly, and in particular affected utilities such as ENDESA which rely heavily on hydroelectricity (80% of the energy used in the central grid). The drought, coupled with the untimely failure of two thermal plants, forced most of the country to ration for two weeks in mid-November 1998.

Chile was the first country in Latin America to liberalize and privatize the power sector in the 1980s. Its power sector is highly competitive. Two companies, however, ENDESA and CHILGENER, dominate the sector.

Fifty percent of Chile's energy is supplied by private producers. Electricity costs range between 5¢/kWh and 8¢/kWh in the north where thermal sources are predominant, and 3¢/kWh in the south where hydropower resources dominate.

Government / Legislation

Comisión Nacional de Energía (CNE)

CNE was established in 1978 with a law decree in the Ministry of Mines. It is charged with coordinating the plans, policies and standards of the energy sector and in particular the electricity subsector. CNE has created three committees: Electrification of Rural Zones, Energy Efficiency, and Energy Alternatives.

CNE regulates electricity prices by setting the "node" price of electricity in various parts of the country every six months. This is the price that distribution companies pay for electricity and is based on the marginal cost of energy and capacity. Node prices have varied widely over the past ten years.

The only government subsidy that exists in Chile is for investments in rural electrification, primarily for small solar and wind projects. The GOC subsidizes part of the investment that the private sector must make in rural electrification with the understanding that the private sector would not be interested in the business without a subsidy.

Companies engaged in the generation of electricity must coordinate their operations for the country's Central Interconnected Power System (SIN) and the Northern Interconnected Power System (SING) with the Economic Load Dispatch Center (CDEC).

The CDEC as an independent operator, plans and coordinates the operation of the plants to ensure secure and economic efficiency in the electricity sector irrespective of ownership. Demand is met by dispatching the available plants according to their variable production costs, from lowest to highest, and is thus always done at the minimum attainable cost. Generation companies sell to three markets: the spot market, the unregulated market, and the regulated market.

Draft "Law for the Development of Geothermal Resources" Sent to National Congress (1991)

A draft "Law for the Development of Geothermal Resources " was sent to the National Congress for consideration in 1991 and is presently nearing passage. Approval, and the process needed to develop the regulations needed to transform the Law into operation, should take less than a year.

The Draft Geothermal Law attempts to regulate the exploitation of geothermal energy and the terms of concessions and licenses, to establish the procedures necessary for the development of the resource, to lay out the conditions for the environmental development of the resource, and finally to establish how the proprietor or owner of a geothermal concession is related as much to the State as to the private sector.

The Draft Geothermal Law defines geothermal energy as "a bodyless property, unappropriable in ownership, but useable and enjoyable in the way assigned by authority." It notes that a franchise implies property rights and that it can be established over other franchises or rights. It is granted through a Supreme Resolution of the Mining Ministry with a previous application or public bid and a report by the CNE.

The franchise conditions included the use of a legal contract. The franchisee is obliged to make the investments that were agreed to in the contract, including those regarding the exploration period and the ones concerning the installation project for the geothermal area exploitation. The payment of an annual patent fee to the State is established after the exploitation project is finished. An exploration period with a maximum of five years (that may he extended two years more) is established. Three months before its end, plans for an installation project must be presented and they must include a working schedule and minimum annual investments.

The Mining Ministry can cancel a franchise if the investment plan is not followed (González, 1995). A relevant issue for Chile is where geothermal fields are located and the possibility that a geothermal and mining concession could be located in the same area.

Chile's mining sector, the single biggest industry in the country, remains in government hands. At least a partial privatization of state oil (ENAP) and mining (ENAMI) is under consideration. CODELCO, the state copper corporation, is by far Chile's largest company, as well as the world's largest copper company.

An issue which is still largely debated is how to guarantee the right to have or explore a geothermal concession without granting a right which has a speculative character. There are several reasons why a private entity that has a geothermal concession could not make an investment. The Law establishes that the owners of a concession have certain developmental benchmarks to reach in certain periods of time. If these benchmarks are not attained, the developer could lose the concession.

Geothermal Sites / Projects

<u>Chile has an estimated 2,350 MWe of geothermal power potential.</u>

There are currently no geothermal power projects in Chile. Any future projects would have to compete equally with existing generation on the interconnected grid. The average cost of generation in Chile is 2.1-3.5 ¢/kWh (Germain, 1998).

Chile began identifying its geothermal resources in the late 1960s with assistance from the UNDP. Exploration has primarily occurred in the northern part of the country, in Tarapacá (Region I) and Antofagasta (Region II). The most in-depth studies have been done at El Tatio. Geothermal exploration has been concentrated in this part of the country because it has few alternative energy sources.

Investigations have shown the existence of at least 200 geothermal features scattered throughout the country. Low enthalpy resources (less than 100ºC) have been identified and are abundant along the eastern side of the Central Valley. Medium and high enthalpy resources are located all along the volcanic mountain chain of Los Andes Cordillera, in the Quaternary volcanic zones, often in isolated areas.

Limited hydroelectric resources have been developed and oil exploration has been unsuccessful in the northern mining areas. As a result, the Chilean Government considers geothermal energy to be a good alternative in these areas.

While in the northern part of the country the electricity systems work on the basis of fossil fuels (oil and coal), in southern-most Chile the electric power derives both from hydroelectric energy and fossil fuels. In many remote areas diesel electric power is used. Although the portability and relatively low cost of diesel electric plants has brought electricity to many rural communities and industries, the high price of the fuel and system maintenance have increased the cost of electricity, particularly in remote areas.

The above factors suggest that highest priority should be assigned to the development of geothermal resources for electricity generation in rural areas. The use of geothermal energy could reduce the dependence on expensive imported oil and encourage the establishment of local industries (Gonzalez, 1995).

Both in northern and central-south Chile there are various areas with high-temperature (200-250ºC) geothermal resources that could be used for electricity generation. In the northern zone, the existence of fluids with temperature of up to 260ºC would permit not only the generation of electricity but also the production of fresh water, the recovery of chemical elements contained in the geothermal fluids, and the exploitation of important non-metallic mineral resources.

In central-south Chile, generally more inhabited than the northern zone, small electric schemes based on geothermal energy, could be developed in conjunction with agriculture and aquaculture projects.

Considering the available geothermal resources' potential as well as the geographic and social-economic conditions which exist in the different regions of the country:

1. In northern Chile, the most important utilization of geothermal energy must be the production of electric energy. This would allow the development of important industrial processes such as fresh water production. recovery of chemicals from evaporite deposits and from the brines of salars, sulfur refining, and others.

2. In central-south Chile, in addition to power generation for rural communities and industries, the most suitable applications of geothermal energy are in agriculture, aquaculture, and animal husbandry (Lahsen, 1988).

1. Alitar
2. Catillo Hot Springs
3. Chanchocó-Copahue
4. Chillán Hot Springs
5. El Tatio
6. Jurase
7. Laguna Tujacto
8. Pampa de Lirima
9. Panimávida Hot Springs
10. Puchuldiza
11. Salar de Aguas Calientes
12. San Pedro
13. Suriri

Alitar	
LOCATION Region II	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1980 - Identified in Antofagasta (Region II) Geothermal Resources Register.	
NOTES	

Catillo Hot Springs	
LOCATION Region X	
STATUS Prefeasibility study	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-

TEMPERATURE (EC)	-

CHRONOLOGY
1993 - Prefeasibility study done.

NOTES
Cascaded exploitation of the resource would allow an return on investment in 4.3 to 8.5 years (Gonzalez, 1995).

Chanchocó-Copahue

LOCATION
In the high mountains of the southern part of Region VIII. Across the border from the Argentine site at Copahue-Caviahue.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1979 - Preliminary report completed as part of Geothermal Resources Register program. Report concluded that this remote area is a vapor-dominated field.

NOTES

Chillán Hot Springs

LOCATION
Region X at 36º57'S, 71º33'W.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	2
TEMPERATURE (EC)	210

CHRONOLOGY
1993 to 1995 - Prefeasibility study done by state-owned Ente Nacional de Petrolio (ENAP) and Compagnie Francaise Geotmique de Francia (CFG); included geological study, water quality analysis, and limited drilling program; 270 m deep slimhole well; found thermal waters with 200ºC and pressure of 22 kg/cm².

Investigators concluded that area could be developed for both power generation and direct use (tourism).

ENAP has officially requested support for the project from UN/ECLAC for:

(1) Identifying potential joint venture partners for ENAP, and

(2) Identifying possible co-financing sources for continued study.

NOTES
Geothermometers show temperatures that would allow the installation of a small Rankine cycle plant generating 2 MWe. Na-K-Ca geothermometer temperature (Truesdell, 1975).

The cost of kW generated would compete with the average cost of kW generated by traditional methods in Chile (Gonzalez, 1995).

El Tatio

LOCATION
In the Andes Mountains Range in northern Chile, 100 km east of the town of Calama and the Chuquicamata copper mine; at 22.3ºS, 68ºW; 4300 masl (Region II).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	100
TEMPERATURE (EC)	160-285

CHRONOLOGY
1917 - Exploration begun by government agencies and private companies.

1967 - The Corporation for the Promotion of Development (CORFO), with UNDP support, began investigation of field.

1969 to 1971 - Six exploration wells drilled with an average depth of 600 m. Verified the existence of permeable zones (reservoirs) with a temperature range of 212ºC to 254ºC.

1973 to 1974 - Seven production wells drilled which discovered three permeable layers, from top down: 150-250 m deep with temperature of 160ºC; 460-600 m deep and 225-230ºC; and 700-1600 m deep and 200-260ºC. At present, of the seven wells, only two are useable with a flow rate of 240 t/h and the ability to each generate 8.5 MWe.

1975 - Electroconsult conducted a feasibility study for the installation of a 35 MWe plant.

1975 and 1976 - A pilot plant for geothermal fluid desalination was put into operation to investigate the feasibility of obtaining fresh water from electricity generation. The plant showed that ten liters of fresh water could be recovered per second per MW of power potential.

1977 - ENDESA, which was then part of the State, conducted a feasibility study of constructing a 30 MWe plant.

1988 - Freeport-McMoran offered CORFO an agreement to complete at its own cost the exploration of the field on the condition that it would be granted preferential option, for a period of five years, and to buy the rights related to the project for a sum of $3.7 million.

1990 - Trans-Pacific Geothermal Corporation offered an agreement with similar conditions as Freeport-McMoran's, for $4 million.

These two agreements did not become concrete due to a lack of the promulgation of a geothermal law whose approval was yet to come.

1996 - Chilean consultants on account of CORFO, carried out a study with the objective of defining the base for licensing the property for private initiative. In effect, the project is the property of the Geothermal Society of Tatio, S.A., which was constructed in 1962 and in which CORFO has a 58% share, leaving the 42% remainder to private property.

NOTES
With the recent construction of the Atacama Gas Line and distribution of approximately 5 million m³ of gas per day in the north of Chile at very low cost, it would be difficult to generate electricity by geothermal at competitive costs.

Electric power production potential estimated at a minimum of 100 MWe. Plant could be made a part of the existing interconnected electrical system.

The geothermal fluid is a mixture of salty water, steam, and a small gas fraction.

Jurase

LOCATION
Near the city of Putre at 18º12'S, 69º32'W.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	131

CHRONOLOGY

NOTES
Waters belong to the acid-sulphate type.

Na-K-Ca geothermometer temperature (Truesdell, 1975).

Laguna Tujacto

LOCATION
Region II

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1980 - Identified in Antofagasta (Region II) Geothermal Resources Register.

NOTES
Interesting due to its proximity to the iron mine of El Laco.

Pampa de Lirima

LOCATION
Location of Quiguata; 3900 masl at 19º53'S, 68º56'W (Region I).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	169-211

CHRONOLOGY
1969 - UN geophysicist found a 10 ohm/m anomaly. Studies began which indicated underground temperatures of between 169ºC and 211ºC.

1980 - Included in a group of promising areas for further study.

NOTES

Panimávida Hot Springs

LOCATION
Region X

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1993 - Prefeasibility study.

NOTES
Cascaded exploitation of the resource would allow an investment return-time of 4.3 to 8.5 years (Gonzalez, 1995).

Puchuldiza

LOCATION
19.3ºS; 69ºW; 4250 masl (Region I).

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	190
TEMPERATURE (EC)	175-200

CHRONOLOGY
1967 - CORFO, with UNDP support, began investigation of field.

1976 - Agreement of Cooperation with JICA signed. Five wells were drilled, the deepest to 1013 m, with a maximum temperature of 175ºC. A superficial thermal aquifer, detected between 200 and 550 meters, was interpreted to have a temperature of over 200ºC.

Well 6 was drilled to 1200 m.

NOTES

Salar de Aguas Calientes

LOCATION
Region II near the Lastarria Volcano.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0

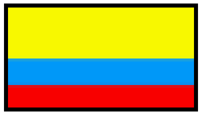
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY 1980 - Identified in Antofagasta (Region II) Geothermal Resources Register.	
NOTES	

San Pedro

LOCATION 35.1ºS; 70.5ºW	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	195-245
CHRONOLOGY	
NOTES	

Suriri

LOCATION A salt lake at 19ºS; 69ºW (Region I), along the Arica-La Paz highway.	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	50-60
TEMPERATURE (EC)	110-234
CHRONOLOGY 1972 - Study began. 1979 - Geological and geochemical studies conducted. 1980 - Study abandoned due to lack of funding.	
NOTES Superheated steam at the Polloquere fumaroles with a surface temperature of 110ºC considered to be a promising area. Na-K-Ca geothermometer temperature of 234ºC (Truesdell, 1975).	



Columbia

Population (millions) - July 1998	38.58
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1997 est.	$231.1
Real GDP Growth Rate - 1997 est.	3.1%
Inflation Rate (CPI) - 1997	17.7%
Total Installed Capacity (MWe) - 1995	10584
Electricity Consumption per Capita (kWh) - 1997	972
Energy Demand Growth Rate	6.6%
Prices (US¢/kWh) - June 1998	
Residential	3.33
Commercial	8.00
Industrial	6.69
Estimated Geothermal Potential (MWe)	**2,210**

Power Summary

Colombia is a major exporter of coal and petroleum. Hydropower currently provides most of the country's electricity. Colombia is investing in the expansion of its electric generating capacity with plans to add over 3 gigawatts (GW) by 2000 and an additional 6 GW by 2010.

Colombia's plans for the power sector favor investment in thermoelectric generating capacity (primarily natural gas) at the expense of hydroelectricity. Coal-fired capacity (currently about 7% of the total) could also increase. The diversification of electric generating capacity reflects concern over the impact of droughts on hydroelectric generation, which has periodically forced the country to ration electricity. In 1992 and 1993, Columbia was virtually shut down for eight hours a day due to power shortages resulting from the drought produced by El Niño.

In addition to domestic supply, Colombia also imports electricity from Venezuela. A new interconnection established in July 1998 will allow Colombia to export electricity to neighboring Ecuador, which is experiencing electricity shortages.

Analysts describe Colombia's electricity markets as highly competitive—most power is simply sold into a grid system that favors low cost producers. About 20% of the power generated in Colombia is traded on the country's Electricity Exchange, with the rest sold under term contracts. As of February 1998, 120 energy companies (including generators, transporters, distributors, and marketers) were listed on the Exchange.

The spot market is so well developed that future contracts have been structured around it. Nevertheless, electricity prices have fluctuated over the past few years primarily as a result of the country's over reliance on hydroelectricity and the changes in water levels caused by El Niño. It is hoped that the addition of efficient thermal power will stabilize Colombia's prices.

Privatization of Colombia's electricity sector began in 1994 after it became clear that the government could not keep up with the increasing energy demand. By the end of 1997, foreign investors owned over 40% of the country's generating capacity, worth about $4 billion. Approximately 55% of power generation is now in private hands; by 2010, public utilities are expected to own only 32.7% of the country's electricity generation capacity (compared to 75.5% in 1996).

Privatization of Columbia's power sector began slowly with the construction of several electric power generation plants under Build-Operate-Maintain-Transfer (BOMT) agreements.

Colombia's privatization process will enter its final phase in 1999 with the sale of 76.8% of state-owned ISAGEN, the country's largest power producer and transmission company. Interconexión Electríca (ISA), the transmission company, will be offered to private bidders later in the year.

The Colombian government is also prepared to capitalize in the first semester of 1999 several electricity companies including Cedelca, Cedenar, Quindino, Choco and Tolima, which are currently weighing down the national budget. The Government of Columbia (GOC) hopes to raise as much as $3.5 billion from electricity privatization in 1999.

The all-encompassing issue of narcotics will continue to affect nearly all aspects of Colombia's political and economic environment. In addition to narcotraffickers, the country's high crime rate and guerrilla terrorism have hurt the business climate.

The IDB has approved a $350 million loan to help modernize Colombia's electricity sector. Part of the loan will be used to help the GOC develop policies based on competition and involvement of the private sector and strengthen the independence of the sector's regulatory agency. The promotion of private participation will be done mainly in distribution including the privatization of seven state distribution companies.

Government / Legislation

MINISTERIO DE MINAS Y ENERGÍA

According to Minister Luis Carlos Valenzuela, the State's role in the power sector is to regulate markets to prevent monopolies.

Instituto de Investigacion en Geosciencias Mineria y Quimca (INGEOMINAS) is part of the Ministry of Mines and Energy.

Laws 142 and 143 (1994)

Laws 142 and 143 developed private competitiveness in power generation, transmission, and distribution, as well as free access to the transmission and distribution networks.

No Specific Law for Geothermal

Geothermal Sites / Projects

Columbia has an estimated 2,210 MWe of geothermal power potential.

Following the severe 1992-93 energy crisis, the GOC began working to decrease the country's reliance on hydroelectric power and diversify power generation resources. The goal is to reduce hydroelectric's share of total installed capacity from 75% to at least 60% by 2010.

The first geothermal reconnaissance studies were conducted in the late 1960s; 1500 km² were evaluated in the Antioquia Department. A series of additional studies were then carried out in the 1970s and early 1980s. More recently, Colombia has not manifested official interest in developing its geothermal resources.

Potential for small-scale geothermal plants is large considering that 70% of the municipal governments have less than 10,000 inhabitants whose current level of energy consumption could be met through geothermal (Lawrence, 1998).

1. Azufral Volcano
2. Laguna del Otún
3. Las Nereidas-Botero Londoño
4. Tufiño "Binational"
5. Volcán Machín-Río Toche

Azufral Volcano

LOCATION
In southern Colombia near the border with Ecuador; 12 km northwest of Túquerres, a city with a population of 40,000 (Nariño Province).

The Azufral Volcano summit is at 4020 masl where a caldera structure is found with a diameter of about 3 km. Inside the caldera is a green acid lake, "La Laguna Verde."

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	200-250

CHRONOLOGY
1996 and 1997 - INGEOMINAS began sampling and prefeasibility study of field; included interpretation of satellite imagery and geological and volcanological studies.

1998 and 1999 - Two-year exploration program to locate and characterize the geothermal system(s) and to identify possible drilling targets for a feasibility study to be carried out. Program will include geochemical, hydrogeological, and geophysical studies, volcanic hazard study, and assessment of environmental impacts planned. Estimated total cost is $1.3 million—$1 million as a Japan Special Fund Grant, the balance of the loan from the Inter-American Development Bank.

NOTES
Field currently being studied.

Although there are several volcanoes with associated geothermal systems in the area, Azufral is the most promising prospect because of its location as well as from geothermal exploration and volcanological points of view (Bernal, 1998).

Six springs are associated with Azufral: MALAVERES, LAGUNA VERDE, QUEBRADA BLANCA, LA CABAÑA, SAN RAMON, and RÍO VERDE. Na-K geothermometer temperatures range from 200ºC to 230ºC; pH from 2.5 at Laguna Verde, to 9 at Malaveres (Bernal, 1998).

Laguna del Otún

LOCATION
Probably associated with the Nevado de Santa Isabel volcano; part of the Macizo Volcánico del Ruiz.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1983 - Prefeasibility studies done by Central Hidroeléctrica de Caldas (CHEC); selected three areas of priority for the drilling of deep exploratory wells: Las Nereidas, Laguna del Otún, and the Machín Volcano. Wells were drilled at Las Nereidas first.

NOTES

Las Nereidas-Botero Londoño

LOCATION
An area of 130 km² located in the Central Range of Colombia on the western slope of the Nevado del Ruiz Volcano at 3450 masl; part of the Central Colombian Ridge, the northern part of the Andes; part of the Macizo Volcánico del Ruiz.

STATUS
Well(s) or hole(s) drilled

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	50
TEMPERATURE (EC)	200-260

CHRONOLOGY
1968 and 1969 - First geothermal study was done in an area covering 1500 km² near the Macizio Volcano by ENEL of Italy and CHEC.

1970s - Intense regional geothermal exploration by Instituto Colombiano de Energía Eléctrica (ICEL).

1983 - Prefeasibility studies done by CHEC; selected three areas of priority for the drilling of deep exploratory wells: Las Nereidas, Laguna del Otún, and the Machín Volcano.

November 1985 - Nevado del Ruiz Volcano erupted killing 25,000.

1992 - CHEC and EPN of México decided to reevaluate the existing data and sample additional thermal fluids. The result of the study indicated a deep temperature (geothermometer) of 220-260ºC and recommended drilling two wells of 1500 m in a zone located between Las Nereidas and the thermal springs of Botero Lodoño.

The cost of the first well is estimated at $4.2 million.

The total project cost of constructing a 50 MWe plant is estimated to be $85 million.

1997 - First exploratory well (Nereidas I) drilled July-August. The well was programmed to reach 2000 m but suffered a strong deviation, up to 42º, to reach a total depth of 1466 m (Monsalve et al, 1998). Temperature measured on the bottom was 200ºC. Waters from Las Nereidas are bicarbonate-sulfate with composition (Giggenbach et al, 1990, in % mol): 94.9 CO_2, 3.2 H_2S, 0.59 N_2, 0.47 CH_4, and 0.34 H_2.

NOTES
Waters from Botero Londoño belong to the neutral sodium chloride geochemical type. Gases from the hot springs have the following composition (Giggenbach et al, 1990, in % mol): 93.3 CO_2, 4.0 H_2S, 2.57 N_2, 0.089 CH_4, and 0.06 H_2.

Tufiño "Binational"

LOCATION
Located on the border with Ecuador.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE) 0

POTENTIAL (MWE) -

TEMPERATURE (EC) -

CHRONOLOGY
1983 to 1985 - Prefeasibility study done by OLADE with Italian financing; located best site for deep exploratory wells in the Aguas Hediondas area. The geothermal potential of the area appears high although the results of the study are inconclusive.

NOTES
Area includes various slopes of medium temperature of which the most important are: Aguas Hediondas (53ºC) and Aguas Verdes (26ºC) in Ecuador and Baños del Indio (45ºC) in Colombia.

The geothermal resource is currently used in small thermal complexes in Ecuador and Colombia.

Volcán Machín-Río Toche

LOCATION
Part of the Macizo Volcánico del Ruiz.; related to the Machín volcano.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE) 0

POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

1983 - Prefeasibility studies done by CHEC; selected three areas of priority for the drilling of deep exploratory wells: Las Nereidas, Laguna del Otún, and the Machín Volcano. Wells drilled at Las Nereidas first.

NOTES

A deep exploratory well could be drilled inside the caldera at the volcano's summit, between the caldera trace and the western dacitic intra-calderic dome. The possible geothermal system in this area would probably be smaller than the one at Las Nereidas-Botero Londoño (Gutíerrez-Negrín, 1995).

Ecuador

Population (millions) - July 1998	12.34
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1997 est.	$53.4
Real GDP Growth Rate - 1997 est.	3.4%
Inflation Rate (CPI) - 1997	31.0%
Total Installed Capacity (MWe) - 1998	3000
Electricity Consumption per Capita (kWh) - 1997	612
Energy Demand Growth Rate	8 0%
Prices (US¢/kWh) - June 1998	
Residential	4.55
Commercial	4.46
Industrial	4.17
Estimated Geothermal Potential (MWe)	**1,700**

Power Summary

Ecuador is an important player in world energy markets, being Latin America's sixth largest crude oil producer and its fourth largest exporter. Although the country's political situation stabilized in 1998, with the democratic election of President Jamil Mahuad, who took office in August 1998[6], its economic prospects have become somewhat more difficult as a result of the fallout from the global economic and financial crisis as well as low commodity (including oil) prices.

Ecuador has an installed electric power capacity of 3,000 MWe and an annual electricity deficit of 10%. Overall, the country faces an electricity deficit of up to 1.4 terrawatt hours, with demand growing at 7% to8% annually.

Ecuador is a significant regional crude oil producer and exporter. The largely state-operated petroleum sector remains extremely important, accounting for one-third of both public sector revenue and export earnings. With expansion of the Transecuadorean pipeline, the country hopes to boost its oil output significantly.

6 Mahuad's election ended a year and a half-long political crisis and stalemate which began when Abdala Bucaram was removed from the presidency and replaced by Fabian Alarcon, leader of the Congress. Although Alarcon later won a popular referendum allowing him to maintain office until August of 1998, he was unable to undertake the necessary political and economic reform.

Due to an over-reliance on hydroelectric power—the 1,600 MWe Paute plant alone produces more than 60% of Ecuador's electricity—and seasonal droughts, rationing has been needed yearly since 1992. It is estimated that these yearly shortages cost Ecuadorean businesses roughly $500 million per year. The seasonal generating shortages, coupled with the nation's already existing electricity deficit, result in a national deficit which can reach over 30% of demand.

Subsidies for electricity were cut, raising the price by 25% in September 1998. Also in 1998, a peace treaty with Perú was signed, ending a long-standing border conflict which had existed between the two countries for more than half a century. In November 1998, Ecuador and Colombia signed an electricity interconnection agreement. Under the agreement, Colombia will export 15 MW of electricity to Ecuador's power grid.

Ecuador was slow to embrace the market-oriented economic reforms taking place elsewhere in Latin America and the electricity sector is only beginning to be privatized. The Government of Ecuador (GOE) expects that the privatization and capitalization program, which will include the partial privatization of electricity and oil assets, will generate US$1 billion by the end of 1999.

It has been estimated that this demand will require investments of $3.5 billion to install 2.2 GWe at nine power plants through 2010, all on a BOT basis. Energy Corp won a contract in June 1998 to supply Ecuador with 105 MWe of electricity. The energy will be supplied over two years at an average price of $.0758 per kilowatt hour.

By September 1998, 20 permits for power generation projects had been awarded to private firms, including the Daule Peripa hydroelectric facility (213 MWe) scheduled to come online in 1999; the Toachi-Pilaton thermoelectric project (190 MWe) to come online in 2002; and the 30-year BOT San Francisco hydroelectric project (230 MWe).

A $15-million World Bank project is being identified for Ecuador. The project will support structural and regulatory reform and privatization of the hydrocarbon, electricity, and telecommunications sectors (Development Business, 16 February 1999).

Government / Legislation

Subsecretaria de Electrificación

The Subsecretaria de Electrificación assumes the duties formerly held by the State utility monopoly, the Instituto Ecuatoriano de Electrificación (INECEL). As a result of the 1996 Electric Law, INECEL will divest itself of all its assets and cease to exist. The utility will be privatized by July 1, 1999.

Consejo Nacional de Electrificación (CONELEC)

CONELEC replaced INECEL to become the agency responsible for the development of a national electric plan as well as the regulation and control of the electric sector. CONELEC will have final approval of all electric power rates.

Power generation activities will be developed either through concessions or capitalization granted by CONELEC. Concession of transmission services will be granted exclusively to one company owned by the GOE; concession of distribution and commercialization will be granted by CONELEC to several corporations with exclusivity in their assigned areas.

Companies granted concessions must carry out activities in accordance to Ecuadorian environmental regulations, establishing an environmental impact study and an environmental management plan.

Law for the Electric Sector (September 18, 1996)

The Electrification Law ends the GOE's monopoly in the generation, transmission, and distribution of electric power and encourages free market competition, transparency, and efficiency.

It allows for the transfer of INECEL's assets to public corporations that can then sell up to 39% of their stock to private investors and an additional 10% to employees. The newly created companies will operate existing electric generation projects or will build new plants under concession agreements.

The Solidarity Fund was created to manage resources resulting from the privatization process. Shares will be offered to qualified operators, either national or international.

No Specific Law for Geothermal

The new Electricity Law promotes the use of non-conventional energy generation sources. Companies that install and operate electricity plants using non-conventional energy sources are exempt from paying income tax for a period of five years.

Under Ecuador's constitution, all subsurface resources are property of the State.

Water Law (1972)

Ecuador's surface and subsurface water resources were nationalized by the Water Law of 1972.

Geothermal Sites / Projects

Ecuador has an estimated 1,700 MWe of geothermal power potential.

INECEL began the first assessment of the country's geothermal potential in 1978, and in conjunction with OLADE, conducted a nationwide reconnaissance. Ecuador's geothermal resources are located in the Andes Mountains and along the border with Colombia.

From these initial studies, which were completed in 1980, high-enthalpy geothermal areas were selected and prioritized based on the results of hydraulic and water chemistry analyses. The three areas with the highest priority are Tufiño-Chiles (located on the Colombian border), Chalupas, and Chachimbiro in Imbabura Province. Additional studies of these areas were done in the early to mid 1980s by INECEL, OLADE, and the Italian Government.

Other areas classified as promising are the Iguan Volcano and Chalpatan Caldera area and Valle de los Chillos. USAID funded a prefeasibility study for a direct use project at the latter site from 1982 to 1985.

1. Chachimbiro
2. Chalupas
3. Cuenca
4. Iguan Volcano-Chalpatan Caldera
5. Tufiño "Binational" 2

Chachimbiro	
LOCATION In the West Andes Range (Cordillera Occidental) about 70 km north-northwest of Quito and 17 kn northwest of Ibarra; at 0º25'N, 78º17'W in the Cayapas-Cotacachi National Park; at 2560 masl (Imbabura Province).	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	60-240
CHRONOLOGY	

1983 to 1986 - Geothermal exploration studies funded and carried out by INECEL.

Found most frequent thermal manifestations are of the alkali chloride type with medium to high thermality and flows of 70 liters/minute. The total dissolved solids increase as heavy isotopes in solution increase (Aquilera, 1998).

The inferred depth of the reservoir is between 1000 and 2000 m in volcanic fractured rocks at the base of the pile of Pilocenic lavas.

1987 to 1990 - Superficial geological and geochemical studies undertaken by INCEL interrupted.

NOTES
Temperature at depth based on geothermometry is 240ºC (Aquilera, 1998).

From Ibarra, a 20 km paved road goes to Ureuqui. From Ureuqui, an 18 km gravel road goes to the site. The 130 kV Quito-Ibarra transmission line of the National Interconnected System is about 25 km from the center of the area.

Chalupas

LOCATION
In the Cordillera Real about 60 km southeast of Quito and 35 km northeast of Latacunga; in an isolated, not easily accessible area (Pichincha Province). The Cotopaxi National Park, site of the Cotopaxi Volcano, is the closest neighbor to the Chalupas field.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	180

CHRONOLOGY
1983 to 1986 - Geothermal exploration studies funded and carried out by INECEL.

Geochemical studies conducted, including 45 surface and subsurface water sampling points both inside and outside the caldera. Of the 45, 26 are thermal with temperatures ranging from 26ºC to 37ºC. The most frequent chemical types found were alkaline-earth and alkaline bicarbonate, within which subgroups based on their salinity and temperature have been defined. Values are pH are between 6.1 and 6.8.

North of the caldera sulfate water with ammonia and boron anomalies have been found; deep temperatures should exceed 180ºC.

The heat source is inferred to be a large magma chamber at a depth of about 10 km (Aguiera, 1998).

NOTES
The evidence of a geothermal area is a large caldera structure of recent age which are associated with igneous eruptions and hot springs of medium temperature.

The field can be reached by an about 50 km-long gravel road which runs along the northern and eastern flanks of the Cotopaxi Volcano, and is connected to the Pan American highway near the town of Lasso.

The 130 kV Pisayambo-Santa Rosa transmission line of the National Interconnected System is about 25 km from the center of the field.

Cuenca

LOCATION
In Azuay Province, location of some of the most well-known hot springs in Latin America.

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES
No specific data is known about the high enthalpy potential of this resource. There are various possibilities for its direct use in addition to its current tourist and therapeutic uses.

Iguan Volcano-Chalpatan Caldera

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES

Tufiño “Binational” 2

LOCATION
On the border with Colombia.

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1983 to 1985 - Prefeasibility study done by OLADE with Italian financing; located best site for deep exploratory wells in the Aguas Hediondas area. The geothermal potential of the area appears high although the results of the study are inconclusive.

NOTES
Area includes various slopes of medium temperature of which the most important are: Aguas Hediondas (53ºC) and Aguas Verdes (26ºC) in Ecuador and Banos del Indio (45ºC) in Colombia.

The geothermal resource is currently used in small thermal complexes in Ecuador and Colombia.

Perú

Population (millions) - July 1998	26.11
Overall Electrification (% of population)	72%
GDP (billion US$) - 1997 est.	$110.2
Real GDP Growth Rate - 1997 est.	7.3%
Inflation Rate (CPI) - 1997	6.7%
Total Installed Capacity (MWe) - 1995	4520
Electricity Consumption per Capita (kWh) - 1997	502
Energy Demand Growth Rate	10.0%
Prices (US¢/kWh) - June 1998	
Residential	12.56
Commercial	10.22
Industrial	4.75
Estimated Geothermal Potential (MWe)	**2,990**

Power Summary

Perú's electric power demand is growing rapidly, and is expected to require $300-$350 million annually in investment through 2000. Power demand increases are being driven by population and economic growth, along with expansion of the country's copper mining sector, which is highly energy-intensive.

Peruvian energy production increased 4.6% in the first 11 months of 1998, according to the Ministry of Energy and Mines. Hydro energy accounted for just under 77% of all generation, up 6.4% from 1997. State-owned ElectroPerú still accounted for 35.9% of all generation followed by privatized EDEGEL and EGENOR. Electricity coverage increased to 72%.

Perú's over reliance on hydropower has led to sporadic power outages in times of drought and during severe El Niño occurrences (1992-1993). The Government of Perú (GOP) estimates that the most recent El Niño (1997-1998) caused at least $1 billion damage.

Perú's power sector was nationalized in 1972 with ElectroPerú serving as the main holding company of ten smaller regional electricity companies. The legal framework governing Perú's electricity sector since late 1992 represents a radical change with respect to prior legislation. It is modeled after the Argentinean, Chilean, and British frameworks.

The GOP is continuing privatization of power utilities and encouraging foreign investment in new generation plants. Between 1992 and 1995, this program raised about $5 billion (plus $4 billion in investment pledges). Recently, privatization has continued at a somewhat slower pace.

The GOP expects to collect between US$800 million and US$1billion from privatizations in 1999, mostly in the oil, mining, agriculture and electricity sectors. Privatization is expected to be completed by 2000.

The GOP received a hard blow in July 1998 when Shell announced its decision to pull out of the huge Camisea project giving the following reasons: the underlying economics of the project had been weakened by the discovery of difficult fractures in the rock which would have made production more problematic and costly; and low oil prices made it harder to find financing. Domestic issues, e.g., an inability to reach agreement over gas distribution, disagreements over tariff structure, and the GOP ruling out gas exports, appear to have tipped the balance against the project (Latin America Monitor, August 1998).

According to Jorge Camet, former economy minister and head of the commission for Camisea (formed after the Shell-Mobil pullout), Camisea will be tendered in the first quarter of 1999. Camet acknowledged that no market for gas currently exists in Perú and would have to be developed.

Rural electrification is a high priority for the GOP which will invest more than US$100mn annually over the next few years to generate 270 MWe for supply to rural zones. The target is overall electrification of 75% by 2000. Each 1% increment demands US$70-80 million.

Government / Legislation

Ministerio de Energía y Minería (MEM)

The Energy Ministry is responsible for enforcing compliance with laws regarding electricity, and implementing the Organic Law on Geothermal Resources.

Organismo Supervisor de la Inversión en Energía (OSINERG)

OSINERG has oversight authority over energy investments and enforcement responsibility for the Geothermal Law.

Centro de Conservación de Energía y del Ambiente (CENERGIA)

With the privatization of ElectroPerú in 1993, CENERGIA assumed the country's renewable energy programs including geothermal.

CENERGIA's principal objective vis-á-vis geothermal, is to promote the development of geothermal through private initiative and technical assistance and international financing.

Decree Law No. 25844, Law of Electrical Concessions (1992)

The Law of Electrical Concessions established a free-market legal framework for Perú's electricity sector. The comprehensive privatization plan will transfer all public power enterprises to the private sector by 2000.

The Law and its regulations encourage the flow of private capital into the sector through the creation of a competitive environment, implemented by dividing the sector into separate business lines and establishing regulated and non-regulated markets.

The Law also establishes regulatory bodies, which are responsible for the functioning of the reformed sector. These regulatory bodies are:

1. the General Bureau of Electricity, a division of the MEM which is responsible for enforcing the laws and regulations for the electric sector;

2. the Electric Tariff Commission (CTE), an autonomous organization of the MEM responsible for determining electric tariffs in the regulated segment of the market; and

3. The Committee for Economic Operation of the System (COES) composed of the owners of generation plants and the primary transmission systems whose facilities are interconnected which operates with the aim of coordinating member operations at the minimum cost, guaranteeing the reliability of supply, and ensuring the efficient use of power resources.

On November 6, 1997, the Peruvian Congress approved legislation which limited firms to a 15% market share in electricity generation, transmission, or distribution. The law also allows the GOP to block any acquisition which would give a private company more than a 5% market share in more than one electric power sector. Finally, the legislation gives the GOP the right to veto any acquisitions deemed contrary to the "national interest."

Organic Law on Geothermal Resources (1997)

The Organic Law on Geothermal Resources (Ley Orgánica de Recursos Geotérmicos) was enacted in July 1997. The document specifies the regulations on the exploration and development of Perú's geothermal resources. Regulations have yet to be written.

The Law will allow any properly qualified person, individual, or company, Peruvian or foreign, title to geothermal rights. Geothermal concessions, required for exploration beyond reconnaissance work (surface), will be granted in 25-hectare units up to 1000 hectares for a 30-year period which can be extended.

Equipment and supplies required for geothermal exploration are tax exempt. In addition, the concession holder will have the right of way to carry out exploration and development of geothermal energy. If geothermal energy is used to generate electricity, the concession contract for development will be automatically extended for electrical generation (governed by the Law of Electrical Concession).

The principal characteristics of the Geothermal Law are:

1. Defining the differentiation between exploration permits and exploitation concessions,
2. Identifying the MEM as the "one-stop shop" for geothermal activities,
3. Providing royalties to the State and rates for the area exploited,
4. Defining a program of exoneration of certain import duties, and
5. Permitting amortization of exploration costs over five years.

Geothermal Sites / Projects

Perú has an estimated 2,990 MWe of geothermal power potential.

The development of Perú's geothermal resources would offset the country's over-dependence on hydropower which is affected by periodic droughts.

With at least 1,000 MWe of geothermal potential, Perú could easily double or triple its energy supply, and replace all diesel generators and hydrocarbon use by using geothermal as baseload. To date, hundreds of megawatts of geothermal energy are being produced by mining companies and industrial facilities for private use.

Geothermal resources have been evaluated in over 100,000 km² of southern Perú. The most promising six areas identified by ElectroPerú are: Cajamarca and La Libertad, Callejon de Huaylas, Churen, the central highlands, the volcanic cordillera in the south (Aarequipa, Moquega, and Tacna), and Cuzco and Puno (Lawrence, 1998).

Perú has several active volcanoes, e.g., Corpuna (6425 m), Sabancaya (6000 m), Misti (5825 m), Ubinas (5672 m), Tutpaca (5806 m), Ticsani (5450 m), Yucamani (5500 m), and Calientes (5200 m); hundreds of inactive volcanoes of all sizes; thermal springs rich in minerals in many regions of the country; and several geysers with temperatures close to 100ºC.

Perú's geothermal resources are primarily located on the western slopes of the Andes Mountains and in the high plateau in the southern part of the country. The zones which represent the best conditions for the exploitation of geothermal resources are aligned in an axis approximately parallel to the western cordillera of the Andes and near the active and inactive volcanoes located in this zone.

Reconnaissance and prefeasibility studies of the country's geothermal potential have been conducted by several Peruvian institutions including ElectroPerú, INGEMMET, CENERGÍA, the Proyecto Especial Tacna (PET), and the Instituto Peruano de Energía Nuclear (IPEN), with the cooperation of various international organizations, e.g., OLADE, IIE, Aquater, and IAEA. Feasibility studies to determine specific areas' potential are yet to be done.

The areas that have been evaluated are: Chivay, Borateras, Calacoa, Calientes, and Callazas. Using OLADE's evaluation criteria, Colca-Chivay was selected as the site with the greatest short-term potential for development.

Perú began exploring the country's geothermal resources in 1978 when INGEMMET conducted a national inventory and identified six areas of geothermal interest—1 - Cajamarca, 2 - Huaraz, 3 - Churin, 4 - Central, 5 - Cadena de Conos Volcanicos, and 6 - Puno-Cuzco.

The inventory was followed up in 1979 to 1980 by geothermal surveys of three departments in southern Perú: Arequipa, Moquegua, and Tacna. The most promising areas in these departments, in order of importance, were Group A: Calacoa, Maure, Salinas, Chachani, and Chivay; Group B: Puquio, Painacochas and Orcopampa; and Group C: Cotahuasi, Coropuna, Cailloma, and Mazo Cruz (Diaz, 1988).

ElectroPerú continued geothermal development in 1980 with a prefeasibility study of region 5 with assistance from the Italian Government. Challapaca and Arequipa were slated for prefeasibility studies followed by drilling, field development, and the installation of power plants beginning in 1988. In 1983, work began on assessing the potential of regions 1-4.

In 1997, international experts from the European Commission under a joint program with the United Nations-Economic Commission for Latin America and the Caribbean (UN/ECLAC) identified a pilot project in the Colca Valley in southern Perú.

A USGIC field survey team funded by Sandia National Laboratories, traveled to southern Perú in September 1998. The trip confirmed the existence of at least three high temperature geothermal areas—Borateras, Calientes, and Hualca-Hualca—that could be developed to produce significant (10 to over 100) MWe of electric power. The andesitic and rhytolitic terrain in these areas is similar to that found in California, Nevada, Idaho, Oregon, Washington, and Alaska.

U.S. geothermal companies can contact Project Especial Tacna (PET) to become involved in the Borateras project. When geothermal regulations have been written, and power prices rise to 6-7¢/kWh, Calientes and Hualca-Hualca may become economically viable.

It is unlikely that Perú will buy power much above 4¢/kWh or from facilities that cost more than $1000-1500/kW installed. Accordingly, geothermal power will be purchased when and if it can meet these criteria (Huttrer, 1998).

1. Borateras (Maure River Project)
2. Calachaca
3. Calacoa
4. Calientes
5. Callazas
6. Callejón de Huaylas
7. Chivay
8. Hualca-Hualca
9. La Grama
10. Otuzco
11. Tacalaya
12. Tutupaca-Calaoca

Borateras (Maure River Project)	
LOCATION In southern Perú; within the Barroso volcanic region; near the mining centers of Toquepala, Cuajone, and Quellaveco; near the Río Maure; 4500 masl (Challapalca Lot, Tacna Department).	
STATUS Well(s) or hole(s) drilled	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	5
TEMPERATURE (EC)	204-240

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

Geologic and chemical studies have been done by INGEMMET, PET, and IAEA-IPEN. Na/Li geothermometer temperatures = 204-240ºC; Na/K/Ca = 184-212ºC.

1998 - USGIC field survey group traveled to site in September; took measurements and obtained data; concluded that Borateras appear to be a locus of the boron and arsenic which PET observes is polluting the Maure River.

Borateras has about the same geothermal power potential as Calientes, and a project developed here could help PET with its boron and arsenic problems and sell power to PET (Huttrer, 1998).

NOTES
Borateras is comprised of upper and lower springs, a travertine mound, and fault-controlled springs. Within the volcanic arc of Barroso caldera structures and domes in Challapalca evidence the existence of a geothermal source at shallow depth. Project Especial Tacna (PET) has sampled these waters and drilled some slimhole test holes so preliminary chemical analyses and cores are available.

Boron and arsenic rich thermal springs are contaminating water destined for consumption in Tacna. The project is to set up a 5 MWe power plant to supply power to the local population and power pumps in the Callapuma and El Ayro aquifers. The Aricota-Tarata transmission line is 25 km away.

Calachaca

LOCATION
Tacna Department

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

1998 - USGIC field survey group traveled to site in September; took measurements and obtained data; concluded that Calachaca appears to be a locus of the boron and arsenic which PET observes is polluting the Maure River (Huttrer, 1998).

NOTES

Calacoa

LOCATION
In southern Perú; within the Barroso volcanic arc near the Ticsani Volcano (extinct) and the Ubinas Volcano (active); in the high plateau in the basin of the Carumas and Tambo Rivers; 3500 masl (Tutupaca Lot, Moquegua Department).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	180-190

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

1994 - Geovolcanologic study and inventory of the Tutupaca area conducted by ElectroPerú and INGEMMET. Na/K geothermometer temperatures = 180-190ºC; SiO_2 = 110-160ºC.

1997 - IIE conducted a prefeasibility study of area.

NOTES
The electricity generated could satisfy the domestic demand of the surrounding towns, and could be connected with the Aricota-Cuajone transmission line which is 25 km away. A geothermal plant could replace the existing thermal plants.

Calientes

LOCATION
In southern Perú in Locumba Province; within the Barroso volcanic arc between the Tutupaca and Yucamane Volcanoes (extinct); in the high plateau of the Calientes River basin; connected to the Toquepala and Cuajone Mines; thermal area is 2-3 km long, 200-300 m wide, has abundant boiling springs, some small (1 m high) geysers, siliceous sinters; 4500 masl (Tutupaca Lot, Tacna Department).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	5
TEMPERATURE (EC)	180-240

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

1994 - Prefeasibilty study done by IIE. Geovolcanologic study and inventory of the Tutupaca area conducted by ElectroPerú and INGEMMET. Na/K geothermometer temperature = 240ºC; SiO2 = 180ºC.

The existence of dacitic domes and fumaroles in relation to the recent magmatic activity indicates the existence of a shallow active magma chamber.

1997 - IIE conducted a prefeasibility study of area.

1998 - USGIC field survey group traveled to site in September; took measurements and obtained data; concluded that Calientes appears to have significant potential for electric power generation and possible cascaded crop-drying applications (Huttrer, 1998).

NOTES
The electricity generated could satisfy the domestic demand of surrounding towns and could also supply energy to the southern part of the country through the Aricota-Cuajone transmission line. It would also diminish contamination by arsenic to the waters which are actually used in Ilo, Item and the Locumba Valley.

Callazas

LOCATION
In southern Perú in the high plateau of the Río Callazas basin in the Locumba Province; within the Barroso volcanic arc near the Tutupaca Volcano (extinct); connected to the Toquepala and Cuajone Mines; 4500 masl (Tutupaca Lot, Tacna Department).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	180-240

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

1994 - Geovolcanologic study and inventory of the Tutupaca area conducted by ElectroPerú and INGEMMET. Prefeasibility study done by IIE. Na/K geothermometer temperature = 240ºC; SiO2 = 180ºC.

1997 - IIE conducted a prefeasibility study of area.

NOTES
The electricity generated could satisfy the domestic demand of surrounding towns and could also supply energy to the southern part of the country through the Aricota-Cuajone transmission line.

Callejón de Huaylas

LOCATION	
STATUS Preliminary identification/report	
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-
CHRONOLOGY	
NOTES	

Chivay

LOCATION
In southern Perú;; within the volcanic arc of Barroso near the extinct Ampato and Hualca-Hualca and the active Sabancaya volcanoes; in the 60 km long Colca River Valley, the second deepest valley in the world known for its agriculture and tourism; 2800 masl (Arequipa Lot, Arequipa Department).

STATUS
Prefeasibility study

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	2-4
TEMPERATURE (EC)	170-190

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

Studies conducted by OLADE, IAEA, AQUATER, INGEMMET, and the European Community. Si/O2 geothermometer temperatures of 170-190ºC.

1997 - Identified by UN/ECLAC as part of the "Development of Geothermal Resources in Latin America and the Caribbean" Project. There is a good possibility that the EU and a private company may co-finance the project (Morey, 1998).

NOTES
Colca-Chivay is an isolated area with good tourist potential due to its thermal hot springs in a remote, mountain setting. The project concept is to install 2-4 MWe for the local population (10 surrounding towns) as well as to serve the tourist resort.

The existence of small active domes indicate the presence of magmatic chambers at shallow depths. It is estimated that volcanic activity (lava) ended 100,000 years ago.

This zone is not yet connected to the national grid of the Southern Interconnected System of Perú but plans are underway to do so in the near future. The Tintaya-Charcani transmission line is 20 km away.

There are no exploration studies of the geothermal resources along the Valle del Río Colca, but there is evidence of the great potential of the area. Volcanic activity is recent and of a different kind with domes, igneous rocks, and outflows, and at the end of the 1980s, the Sabancaya Volcano became active again with the emission of ashes and causing a lava flow in 1993 which reached Río Colca.

In addition, there are recent fractures of the neotectonic type which indicate that not only Sabancaya but the whole valley is active. A test of this is the gushing forth of a new geyser along the Shihuihayco. This evidence and the presence of thermal baths in La Calera and along the Río Colca point to the Chivay zone as the highest priority in the country.

Hualca-Hualca

LOCATION
In southern Perú; in the 60 km long Colca River Valley, the second deepest valley in the world known for its agriculture and tourism; area is 1-2 km² with superheated dry steam vents, boiling mud pots, hot springs, and paleosolfataras; 4450 masl; (Arequipa Department).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

1998 - USGIC field survey group traveled to site in September; took measurements and obtained data;

concluded that Hualca-Hualca has world-class potential for power generation. Drawbacks include that transmission lines are now only being built in the Coca Valley and danger to a power plant from the eruption of the Hualca-Hualca Volcano is very real (Huttrer, 1998).

NOTES

La Grama

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES

Otuzco

LOCATION

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY

NOTES

Tacalaya

LOCATION
Tacna Department

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	-

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET,

NOTES

Tutupaca-Calaoca

LOCATION
In southern Perú; in the provinces of Canderave and Sanchez Cerro, near the headquarters of the mining centers of Toquepala, Cuajone, and Quellaveco (Moquegua Department).

STATUS
Prefeasibility study

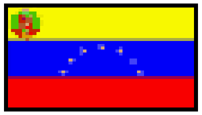
INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	200

CHRONOLOGY
1979 to 1980 - Survey conducted by INGEMMET.

1987 to 1994 - Prefeasibility studies indicated a possible temperature in the deep aquifer of approximately 200ºC,

1995 - CENERGIA developed a program to invite private entities and international cooperation to continue investigation of the area.

NOTES
The existence of volcanic explosions and domes of recent age and the abundance of hot springs and fumaroles of high temperature indicate the presence of a high enthalpy resource.



Venezuela

Population (millions) - July 1998	22.80
Overall Electrification (% of population)	NA%
GDP (billion US$) - 1997 est.	$185.0
Real GDP Growth Rate - 1997 est.	5.0%
Inflation Rate (CPI) - 1997	38.0%
Total Installed Capacity (MWe) - 1995	18980
Electricity Consumption per Capita (kWh) - 1997	2578
Energy Demand Growth Rate	4.5%
Prices (US¢/kWh) - June 1998	
Residential	1.11
Commercial	3.40
Industrial	2.88
Estimated Geothermal Potential (MWe)	**910**

Power Summary

Venezuela has the highest per capita rate of power consumption in Latin America and abundant sources of generation: vast rivers systems for hydroelectricity and a plentiful supply of fossil fuels for thermoelectricity. Power outages are relatively rare, and normally limited to small sectors, usually caused by distribution transformer breakdowns.

About 75% of Venezuela's total installed capacity is hydropower. During early 1998, low rainfall caused at least in part by the El Niño weather phenomenon, cut Venezuela's hydroelectric output and raised the possibility of rationing. In August 1997, a transformer failed at the huge Guri hydroelectric complex, causing a power outage throughout 80% of Venezuela.

Venezuela's electricity sector is a hybrid of five state-owned and seven private companies; the former accounting for 87% of national capacity and 100% of hydroelectric capacity. The largest state company is Electrificación del Caroní (EDELCA), with 63% of operating capacity and 79.4% of the power generated by the public sector.

Venezuela has the world's sixth largest oil reserves. In 1998, oil accounted for 70% of the country's GDP. Driven by weak oil prices, Venezuela slipped into recession in late 1998, losing $1 billion for every $1 per barrel drop in oil prices. Business confidence fell to a 2½ year low. Interest rates are up sharply (to 70% or more), while inflation and unemployment remain high. New investments and privatizations have been delayed.

Venezuela faces rapid electricity demand growth, combined with serious under-investment in its power sector, which has resulted in shortages and a need for private investment (an estimated $5.7 billion over the next five years in transmission and distribution alone). Hydroelectric's share of power generation is expected to grow as Venezuela adds about 8 GWe over the next five to ten years. With hydropower potential estimated at 70 to 80 GWe or more, Venezuela has plans for several additional plants.

Venezuela has taken initial steps toward privatizing and reorganizing its state-owned power sector companies but the process has been delayed several times. The Government of Venezuela (GOV) will privatize thermal generation facilities, electricity distribution companies, and small-scale transmission (115 kV or lower voltage).

The GOV has begun the privatization of several large electric utilities to modernize and improve the reliability of its electric system. To attract private sector investment, the government has taken steps towards reforming the legal framework which governs its sector. According to a recent Duff & Phelps report, many large industrial customers are facing high electricity costs with poor quality and reliability due to the lack of capital investment and maintenance.

The Electric Power Management and Development Company (CADAFE) has undertaken several renewable rural electrification programs, focusing on potential markets in large rural areas that are not attractive to the private power industry. Providing electric services to 100% of towns having more than 1,000 inhabitants, CADAFE has been able to extend service to 90% of the national territory (Lawrence, 1998).

Hugo Chávez, a populist who was imprisoned for an unsuccessful military coup attempt in 1992, was elected president in December 1998 and sworn in on February 2, 1999. He has proposed to redraft the country's 1961 constitution through a popular convention or constituent assembly. This may allow him to undertake long overdue economic reforms.

Government / Legislation

Ministry of Energy And Mines

The GOV will retain responsibility for the major hydroelectric generation facilities of the Caroni, the national transmission grid, and all regulatory activities, including the design of guidelines and regulations for the industry and the monitoring of the performance of the electric utilities.

Lacking an umbrella law for the electrical sector, the Electrical Energy Regulatory Commission (CREE) is administratively and financially linked to the Ministry of Energy and Mines, and is funded from

resources allocated through the annual budget and special funds authorized by the Executive Branch. A proposed bill for the electrical sector contains a provision that would strengthen the regulatory framework.

A new bill introduced to the Congress of Venezuela in March 1998 established a definite regulatory framework for the electricity sector and created a national electricity board. The new law would provide the basis for determining tariff adjustments based on costs, and requires the accounting separation of generation, transmission, and distribution for all market participants. In the meantime, buyers must participate in the absence of clear rules and rate mechanisms.

Decree No. 1558, Normas Para La Regulación Del Sector Electrico (November 1996)

The Electric Sector Regulatory Framework came into force at the end of 1996, and allows for the participation of private and independent power producers in the Venezuelan market. This legal measure is seen as the first step to the eventual enactment of an Electric Power Law.

Organic Law of Concessions (April 1994)

The Organic Law of Concessions opened up investment opportunities for infrastructure and other public works projects. Under the law, the State guaranteed up to 75% of the investment and under certain circumstances may raise this guarantee to 90%. The president may also authorize 100% income tax waiver and exoneration of all import duties and taxes on equipment and services needed.

The State will guarantee the economic/financial health of the project if for reasons not attributable to the concessionaire the conditions of the project change. Such conditions could be social, war, uprising, natural disasters, and other force majeure.

Analysts have widely observed that the new law is a vast improvement over the previous law, but so far little concrete has been accomplished through it.

No Specific Law for Geothermal

Geothermal Sites / Projects

Venezuela has an estimated 910 MWe of geothermal power potential.

About 60% of Venezuela has been covered by reconnaissance geothermal surveys including geologic and water geochemical studies.

The German naturalist, Alexander von Humboldt, was the first to make a scientific description of a Venezuelan hot spring in 1800. Systematic study of the hot springs of central Venezuela began in 1969 and was continued in the northeastern part of the country in 1975 where geological and geochemical studies showed that some areas have potential for electricity generation.

In 1981, the Universidad Central de Venezuela (UCV) started a detailed "National Geothermal Inventory" covering the central, eastern, and southern regions. The geothermal systems of Táchira and Mérida were investigated by Burguera et al. The states of Zulia, Trujillo, Lara, Barinas, and Portuguesa have not been covered to date. The data from the inventory and from previous published and unpublished reports has been stored in a computerized data bank that contains geographical, geological, and geochemical information from 361 geothermal sites. No drilling has taken place.

Geothermal manifestations and related features in northeastern Venezuela , particularly in the state of Sucre, e.g., sulfur deposits, acid-sulfate alteration zones, and mud volcanoes, have been investigated in detail. The most promising system for possible electrical generation is Las Minas, near El Pilar, in Sucre. The El Pilar fault system is seismically active with foci of up to 15 km depth. Other major faults in northeastern Venezuela are the San Francisco and Urica right-lateral strike-slip faults.

Other medium and low temperature systems appear useful for direct use applications.

In 1975, a systematic study began to identify Venezuela's geothermal potential, and in 1979 a geothermal resources assessment was published. In 1980, a basic plan for evaluating the country's geothermal resources was prepared, and a reconnaissance study begun in 50,000 km^2 in the northeastern part of the country. As a result, in 1981, El Pilar-Casanay and Barcelona-Cumana were selected as priority areas for more detailed geothermal studies.

From 1983 to 1988, a prefeasibility study began in the El Pilar-Casanay geothermal zone. The results of the prefeasibility effort, although still incomplete, indicate the possible existence of a geothermal reservoir with temperatures of 200-300ºC at inferred depths of 1,200-2,500 m. Based on these results, technical experts from the Ministry of Energy and Mines have recommended that the investigation continue with the drilling of deep boreholes. OLADE's Energy-Economic Information System (SIEE) estimates Venezuela's geothermal potential at 0.065 million BOE/day (Lawrence, 1998).

1. El Pilar-Casanay (Las Minas)
2. Los Baños
3. San Diego

El Pilar-Casanay (Las Minas)

LOCATION
Southwest of El Pilar; in the northeastern part of the country along the El Pilar fault; springs are located on the northern slope of the west-east trending valley of the Río Chaguaramas; 230-280 masl; 63º12'28'' longitude, 10º31'52'' latitude (state of Sucre).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	200-300

CHRONOLOGY
Mid 19th century - Sulfur mining began in area.

1981 - Identified system in national inventory.

1984 - Geothermal inventory conducted by Hevia and Di Gianni.

1985 to 1986 - Thermal manifestations, several boiling springs of the sodium chloride type, sampled and analyzed during a regional geochemical survey from the Gulf of Cariaco to the Gulf of Paria and the San Juan Valley.

Work conducted by the Ministry of Energy and Mines in cooperation with the International Institute for Geothermal Research (Italy).

NOTES
El Pilar-Casanay is the most promising area for geothermal exploitation in Venezuela (D'Amore, 1994).

The area investigated seems capable of producing high-enthalpy geothermal fluids; a deep reservoir is inferred, composed of a medium salinity (< 5000 ppm) and neutral brine, with computed temperatures between 250 and 300ºC, and with a high CO_2 partial pressure. A second shallower reservoir is assumed to exist, with a temperature on the order of 200-220ºC. The deep reservoir is shown to be liquid-dominated, while water and steam occupy the shallow one (D'Amore, 1994).

Los Baños

LOCATION
South the of the San Diego fault near the town of El Pinto; at the southern and southeastern ends of the Eastern Mountains Massif (state of Monagas).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	61-150

CHRONOLOGY
1981 - Identified system in national inventory; measured temperatures of 24-36ºC; Na-K-Ca geothermometer temperatures of 61-79ºC and 97-127ºC. Several plots of t vs SiO_2 and Cl suggest mixing, allowing for an estimated temperature of 150ºC (Urbani, 1989).

NOTES
Los Baños has the highest temperature and salinity in the state of Monagas. It seems plausible that these springs are a mixture of deep Na-Cl hot water (plus hydrocarbons) coming from the marine Tertiary oil-bearing basin to the south, with colder Ca-HCO_3 water (Urbani, 1989).

San Diego

LOCATION
Along the valleys of the Río Neverí in the eastern part of the state; at the western end of the Eastern Mountains Massif, north of the Urica fault system; 90 masl; 64º31'33" longitude, 10º9'40" latitude (state of Anzoátegui).

STATUS
Preliminary identification/report

INSTALLED CAPACITY (MWE)	0
POTENTIAL (MWE)	-
TEMPERATURE (EC)	29-108

CHRONOLOGY
1981 - Identified system in national inventory; measured temperatures of 29-53ºC; Na-K-Ca geothermometer temperatures of 50-70ºC. A t vs SiO_2 plot indicated a

temperature of 108ºC for the possible deep hot aquifer (Urbani, 1989).
NOTES San Diego has 10 warm to hot springs which issue mainly from strongly faulted and folded shales and sandstones of Early and Late Cretaceous age. This area has the highest temperature springs in the state of Anzoátegui (53ºC).

Conclusion

According to Victor Bolano, Vice President for Latin America for ABB Energy Ventures, Latin America will add 283.4 GWe of installed capacity by 2020, up from the region's current capacity of 168.1 GWe , and bringing total installed capacity to 451.5 GWe (see table on the following page).[7]

With over 50 GWe of estimated power potential, geothermal energy can and should supply a portion of the additional capacity required. To date, however, geothermal development by U.S. companies is recent across the region and primarily in Central America where geothermal power generation has a comparative advantage.

Hurricane Mitch; the U.S. and multilateral assistance effort which has followed based on the premise to "Build back better;" and SIEPAC, the proposed regional electric grid, may provide additional impetus to development of the region's substantial geothermal resources.

[7] *Power in Latin America*, December 1998, pp. 7-8.

Region	**Geothermal Potential (MWe)**
Caribbean	16,390
Central America	19,720
South America	14,660
Total	**50,770**

Geothermal power, in addition to easing Central America's debt problems, will also offset global gas emissions. A Carbon Dioxide (CO_2) Market could make geothermal power competitive with thermal power, reducing its price from 6-7¢/kWh to 4.5-5.0¢/kWh.

Elsewhere in Latin America, the news is less optimistic. In the Caribbean, there are unconfirmed reports that the St. Vincent project has been put on hold due to financing difficulties. And, further south in South America, low electricity prices make geothermal power generally uncompetitive in free market-based power sectors. The sole geothermal plant located in Argentina has been shut down.

Opportunities for geothermal power development do exist, however, in those countries across Latin America and the Caribbean where a resource is close to a market, its price can be competitive with other forms of electricity, and financing can be found. Additional data can be incorporated into the Database to construct these juxtapositions.

LATIN AMERICAN POWER DEMAND TO 2020 (GWe)

Country	1996	2000	2020
Argentina	20.2	23.1	60
Bolivia	0.8	1	2
Brazil	60.7	70	180
Chile	7.4	8.8	18
Colombia	10.6	14	21.5
Ecuador	2.7	3.2	5
México	34.8	37.3	86
Perú	4.8	4.4	10
Venezuela	20.7	21.1	53
Central America	5.4	7	16
Total	**168.1**	**189.4**	**451.5**

Source: ABB

Index of Sites

Bibliography

GENERAL SOURCES

Central Intelligence Agency (1999). "World Factbook 1998," http://www.odci.gov/cia/publications/factbook/index.html

Energy Information Administration, U.S. Department of Energy, http://www.eia.doe.gov/emeu/international/contents.html.

———— (1998). "Regional Indicators: Central America" U.S. Department of Energy, June.

"Evaluation of the Renewable Energy Environment in USAID-Assisted Countries" Draft Report (1998). Prepared for the U.S. Agency for International Development for Advanced Engineering Associates International and Princeton Economic Research, Inc., November 30, 1998.

Financial Times: Power in Latin America (1998-1999). Financial Times Business, Ltd., London, United Kingdom, Issue Nos. 34 to 43, April 1998 to January 1999.

Geothermal Energy Association (1999). *Preliminary Report: Geothermal Energy, The Potential for Clean Power from the Earth*. Prepared by Karl Gawell, Dr. Marshall Reed, and Dr. P. Michael Wright; Washington, D.C.; April 7, 1999.

Geothermal Resources Council, http://www.geothermal.org/index.html.

Germain, Richard (1998). Geothermal Investigation in Latin America conducted for E&Co.

International Geothermal Association, http://www.demon.co.uk/geosci/igahome.html.

Ishikura, Yoko, Jim Miwa, and Brenda Sturdivant (1999). *Geothermal: International Market Opportunities*, California Energy Commission, Energy Technology Export Program, Sacramento, CA.

La Comisión Económica para América Latina (CEPAL) and Comisión Europea Dirección General para la Energía (1998). *Proyecto: Desarollo de los Recursos*

Geotermicos en America Latina y el Caribe, Informe Final, Santiago, Chile.

Lawrence, Othalene (1998). "Annex 1: Renewable Energy Technologies: A Stocktaking of the Latin America and Caribbean Region (draft)," The World Bank, Latin American and the Caribbean, Environmentally and Socially Sustainable Development, May 28.

La Organización Latinoamericana de Energía (OLADE), Sistema de Información Económica-Energética (SIEE®), http://www4.olade.org.ec/.

Project Finance: Latin American Report (1998). Euromoney Publications plc, London, UK, September 1998.

Project Finance (1998). Euromoney Publications plc, London, UK, December 1998.

Rudnick, Hugh (1998). "The Electric Market Restructuring in South America: Successes and Failures on Market Design." Presented at the Plenary Session of the Harvard Electricity Policy Group; San Diego, CA; January 29-30, 1998.

Sanyal, Subir (1998). "An Overview of Geothermal Prospects in Central America." Presented at the "Regional Development of Geothermal Resources" Conference, Managua, Nicaragua, June 10-12, 1998.

Trocki, Linda et al. (1987). *The Energy Situation in Five Central American Countries*. Central American Energy and Resource Project, Los Alamos National Laboratory; Los Alamos, NM; LA-10988-MS; Technical Report No. DE87012708.

Vimmerstedt, L. (1998). *Opportunities for Small Geothermal Projects: Rural Power for Latin America, the Caribbean, and the Philippines*, National Renewable Energy Laboratory, Golden CO, under Contract No. DE-AC36-83CH10093.

Werrett, Rosemary H. (1999). "Latin America: More state spin-offs mean continued growth for project market," *Development Business*, Volume 22, Number 503, 31 January 1999, pp. 1-3.

Zambranos, Marco (1997). "Financiamiento de Proyectos: La Perspectiva de las Agencias Multilaterales." Presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

ARGENTINA

Coira, Beatriz (1995). "Cerro Tuzgle Geothermal Prospect, Jujuy, Argentina," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1161-1165.

Energy Information Administration (1999). "Argentina: Country Analysis Brief." U.S. Department of Energy, November.

Etcheverry, Ruben and Alexander Berwyn (1998). Exposiciones al Taller "Usos Productivos de Aguas Termales." Sponsored by the National Rural Electric Cooperative Association, International (NRECA) and the U.S. Department of Energy; Arica, Chile; 21 y 22 de julio de 1998.

Mendéz, Ignacio. "The International Cooperation Geothermal Development Project in Domuyo Volcano Area, Argentine Cordillera. Synthesis of the Prefeasibility Study Conclusions."

Miranda, Fernando J. and Abel H. Pesce (1997). "Argentina Geothermal Resources: New Trends in Development," GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 337-339.

Muñoz, Miguel et al. (1995). "Geothermal Resources in Southwestern South America (Argentina, Chile)," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1157-1159.

Nakanishi, Shigetaka et al. (1995). "Copahue Geothermal System, Argentina—Study of a Vapor-Dominated Reservoir," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1167-1172.

Pesce, Abel (1995). "Argentina Country Update," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 35-43.

———— (1998). "Argentina, Direct Use Projects," *IGA News*. No. 31, January-March, pp. 4-8.

———— (1997). "Diagnostico de la Region Sudamericana: La Situación Argentina." Presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

———— (1998). "Direct Uses of Geothermal Energy in Argentina," GRC Transactions (Vol. 22): Geothermal, The

Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 269-273.

———— (1997). "Programas Geotérmicos en América del Sur: Obstaculos para su Desarrollo: La Experiencia Argentina." Presented at the Seminario Regional, "El Papel de las Fuentes de Energía Nuevas y Renovables en el Desarrollo Sustenable de América Latina y el Caribe: El Caso de la Geotermia."

———— and Graciela Pedro (1995). "Thermal Models of the Low Enthalpy Rio Valdez Geothermal Field, Tierra del Fuego, Argentina," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1173-1178.

———— y Luis Acosta (1997). "Los Proyectos Pilotos: Problemas, Potencialidades y Perspectivas." Presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

Seggiaro R. et al. "Structure and Geothermic Potential of the Rosario de la Frontera Thermal Area, Salta, Argentina," pp. 673-677.

Smith, G. Pete (1998). "Trip Report: Argentina." NRECA International, Inc., March.

U.S. Embassy Buenos Aires (1997). *FY 1998 Country Commercial Guide: Argentina*.

Zucal, Ricardo (1998). "La Energía Geotermica en Argentina." Presented at the Taller "Usos Productivos de Aguas Termales." Sponsored by the National Rural Electric Cooperative Association, International (NRECA) and the U.S. Department of Energy; Arica, Chile; 21 y 22 de julio de 1998.

BOLIVIA

Arnez, Sergio (1998). "Aprovechamiento de Recursos Geotermicos." Presented at the Taller "Usos Productivos de Aguas Termales." Sponsored by the National Rural Electric Cooperative Association, International (NRECA) and the U.S. Department of Energy; Arica, Chile; 21 y 22 de julio de 1998.

Delgadillo T., Zenón (1998). "The Laguna Colorada (Bolovia) Project: A Reservoir Engineering Assessment," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 269-273.

———— (1997). "Situación Actual de Los Proyetcos Geotérmicos en Bolivia," Presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para

América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

Energy Information Administration (1998). "Bolivia: Country Analysis Brief." U.S. Department of Energy, December.

Meidav, Tsvi and William Teplow (1995). "A Regional Exploration Strategy for the Andes Based on Geological Characteristics of the Laguna Colorada Geothermal Field, Bolivia."

Rico, Gonzalo Calderón. "Geothermal Development in Bolivia."

U.S. Embassy La Paz (1998). *FY 1999 Country Commercial Guide: Bolivia*.

CARIBBEAN

Barthelmy, Aloysius (1990). "The Economics of Geothermal Power in Saint Lucia, West Indies," Geothermal Resources Council Transactions, Vol. 14, Part 1, August 1990, pp. 477-481.

———— (1990). "Overview of Geothermal Exploration in Saint Lucia, West Indies," Geothermal Resources Council Transactions, Vol. 14, Part 1, August 1990, pp. 227-234.

"Caribbean Geothermal Potential" (1998). *The U.S. Department of Energy Geothermal Technologies*, Vol. 3, Issue 4, November, p. 4.

D'Archimbaud, Jean Demians and Jean-Pierre Munier-Jolain (1975). "Geothermal Exploration Progress at Bouillante in Guadeloupe," Second United Nations Symposium. Berkeley, CA; Lawrence Berkeley Laboratory; Volume 1, Issue: May, pp. 105-107.

Demange, Jacques et al. (1995). "The Use of Low-Enthalpy Geothermal Energy in France," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 105-114.

Gandino, A. et al. (1985). "Preliminary Evaluation of Soufriere, Geothermal Field, St. Lucia (Lesser Antilles)," *Geothermics*, Pergamon Press plc, Volume 14, No. 4, pp. 577-590.

Huttrer, Gerald W. (1995). "A Report Describing Airphoto Lineaments On and Near Soufrière Volcano, St. Vincent, W.I." Prepared for Lockheed Idaho Technologies Company under Purchase Order No. C95-175738.

———— (1995). "A Report Describing the Results of a Literature Search and Review of the Geology of St. Vincent, W.I.." Prepared for Lockheed Idaho Technologies Company under Purchase Order No. C95-175738.

———— (1996). *Final Report Regarding Prefeasibility Studies of the Potential for Geothermal Development, St. Vincent, W.I.* Work supported in part by Lockheed Idaho Technologies Company under Subcontract C95-175738 and by the U.S. Department of Energy under DOE Idaho Operations Office Contract DEAC07-94ID13223.

———— (1998). "Geothermal Small Power Generation Opportunities in the Leeward Islands of the Caribbean Sea," Presented at the "Geothermal Off-Grid Power Workshop" sponsored by the U.S. Department of Energy's Office of Geothermal Technologies, Sandia National Laboratories, and the Geothermal Resources Council, Reno, Nevada, December 2-4.

———— (1995). "Trip Report: Pre-Feasibility Studies of the Potential for Geothermal Development in St. Vincent, W.I." Submitted to US/ECRE under the terms of Cost Reimburseable Assistance Subagreement No. AID T-94-09-01 under USAID Cooperative Agreement No. LAG-5730-A-00-3049-00.

Jaudin, Florence (1994). "Bouillante Exploitation, " *IGA News*, Number 19, October-December 1994 (see also http://www.demon.co.uk/geosci/wrguadel.html).

Meridian Corporation (1987). "Focus on St. Lucia: A Geothermal International Series," Prepared for Los Alamos National Laboratory under Contract No. 9-X36-3652C.

Rivera, R.J. et al. (1990). "Geothermal Project at St. Lucia (W.I.) — A Preliminary Assessment of the Resource," Proceedings: Fifteenth Workshop on Geothermal Reservoir Engineering, Stanford, CA; Stanford University; January 23-25, 1990; pp. 147-159.

Saba Tourist Bureau, http://www.turq.com/saba, Turquoise Systems Group.

St. Eustatius Tourist Bureau, http://www.turq.com/statia, Turquoise Systems Group.

CHILE

Arias S., Gonzalo E. (1998). "Uso de la Geotermía en Termas Puyehue," Presented at Taller "Usos Productivos de Aguas Termales." Sponsored by the National Rural Electric Cooperative Association, International (NRECA) and the U.S. Department of Energy; Arica, Chile; 21 y 22 de julio de 1998.

Berrios, Ruperto (1998). Exposicion de al Taller "Usos Productivos de Aguas Termales." Sponsored by the National Rural Electric Cooperative Association, International (NRECA) and the U.S. Department of Energy; Arica, Chile; 21 y 22 de julio de 1998.

Bravo, Jaime (1998). Exposicion de al Taller "Usos Productivos de Aguas Termales." Sponsored by the

National Rural Electric Cooperative Association, International (NRECA) and the U.S. Department of Energy; Arica, Chile; 21 y 22 de julio de 1998.

Energy Information Administration (1998). "Chile: Country Analysis Brief." U.S. Department of Energy, October.

Ernst & Young International (1995). "Doing Business in Chile," Ernst & Young's International Business Series. Santiago, Chile: Ernst & Young International, Ltd.

González, Maria Isabel (1995). "Investment Possibilities in Geothermal Energy in Chile," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 469-471.

Lahsen, Alfredo (1988). "Chilean Geothermal Resources and Their Possible Utilization," *Geothermics*, Pergamon Press plc, Volume 17, No. 2/3, pp. 401-410.

U.S. Embassy Santiago (1998). *FY 1999 Country Commercial Guide: Chile*.

COLOMBIA

Bernal C., Nelson F. (1998). "Azufral Volcano, A Geothermal Resource for Southern Colombia," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 253-256.

———— (1998). "The Azufral Geothermal Project," *IGA News*. No. 31, January-March, p. 8.

Carter, Susan (1998). "Columbia: Broadly Based Success," *Institutional Investor*, Sponsored Section, pp. 1-15.

Energy Information Administration (1998). "Colombia: Country Analysis Brief." U.S. Department of Energy, July.

Gutiérrez-Negrín, Luis C.A. and Arturo González-Salazar (1995). "Preliminary Geothermal Assessment of the Macizio Volcanico del Ruiz, Colombia," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1219-1223.

Monsalve, M.L. et al. (1998). "Geology of the Well Nereidas 1, Nevado del Ruiz Volcano, Colombia," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 263-267.

Universal News, Inc. (1999). "Special Report: Colombia," New York, NY, February 15.

U.S. Embassy Bogota (1997). *FY 1998 Country Commercial Guide: Colombia*.

COSTA RICA

Cataldi, Raffaele and Alfredo Mainieri. (1995). "Geothermal Ranking and Resource Assessment of Costa Rica," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 497-502.

Geothermal Energy Association (1994). "Trip Report: Geothermal Industry Mission to Costa Rica for U.S. Department of Energy."

López, Mario S. (abril 1994). "Generación Privada en Costa Rica." Instituto Costarricense de Electricidad, Dirrecion Planificacion Electrica, Departamento Proyectos de Generacion.

Mainieri P., Alfredo (1997). "Miravelles Geothermal Project - An Update," *IGA News*. No. 30, October-December 1997, p. 6.

———— and W. Retana (1997). "Estado del Desarrollo de la Geotermia: Areas de Potencial, Desarrollo y Leyes que Regulan la Participación Publica y Privada en este Tipo de Actividad en la República de Costa Rica." Distributed at the GRC Annual Meeting, 1997.

———— and Edgar Robles F. (1995). "Costa Rica Country Update Report," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 81-85.

Robles F., Edgar (1998). "Increasing Costa Rica's Power Production From Geothermal Energy," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 275-278.

———— and Carlos Obregón Q. (1997). "Diagnostico de la Región Centroamericana: La Situación de Costa Rica," Presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

U.S. Foreign Commercial Service and U.S. Department of State (1996). "Electrical Power System/Panamá/Costa Rica," Industry Sector Analysis (ISA), April 1996.

ECUADOR

Acosta, Marco A. "Valle de los Chillos Low Enthalpy Geothermal Project: A Case History."

Aguilera, Eduardo (1998). "The Chalupas and Chachimbiro Geothermal Fields in Ecuador," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp.247-251.

Energy Information Administration (1998). "Ecuador: Country Analysis Brief." U.S. Department of Energy, December.

Meridian Corporation (1987). "Focus on Ecuador: A Geothermal International Series," Prepared for Los Alamos National Laboratory under Contract No. 9-X36-3652C.

U.S. Embassy Quito (1997). *FY 1998 Country Commercial Guide: Ecuador*.

EL SALVADOR

Campos, Tomas (1995). "Wellhead Units and Geothermal Development in El Salvador," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 93-98.

Cozzini, Mauro et al. (1995). "Economic Planning and Design of Geothermal Electric Generation in El Salvador," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 2859-2863.

González P., Eduardo et al. (1995). "Geology of the Ahuachapán-Chipilapa, El Salvador, C.A Geothermal Zone," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 683-686.

Iglesias, Eduardo R. et al. (1995). "A Reservoir Engineering Assessment of the Chipilapa, El Salvador, Geothermal Field," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1531-1536.

Meridian Corporation (1987). "Focus on El Salvador: A Geothermal International Series," Prepared for Los Alamos National Laboratory under Contract No. 9-X36-3652C.

Nieva, D. et al. (1997). "Geochemical exploration of the Chipilapa Geothermal Field, El Salvador," (Alt. Title: "Ahuachapán-Chipilapa Geothermal Fields, El Salvador"). *Geothermics*, Pergamon Press plc, Volume 26, Issue October/December, pp. 589-612.

Rivas R., José A. (1997). "Status of Geothermal Development in El Salvador," Distributed at the GRC Annual Meeting, 1997.

U.S. Embassy San Salvador (1998). *FY 1999 Country Commercial Guide: El Salvador*.

GUATEMALA

Bethancourt, H.R. and E. Dominco (1982). "Characteristics of the Zúnil Geothermal Field (Western Guatemala)," GRC Transactions, Volume 6, Davis, CA: October 1982, pp. 241-244.

Duffield, W.A. et al. (1992). "Geology and geothermal potential of the Tecuamburro Volcano area, Guatemala." *Geothermics*, Pergamon Press plc,, Volume 21, No. 4, pp. 425-446.

———— (1992). "A Tale of Three Prospects," GRC Transactions, Volume 16, Davis, CA: October 1992, pp.145-152.

Energy Information Administration (1997). "Guatemala: Country Analysis Brief." U.S. Department of Energy, September.

Goff, Fraser el al. (1991). "A Re-Evaluation of the Moyuta Geothermal System, Southern Guatemala," GRC Transactions, Volume 15, Davis, CA: October 1991, pp. 3-10.

Manzo R., Alfredo R. and Julio César Palma A. (1998). "First Geothermal Power Plant," *IGA News*. No. 32, April-June, pp. 8-10.

Meridian Corporation (1987). "Focus on Guatemala: A Geothermal International Series," Prepared for Los Alamos National Laboratory under Contract No. 9-X36-3652C.

Palma, Julio (1997). "Desarollo Geotérmico en Guatemala," Presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

———— and Otto Garcia (1995). "Updated Status of the Geothermal Development in Guatemala," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 135-140.

Santizo, Rodolfo (1998). "Situación Actual del Subsector Eléctrico de Guatemala." Presented at the "Regional Development of Geothermal Resources" Conference, Managua, Nicaragua, June 10-12, 1998.

U.S. Embassy Guatemala City (1997). *FY 1998 Country Commercial Guide: Guatemala*.

HONDURAS

Aldrich, M.J. et al. (1987). *San Ignacio (La Tembladera) Geothermal Site, Departamento de Francisco Morazán, Honduras, Central America*. Central American Energy and

Resource Project, Los Alamos National Laboratory, LA-10696-MS, June 1987.

Di Pippo, R. and F. Goff (1994). "Platanares Geothermal Field, Honduras-Preliminary Power Assessment of the Shallow Reservoir," *Geotherm Sci. & Tech*. Gordon and Breach Sci. Pub. S.A., Volume 4(1), pp. 19-35.

Empresa Nacional De Energía Electrica (1994). "Geothermal Projects in Honduras," *Geothermal Resources Council BULLETIN*. February 1994, pp. 43-44.

Eppler, D.B. et al (1987). *Geology of the Azacualpa Geothermal Site, Departamento de Comayagua, Honduras, Central America*. Central American Energy and Resource Project, Los Alamos National Laboratory, LA-10687-MS, March 1987.

———— et al. (1987). *Geology of the Pavana Geothermal Area, Departamento de Choluteca, Honduras, Central America*. Central American Energy and Resource Project, Los Alamos National Laboratory, LA-10864-MS, September 1987.

"GDP Contraction Possible in 1999" (1999). *Latin America Monitor: Central America*, Vol. 16, No. 1, Business Monitor International, January.

Goff, Fraser (Editor) (1991). Special Issue: Honduras: A Geothermal Investigation, *Journal of volcanology and geothermal research*. Elsevier, Amsterdam-Oxford-New York-Tokyo, Volume 45, No. 1/2, March 1991.

———— et al. (1987). *Hydrogeochemical Investigation of Six Geothermal Sites in Honduras, Central America*. Central American Energy and Resource Project, Los Alamos National Laboratory, LA-10785-MS, June 1987.

———— et al. (1986). *Hydrogeochemical Report of the Second Honduras Sampling Trip*. Central American Energy and Resource Project, Los Alamos National Laboratory, January-February 1986.

Hanold, R.J. et al. (1986). "Geothermal Initiatives in Central America," Geothermal Resources Council Transactions. Vol. 10, September 1986, pp. 181-185.

Meridian Corporation (1987). "Focus on Honduras: A Geothermal International Series," Prepared for Los Alamos National Laboratory under Contract No. 9-X36-3652C.

National Rural Electric Cooperative Association (NRECA) International, Ltd. (1991). *The Roatan Improved Electric System: A Financial-Economic Feasibility Report*, Prepared by the Central American Rural Electrification Support Program (CARES) of NRECA for Empresa Nacional de Energía Eléctrica (ENEE), October 1991.

Paredes P., Jose R. (1987). "Estudio de Prefactibilidad Geotermica en Honduras," IIE, October 1997 Meeting.

Truesdell, A.H. et al. (1986). "The Geochemistry of the San Ignacio Hot Springs, Honduras," *Geothermal Resources Council Transactions*. Vol. 10, September 1986, pp. 155-160.

U.S. Embassy Tegucigalpa (1998). *FY 1999 Country Commercial Guide: Honduras*.

U.S. Foreign Commercial Service and U.S. Department of State (1998). "Honduras Economic News," International Market Insight (IMI), February 1998.

Winchester, Willanne W. and Sue J. Goff (1993). *Energy Development in Honduras: A Review and Analysis of Honduran Energy Sector Regulations and Opportunities for the Production of Energy*. Los Alamos National Laboratory, LA-UR-93-4399.

MÉXICO

Beall, J.J. et al. (1997). "Dry steam feed zones and silica scaling as major controls of total flow enthalpy at Cerro Prieto, México." GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 153-156.

Birkle, Peter and Broder Merkel (1998). "Environmental Effects of Surface Outflow of Geothermal Water at the Geothermal Field of Los Azufres, México," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 287-291.

Blanco, Herminio (1998). Speech of the Secretary of Commerce and Industrial Development of México at the U.S. Export-Import Bank's Annual Conference, May 1998.

Cadenas, C. and De la Torre G. (1998). "Main Features of the Las Tres Vírgenes I Geothermal Project," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 293-295.

Carnec, C. et al. (1998). "Monitoring Surface Deformation with Radar Interferometry at the Cerro Prieto Geothermal Field (México)," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 297-301.

Cerini, Donald et al. (1997). "Progress on the Biphase Turbine at Cerro Prieto." Proceeding Geothermal Program Review XV: The Role of Research in the Changing World of Energy Supply, San Francisco, CA, March 24-26, 1997, pp. 3.19-3.27.

Cerro Prieto Geothermal Field - México Field Trip (1998). 1998 GRC Annual Meeting, September 19-20, 1998.

Comisión Federal de Electricidad (1998). *Campo Geotermico: Cerro Prieto.*

Cuauhtémoc A., Hernández and Eugenio J. Pastrana Melchor (1998). "Identification and Assessment of Environmental Impacts of the Los Azufres II Geothermal Project," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 303-307.

Elders, W.A. et al. (1997). "What lies beneath the Cerro Prieto geothermal field?" GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 171-179.

Energy Information Administration (1997). "México: Country Analysis Brief." U.S. Department of Energy, August.

GRC Bulletin (1998). "Energy Privatization in México Faces Hurdles" and "Power Plant Bid Solicitation in México." October 1998, pp. 198-199.

Gutiérrez-Negrín, Luis (1998). "1997 Geothermal Data for México," *IGA News*. No. 3, July-September, p. 5.

Hernández-Galán, José L. (1988). "Small Geothermal Schemes: The Mexican Experience." *Geothermics*, Pergamon Press plc,, Volume 17, No. 2/3, pp. 303-309.

Hinojosa T., Enrique (1997). "Geochemical Model Update of the Los Azufres, México, Geothermal Reservoir." GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 441-448.

Hiriart-Le Bert, Gerardo (1997). Exposicion presented at the Seminario-Taller "Desarrollo de los Recursos Geotérmicos en América Latina y el Caribe," Comisión Económica para América Latina y el Caribe (CEPAL), Santiago del Chile, 10 al 12 de noviembre de 1997.

———— and Luis C.A. Gutiérrez-Negrín (1997). "Geothermal Production Results and Plans in México," GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 425-428.

———— (1998). "Results of the Geothermal Exploitation in México in 1997," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 309-313.

———— and Luis Del Rio (1995). "Mexican Experience in Geothermal Power Generation," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 2025-2030.

Izquierdo, Georgina et al. (1995). "Clay Minerals, Fluid Inclusions and Stabilized Temperature Estimation in Two Wells from Los Azufres Geothermal Field, México," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1083-1086.

Lopez-Hernandez, Aida et al. (1997). "Exploratory drilling at Acoculco, Puebla, México: A hydrothermal system with only nonthermal manifestations." GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 429-433.

————. (1995). "Geothermal Exploration at Las Tres Vírgenes, B.C.S., México," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 707-712.

Ocampo, J. et al. (1997). "Recent Results of Deepening Wells Below Cerro Prieto II and III Traditional Exploitation Zones." GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 585-590.

Oropeza Q., P. Alejandro and Juan Manuel Wong Zúñiga (1998). "Status and Technical Design of the Cerro Prieto IV Geothermal Project," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 315-319.

Ortega-Rubio, Alfredo et al. (1995). "Legislation for Environmental Protection in the Case of Geothermic Drillings in México," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 563-564.

Pelayo L., Andrés et al. (1998). "Production Recovery of Well 627 in Cerro Prieto Geothermal Field," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 321-325.

"Private Power Projects Continue" (1999). *Latin America Monitor: México*, Vol. 16, No. 1, Business Monitor International, January.

Quijano, José Luis. (1997). "Latest News on Geothermal Projects," *IGA News*. No. 30, October-December 1997, pp. 6-7.

———— and Luis C.A. Gutiérrez Negrín. (1995). "Present Situation of Geothermics in México," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 245-250.

Rangel R., María Elena (1998). "Mushroom Growing Project at the Los Humeros, México Geothermal Field." *Geo-Heat Center Quarterly Bulletin*, Vol. 19, No. 4, December 1998, pp. 14-16.

Sánchez Upton, Pedro (1997). "Los Humeros Geothermal Field, México," GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp.435-439.

Secretaría de Energía. *Investment Opportunities in the Mexican Energy Sector*.

————. *Prospectiva del Sector Eléctrico 1997-2006*.

Suárez A., Mario César (1998). "Deep Geothermal Systems in México: An Integral Diversified Resource for the Energy of the Future," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 327-331.

———— et al. (1995). "Fifteen Years of Development of Los Azufres Geothermal Field, México," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1791-1796.

Taboada G., Roberto and Juan I. Andaluz Carmona (1998). "Main Features of the Los Azufres II (100 MW) Geothermal Project," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 333-337.

Torres-Alvarado, Ignacio et al. (1995). "An Oxygen-Isotope Study of Hydrothermally Altered Rocks at the Los Azufres Geothermal Field, México," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1049-1052.

Torres-Rodríguez, Marco A. (1995). "Characterization of the Reservoir of the Los Humeros, México Geothermal Field," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1561-1567.

———— and Magaly Flores-Armenta (1998). "Pressure and Enthalpy Evolution in Wells of the Los Azufres Geothermal Field," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the

World. Davis, CA: Geothermal Resources Council, pp. 339-358.

Torres Rodríguez, Vincente et al. (1998). "Recognition of Hydrothermal Alteration by Remote Sensing at the Acoculco Caldera, Puebla, México," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 359-363.

U.S. Embassy México City (1998). *FY 1999 Country Commercial Guide: México*.

U.S. Foreign Commercial Service and U.S. Department of State (1997). "Geothermal Energy: Industrial Uses in México," International Market Insight (IMI), June 1997.

Upton, P.S. (1997). "Los Humeros geothermal field, México." GRC Transactions, Volume 21: Meeting the Challenge of Increased Competition, Davis, CA: Geothermal Resources Council 1997 Annual Meeting, pp. 435-439.

Verma P., Surendra et al. (1995). "Temperature Field Distribution from Cooling of a Magma Chamber," Proceedings of the World Geothermal Congress, 1995, Florence, Italy: International Geothermal Association, pp. 1119-1124.

Zirahuén O., Ricardo and Celia Gutiérrez Gómez (1998). "Assessment of Environmental Impacts of the Cerro Prieto IV Geothermal Project, Baja California, México," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 365-369.

NICARAGUA

Dick, Jay D. (1998). "Executive Summary: Momotombo Geothermal Project, Republic of Nicaragua."

Geothermal Energy Association (1998). "The Perspective of Geothermal Energy Developers Regarding: El Ante-Proyecto de Ley Geotermica."

Instituto Nicaragüense de Energía (1997). Information distributed at the Geothermal Resource Council's 1997 Annual Meeting, October.

Inter-American Development Bank (1997). "Environmental and Social Impact Brief: Tipitapa Power Plant."

"International Update: Nicaragua" (1998). *Geothermal Energy News*, October/November 1998, pp. 4-5.

Ley No. 272 - Ley de la Industria Eléctrica (1998). *La Gaceta*, No. 74, 23 de abril de 1998, pp. 3211-3225.

Momotombo Geothermal Field - Nicaragua Field Trip (1998). Following *The Development of Geothermal Resources in Central America Workshop* co-sponsored by the Nicaraguan Energy Institute and Geothermal Energy Association, Managua, Nicaragua, June 10-12, 1998.

"Nicaragua: El Hoyo-Monte Galán Geothermal Project," http://www.energyhouse.com/eco/projects/nicaragua.htm.

Povarov, O.A. and S.D. Tsimmerman (1998). "Geothermal Power Plant 'San Jacinto-Tizate,'" Presented at the "Regional Development of Geothermal Resources" Conference, Managua, Nicaragua, June 10-12, 1998.

Tiffer, Ernesto J. Martinez et al. (1988). "Geothermal Development in Nicaragua." *Geothermics,* Pergamon Press plc, Volume 17, pp. 333-354.

———— (1986). "Operation of the Momotombo Geothermal Wells," April.

Trans-Pacific Geothermal Corporation (1997). "Exploration of the El Hoyo-Monte Galan Geothermal Concession, Final Report." Order Number DE98004720, Source: NTIS. (DOE/ID/13453-TI).

U.S. Embassy Managua (1997). *FY 1998 Country Commercial Guide: Nicaragua.*

U.S. Foreign Commercial Service and U.S. Department of State (1997). "Nicaragua Geothermal," 12 September.

Volcano List Server (1998). "Casita Volcano Disaster," report on the October 30, 1998 avalanche and breakout flow of Casita Volcano, Nicaragua, triggered by Hurricane Mitch.

Zúñiga-Mayorga, Ariel (1998). "Nicaragua: Latest Developments in Geothermal," *IGA News*. No. 33, July-September 1998, p. 7.

———— (1998). "Nicaragua Country Update," GRC Transactions (Vol. 22): Geothermal, The Clean & Green Energy Choice for the World. Davis, CA: Geothermal Resources Council, pp. 279-283.

———— (1998). "Situacion Actual de la Geotermica en Nicaragua," Presented at the "Regional Development of Geothermal Resources" Conference, Managua, Nicaragua, June 10-12, 1998.

PANAMÁ

Bath, A.H. and K.H. Williamson (1983). "Isotopic and Chemical Evidence for Water Sources and Mixing in the Cerro Pando Geothermal Area, Republic of Panamá." *Geothermics*, Pergamon Press plc, Volume 12, pp. 177-184.

Energy Information Administration (1998). "Panamá: Country Analysis Brief." U.S. Department of Energy, May.

International Finance Corporation (1998). "IFC Appointed Advisor to Panamá Electricity Company." IFC Press Release, http://www.ifc.org/press/1998/irhe.htm, February 1998.

Ramirez, Arturo H. (1985). "Country Update—Panamá." GRC Transactions, Davis, CA: October 1985, pp. 155-156.

———— (1988). "Present Status of Geothermal Reconnaissance Studies in the Republic of Panamá." *Geothermics*, Pergamon Press plc, Volume 17, pp. 355-367.

Shevnell, Lisa (1989). *Preliminary Evaluation of Thermal and Nonthermal Waters at Selected Sites in Panamá, Central America*. Central American Energy and Resource Project, Los Alamos National Laboratory, LA-11103-MS, November 1989.

U.S. Embassy Panamá City (1996). *FY 1997 Country Commercial Guide: Panamá.*

U.S. Foreign Commercial Service and U.S. Department of State (1996). "Electrical Power System/Panamá/Costa Rica," Industry Sector Analysis (ISA), April 1996.

———— (1998). "Panamá: Electric Sector Privatization," International Market Insight (IMI), October 1998.

———— (1998). "Privatization of Power Company," International Market Insight (IMI), March 1998.

PERÚ

Diaz Huaina, Guillermo Nicanor (1988). "Potential for developing small geothermal power stations in Peru." *Geothermics*, Pergamon Press plc, Volume17, pp. 381-390.

Energy Information Administration (1998). "Perú: Country Analysis Brief." U.S. Department of Energy, January.

Huttrer, Gerald W. (1998). Trip Report—Perú. Trip Number 9806837 funded under Sandia Document AY-1510, September 8-18, 1998.

Morey C., Pablo (1998). "La Geotermia en el Sur del Perú," Presented at the NRECA Taller, "Usos Productivos de Aguas Termales," Arica, Chile, 21 y 22 de julio de 1998.

Parodi I., Alberto (1975). "Feasibility of the Development of the Geothermal Energy in Perú—1975." Lawrence Berkeley Laboratory-Second United Nations Symposium, Berkeley, CA May 1975, pp. 227-231.

"Perú Hurt By Camisea Failure" (1998). *Latin America Monitor: Andean Group*, Vol. 15, No. 8, Business Monitor International, August.

Rojas M., Ruben (1997). "Recent Geothermal Legislation." *IGA News*. No. 30, October-December 1997, p. 7.

U.S. Department of Commerce (1998). *Perú: Economic Trends and Outlook*, National Trade Bank, November 18, 1998.

U.S. Embassy Lima (1997). *FY 1998 Country Commercial Guide: Perú.*

U.S. Foreign Commercial Service and U.S. Department of State (1995). "Perú: Electric Power Generation," Industry Sector Analysis (ISA), December 1995.

VENEZUELA

Almandoz, Alberto Hevia and Rojas, Julieta Jauregui (1988). "Geothermal Prospects in the Central Region of Sucre State, Venezuela." *Geothermics*, Pergamon Press plc, Volume 17, pp. 369-375.

Associated Press (1999). "Venezuela's New Congress Installed," Associated Press, http://dailynews.yahoo.com/headlines/ap...p/19990123/wl/venezuela_politics_1.html, January 23, 1999.

Carter, Susan and Craig Leon (1998). "Focus: Venezuela," *Institutional Investor*, Sponsored Section, pp. 1-24.

Consejo Nacional de Promoción de Inversiones (1998). "CONAPRI, Investing in Venezuela—Investment Opportunities: Electricity," http://www.conapri.org/electricity.html, June 18, 1998.

D'Amore, Franco et al. (1994). "The Geothermal Area of El Pilar-Casanay, State of Sucre, Venezuela, Geochemical Exploration and Model." *Geothermics*, Pergamon Press plc, Volume 23, pp. 283-304.

Energy Information Administration (1998). "Venezuela: Country Analysis Brief." U.S. Department of Energy, September.

Flynn, Daniel (1999). "POLL—Venezuela's recession to double pace in 1999," Reuters Limited., http://biz.yahoo.com/rf/990122/d8.html, January 22, 1999.

Urbani, Franco (1989). "Geothermal Reconnaissance of Northeastern Venezuela." *Geothermics*, Pergamon Press plc, Volume 18, pp. 403-427.

U.S. Embassy Caracas (1996). *FY 1997 Country Commercial Guide: Venezuela*.

U.S. Foreign Commercial Service and U.S. Department of State (1996). "Venezuela: Electric Power Systems," Industry Sector Analysis (ISA), June 1996.

Werrett, Rosemary H. and Trudy Balch (1998). "Venezuela: PDVSA draws up big expansion plans for natural gas," *Development Business*, Volume 21, Number 491, 31 July 1998, pp. 1-2.