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GEOTHERMAL ACTIVITY AND DEVELOPMENT IN MEXICO

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ABSTRACT

Geothermal energy in Mexico is almost entirely used to produce electricity, since its direct uses are still under development and currently remain restricted to bathing and swimming. The net installed geothermal-electric capacity in Mexico as of December 2010 is 958 megawatts (MW). This capacity is currently operating into four geothermal fields: Cerro Prieto (720 MW), Los Azufres (188 MW), Los Humeros (40 MW) and Las Tres Vírgenes (10 MW).

All of the geothermal fields and power plants are owned and operated by the governmental agency CFE (Comisión Federal de Electricidad). One additional geothermal project is under construction (Los Humeros II, 2 x 25 MW) which will add a net additional capacity of 35 MW when commissioned. During 2010, thirty-seven power plants of condensing, back-pressure and binary cycle were in operation into those fields. The annual geothermal production (2010) was 60.43 million metric tons of steam at an annual average rate of 6,898 tons per hour (t/h). Steam was delivered by an average of 226 production wells, and was accompanied by 69.7 metric tons of brine that was disposed through 22 injection wells and a solar-evaporation pond operating in Cerro Prieto. Geothermal power plants at the fields produced 6,792 gigawatt-hour (GWh) of electric energy in 2010, which represented 3.0% of the whole electric generation in Mexico in that year. Exploration of the Acoculco, Tulecheck, El Chichonal, and Cuitzeo Lake geothermal areas is in the execution stage.

1. INTRODUCTION

In Mexico, geothermal resources remain to be mainly utilized to produce electricity. There has been a little development in direct uses of geothermal, and they are basically limited to bathing and swimming. So, this paper is focused on the status of geothermal-electricity in Mexico, yet also presents some available data on direct uses.

The public service of electricity in Mexico is provided by the Federal Government. Until October 10, 2009, two public facilities, the Comisión Federal de Electricidad (CFE) and Luz y Fuerza del Centro (LFC), owned and operated by the government, were in charge of generation, transmission, distribution and commercialization of electric energy. Since that date, only CFE has this responsibility. Electric uses of geothermal are planned, developed and operated by the Gerencia de Proyectos Geotermoeléctricos –the geothermal division of the CFE.

2. THE ELECTRIC INDUSTRY

The Federal Electricity Commission (CFE) is a company created and owned by the Mexican government. It generates, distributes and markets electric power for almost 33.8 million customers. This figure represents almost 100 million people. The CFE incorporates more than a million new customers every year. The infrastructure to generate electric power is made up of 177 generating plants, having an installed capacity of 51,571 megawatts (MW). 29.4% of its installed capacity stems from around 22 plants which were built using private capital and are currently operated by independent power producers (Productores Independientes de Energía or PIE).

The CFE generates power using various technologies and primary energy sources. It has thermoelectric, hydroelectric, coal-fired, geothermal and wind powered plants and facilities, as well as one nuclear power plant. In order to take the power from its generating plants to the household of each one of its customers, the CFE has more than 742,000 km of power lines that transmit and distribute electric power. Electricity reaches almost 137,000 communities (of these, 133,345 are small villages). Also, 96.84 % of the population has access to electric service.

As of September 2010 the total installed electric capacity in Mexico was 51,571 MW (Table 1). This total includes 22 independent power producers (IPP) amounting 11,907 MW, whose power plants were constructed and are operated and owned by private companies (CFE, 2010). By law, the IPPs sell all their electric generation to the CFE through long-term power purchasing contracts, since they are not allowed to negotiate and contract with private costumers.

As indicated in Table 2, almost three quarters of the installed capacity for public service in Mexico (68%) is based on fossil-fueled power plants (hydrocarbons and coal), and more than one fifth (22%) on hydroelectric plants. Geothermal electric capacity represents 2% and wind only 0.1%. The rest (1.9%) is represented by nuclear power plants (Figure 1).

TABLE 1: Mexico development of installed capacity and generation

		2001	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010***
Capacity (MW)	CFE	36,236	36,855	36,971	38,422	37,325	37,470	38,397	38,474	38,927	39,664
	PIE's	484	3,495	6,756	7,265	8,251	10,387	11,457	11,457	11,457	11,907
	Total	35,385	40,350	43,727	45,687	45,576	47,857	49,854	49,931	50,384	51,571
Generation (TWh)	CFE	190.88	177.05	169.32	159.53	170.07	162.47	157.51	157.16	154.14	123.21
	PIE's	1.2	21.83	31.62	45.85	45.56	59.43	70.98	74.23	76.5	58.47
	Total	190	198.88	200.94	205.39	215.63	221.9	228.49	231.4	230.64	181.68

*Data as of September 2010

TABLE 2: Gross installed capacity by generation type (Sep 2010)

Generation Type	**Effective capacity MW**	**Percentage**
Oil and Gas	23,474.67	46%
Hydroelectric	11,174.90	22%
Coal	2,600.00	5%
Geothermal	964.5	2%
Wind	85.25	0%
Nuclear	1,364.88	3%
Oil and Gas (private)	11,906.90	23%
Total	51,571.10	100%

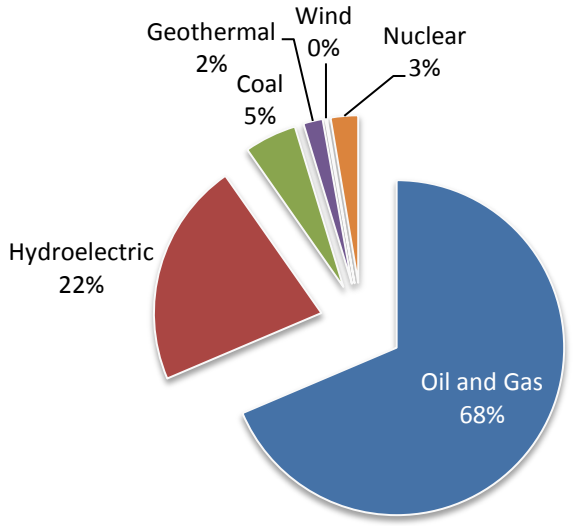

FIGURE 1: Breakdown (%) of the total electric installed capacity in Mexico as of September 2010

The electric generation for public service in Mexico in 2009 was 230,640 GWh, as reported in the same Table 1. Three quarters (73%) of the electric energy for public service in Mexico in 2010 was generated by power plants fuelled by hydrocarbons and coal, only 14% was produced by hydroelectric plants, 3% by nuclear power plants, 2.71% by geothermal-electric plants and 0.06% by wind power plants, as implicated in Table 3 (Figure 2).

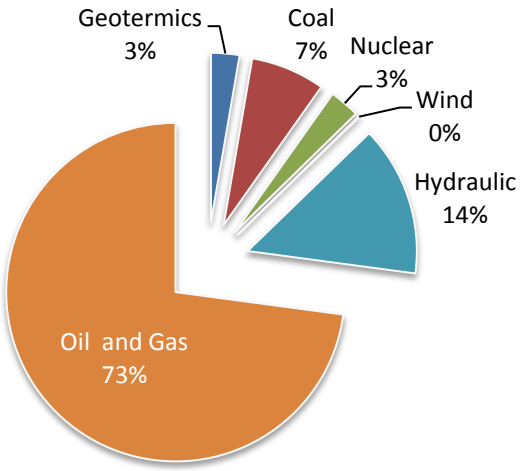

FIGURE 2: Total generation of electricity in Mexico in 2010 by type of power plant and fuel used

TABLE 3: Generation of electricity by source

Generation type	Percentage
Geothermal	2.71%
Coal	7.09%
Nuclear	2.89%
Wind	0.06%
Oil and Gas (Private Producers)	32.18%
Hydraulic	14.37%
Oil and Gas	40.70%

3. GEOTHERMAL ELECTRICITY

The net geothermal-electric capacity in Mexico is 958 MW (964.5 gross MW) as shown in Figure 3, installed into four geothermal fields (Cerro Prieto, Los Azufres, Los Humeros and Las Tres Vírgenes). Table 4 shows the running capacity for each field, the projects under construction and future increases on capacity. The fifth field, La Primavera (Cerritos Colorados project), remains on stand-by, even though a potential of 75 MW was assessed long time ago. Installation of the first units in this field is expected to start soon, since the Environmental Impact Assessment has been approved for a 25 MW power station. However some social opposition is still in the surrounding cities and has to be solved in order to be able to construct the power station there.

That present geothermal-electric capacity represents 2% of the total electric capacity for public service in the country. Thirty seven power plants of several types (condensing, back pressure and binary cycle), between 1.5 and 110 MW, operate in those fields, fed by 229 geothermal wells with a combined production of 7,530 metric tons of steam per hour (t/h). The production wells have depths between 600 and 4,400 meters. Steam comes with almost 9,000 t/h of brine that is injected through 23 injection wells, or treated in a solar evaporation pond of 14 km^2 in Cerro Prieto. During 2009, steam produced in those fields amounted 46.8 million of metric tons, and the power plants generated 6,792 gigawatt-hour (GWh), which represented 2.7% of the electric energy produced in Mexico.

TABLE 4: Geothermal capacity in Mexico

Geothermal field	Start up year	Running capacity MW	Under construction MW	New projects MW
Cerro Prieto, BC	1973	720		
Los Azufres, Mich	1982	188		50
Los Humeros, Pue	1990	40	2 x 25	2 x 25
Las Tres Vírgenes, BCS	2001	10		
Cerritos Colorados, Jal				25

FIGURE 3: Location of Mexican geothermal fields under exploitation (Cerritos Colorados, formerly known as La Primavera, remains in stand-by)

National capacity factor in 2009 was 77% or 0.77 in average, which results lower than obtained in 2005 (Gutiérrez-Negrín, 2007). All the fields and power units are managed and operated by personnel of the CFE.

Cerro Prieto is the oldest and largest Mexican geothermal field in operation. It is located in the northern part of Mexico (Figure 3), and its first power units were commissioned in 1973. There are currently 13 operating units of condensing type: four 110-MW double-flash, four single-flash of 37.5 MW each, four single-flash of 25 MW each and one 30-MW single-flash, low pressure, amounting 720 MWe. These power units produced 4935 GWh in 2009 at an annual capacity factor of 78% (0.78). The decrease in annual capacity factor is due to the production decline of steam in the wells. This geothermal field lies in a pull-apart basin produced between two active strike-slip faults (the Cerro Prieto and Imperial faults) belonging to the San Andreas Fault System. Thinning of the continental crust in the basin has produced a thermal anomaly that is the ultimate cause of the heat source of the geothermal system. The geothermal fluids are contained in sedimentary rocks (lenticular sandstones intercalated in series of shales) with a mean thickness of 2,400 meters. More than 350 geothermal wells have been drilled in 35 years in Cerro Prieto, with depths up to 4,400 m. 164 production wells were in operation during 2009 producing 41.55 million tons of separated steam at an annual average rate of 4743 tons per hour (t/h). The annual average production rate per well was 29 t/h. There were also 12 injection wells in operation that returned to the reservoir 19.6 million tons, out of 63.0 million tons of total separated brine. The rest was disposed in the solar evaporation pond of 14.3 km^2 in surface. Taking into account the steam produced in 2009 in Cerro Prieto, the gross steam specific consumption results in an annual average of 8.4 tons per MWh.

Los Azufres is the second geothermal field operating in Mexico. It is located in the central part of the country, 250 km away from Mexico City, and lies within the physiographic province of the Mexican Volcanic Belt in a pine-forest at 2,800 masl. The first power units were commissioned in 1982, and presently there are 14 power units in operation: one condensing of 50 MW, four condensing of 25 MW each, seven 5-MW back-pressure and two 1.5-MW binary cycles. The total installed capacity is 188 MW (Table 4). Generation of electricity in 2009 was 1,495 GWh, at an annual capacity factor of 90.8% (0.908). Los Azufres is a volcanic field whose geothermal fluids are hosted by andesites affected by three fault systems produced by local and regional tectonic activity. The most important of such systems presents an E-W trend and controls the movement of the subsurface fluids. The heat source of the system seems to be related to the magma chamber of the nearby San Andrés volcano that is the highest peak in the area. Along 2009, 39 production wells were in operation in Los Azufres, which produced 13.6 million tons of steam, at an annual average rate of 1,553.5 t/h. The annual mean production per well was 40 t/h. The produced steam was accompanied by 4.53 million tons of brine that was fully injected into the reservoir through 6 injection wells. The gross specific consumption in Los Azufres in 2009 was 9.09 tons of steam per MWh, which is one of the historically lowest in this field yet still higher than in Cerro Prieto.

The geothermal field of Los Humeros is also of volcanic type. It is located in the eastern-central part of Mexico, at the eastern end of the Mexican Volcanic Belt. Its power units number 1 and 2 started to commercially operate in 1990, and currently there are eight back-pressure units of 5 MWe each with a total operating capacity of 40 MWe. The more recent unit (Unit 8) was commissioned in April 2008 (Table 4). Los Humeros lies inside a Quaternary caldera (Caldera de Los Humeros) at 2,600 masl. The geothermal fluids are also contained in andesites overlying a complex basement composed of metamorphic, sedimentary and intrusive rocks. The heat source is the magma chamber that produced two collapses and formed the Los Humeros and Los Potreros calderas, being the latter nested in the first one. Los Potreros collapse occurred 100,000 years ago, and the last volcanic activity has been dated in 20,000 years. There were 20 production wells operating in Los Humeros during 2009. They produced 4.8 million tons of steam at an annual mean rate of 547 t/h, resulting in an average production per well of 27.4 t/h. The wells in Los Humeros produce usually low brine, and so occurred in 2009 when 0.46 million tons of brine was obtained. The brine was returned to the reservoir by three injection wells. Generation of electricity in Los Humeros was 323 GWh. This energy is almost 10%

higher than generated five years ago and the highest since 1999. The capacity factor in 2009 was 92% (0.92), slightly higher than in Los Azufres and the better in Mexico. The gross specific consumption was 14.8 tons of steam per MWh.

Las Tres Vírgenes is the most recent field in operation in Mexico. It is located in the middle of the Baja California peninsula, at the north of the state of Baja California Sur and inside the buffer zone of the El Vizcaíno Biosphere Reserve. There are only two condensing 5-MW power units in operation that were officially commissioned in 2002. Generation of electricity in 2009 was 39.6 GWh, at an annual mean capacity factor of 45% (0.45). Las Tres Vírgenes is inside a Quaternary volcanic complex composed of three N-S aligned volcanoes, from which the name of the field becomes. The geothermal fluids are hosted by intrusive rocks (chiefly granodiorite) and the heat source of the system is related to the magma chamber of the La Virgen volcano, the youngest and most southern of the volcanic complex. During 2009 there were three production wells in operation that produced 0.48 million tons of steam at an annual mean rate of 54.8 t/h. The annual average production per well was 18 t/h. Unlike Los Humeros, wells of Las Tres Vírgenes produce much brine: in 2009 the associated brine was 1.77 million tons. All this brine was fully injected through one injection well. The gross specific consumption in Las Tres Vírgenes was 12.12 tons of steam per MWh in 2009, which is considerably higher than reported five years ago (Gutiérrez-Negrín and Quijano-León, 2005), and yet is lower than obtained in Los Humeros. The steam produced and the electricity generated in Las Tres Vírgenes in 2008 and 2009 represents the highest ones since the field started to be exploited, even though they are still far away from the optimum. However during 2010, the mean capacity factor has been increased to 80%, thus contributing with almost 65% of the total isolated generation system in that part of the country. In 2012 it is expected to increase the capacity factor in this field to be comparable to Los Azufres and Los Humeros.

Total geothermal production data in Mexico for 2009 are presented in Table 5, where they are compared with data for 2003 and 2008. It can be noted that despite the number of production wells increased in 15% between 2003 and 2009, the production of steam decreased in 10%. This means, of course, that in general the average production per well has dropped almost 27% along the period, as shown in the same table, which forced CFE to drill more wells in order to sustain the steam supplying. However, despite the lower production of steam, generation of electricity jumped 8% meanwhile the installed capacity increased only 0.5%. This means that the available steam has been used more efficiently to produce electricity, which is reflected by the index of gross specific consumption of steam, which improved in the period to be almost 15% lower. Thus, in 2003 the geothermal-electric plants in Mexico required to produce an average of 10.7 tons of steam to generate 1 MWh, but in 2009 this amount dropped to 9.11.

TABLE 5: Main data on geothermal-electric production in Mexico in 2003, 2008 and 2009

Data	**2003**	**2008**	**2009**
Production wells (number)	197	229	226
Injection wells (number)	19	23	22
Steam produced (million tons)	67.5	65.9	60.43
Steam per well (t/h)	39.1	32.8	28.60
Brine Disposed (million tons)	76.7	69.7	70.1
Installed Capacity (MW)	953.00	958	958
Generation (GWh)	6,282.00	7,047.00	6,792.60
Gross specific consumption (t/MWh)	10.70	9.35	9.11

4. DRILLING OF GEOTHERMAL WELLS

There were 62 geothermal wells drilled in Mexico for geothermal-electric purposes in the period 2004-2008, all of which were constructed by drilling companies contracted by CFE (Table 5). The annual average results in ~12 wells, yet actually 21 wells were drilled in 2004, 18 in 2005, 7 in 2006, just one in 2007 and 15 in 2008 (Otero-Solís, 2009). It can be assumed there were no wells drilled for direct uses in the period, because most of bathing facilities use thermal water from hot springs and only exceptionally from hot-water wells constructed with other purposes.

Only one exploration well was drilled in those years: the well EAC-2 constructed in 2008 in the geothermal zone of Acoculco, Pue., at 1,900 m depth. In 2010 two exploration wells were drilled in the Tulecheck area, Baja California.

Five injection wells were drilled between 2004 and 2008, with a total length of 8,427 m (Table 6). Four of them were constructed at the Cerro Prieto field in 2004 (with a combined total depth of 6,677 m) and one in the Los Azufres field in 2005 at 1,750 m depth (Otero-Solís, 2009). Fifty six production wells were constructed in Mexico in the last five years, all with temperatures higher than 150 °C, with a combined depth of 148,035 meters (Table 5). 50 of those wells were drilled in Cerro Prieto (89%), 17 in 2004 and 2005, 5 in 2006 and 11 in 2008. Two production wells were constructed in Los Azufres in 2006 representing 3.6% of the total, 3 in Los Humeros in 2008 (5.3% of the total) and one in Las Tres Vírgenes in 2007 (1.8% of the total) (Otero-Solís, 2009). The average depth for production wells in Cerro Prieto was 2,725 m, 1,550 m in Los Azufres, and 2,200 m in Los Humeros. The only well in Las Tres Vírgenes was drilled at 2,102 m depth. As usual, the geothermal-drilling activity in Mexico was concentrated in Cerro Prieto, where 54 out of 62 wells were constructed (87%) and 90.2% of the total length was drilled. Most production wells constructed in Cerro Prieto had the purpose of replace old wells, because the productive lifespan of a well in this field is typically 10 years, usually requiring a work-over by the fourth or fifth year. Production wells in the Los Azufres and Los Humeros have a longer production span and normally do not require work-over.

Taking into account the drilling data reported five years ago (Gutiérrez-Negrín and Quijano-León, 2005), the accumulative total number and depth of geothermal wells constructed in Mexico can be updated as presented in Table 6. Therefore, between 1963 and December 2008 in Mexico 556 geothermal wells, including exploration, production and injection, have been drilled with a combined depth of 1,188 km and an average depth of 2,137 m per well. 66% of the wells and 73% of the combined length have been constructed in the Cerro Prieto field, which currently counts for 75% of the geothermal-electric installed capacity and 73% of electric generation.

It is worth to note the average depth of geothermal wells, which is similar in the fields of Cerro Prieto and Los Humeros, and even in Las Tres Vírgenes, but is quite short in Los Azufres. The average depth of exploration wells in other geothermal zones is even shallower (1,351 m), but the most recent ones have reached 2000 m depth.

TABLE 6: Geothermal wells drilled in Mexico between 1963 and December 2008

Geothermal field	Wells (no.)	Depth (km)	
		Total	Average
Cerro Prieto	369	868.4	2.353
Los Azufres	85	133.9	1.575
Los Humeros	43	94.0	2.185
Las Tres Vírgenes	10	19.9	1.993
Cerritos Colorados	13	23.1	1.778
Other zones	36	48.6	1.351
Total	**556**	**1,187.9**	**2.137**

Since 2000, CFE began to use the matrix acidizing technique to improve the production / injection capacity of wells in geothermal fields in Mexico. Since that time, 18 production wells and 4 injection wells have been acidized. Savings as a consequence of the gain in production and injection capacity was found to be equivalent to the cost of drilling 14 new production wells and 2 new injection wells (Flores, 2010).

The acidizing treatment statistics in México from 2000 – 2010 for production and injection wells is shown in Table 7. The name of the well and the year in which it was acidized are shown in the first column. The second column shows the volume of mud that was lost into the formation when drilling the well in the open hole section. Otherwise, it indicates the type of scaling present in the well formed during the production or injection stage. LV denotes wells acidized in Las Tres Vírgenes, while AZ means wells at Los Azufres (Flores, 2010). During 2010, the first well at Los Humeros was treated with good results too. As can be seen in the table, 19 of 22 acid treatments were successful in these two geothermal fields. The wells were improved by 13 – 540%, with an average improvement of 176%.

TABLE 7: Acid job results in Mexican geothermal fields

I. Producer wells

Well	Mud Losses	Production Capacity			Improvement	
Name	during drilling (m3)	Original (t/h)	Pre-acid (t/h)	Post-acid (t/h)	%	t/h
1. LV-13 2002	5583	0 t/h	0	21	100%	21.00
2. LV-11 2002	5119	12 t/h	12	35	191%	23.00
3. LV-04 2004	amorphous silica	32 t/h	9	42	366%	33.00
4. LV-13 2004	calcite	21 t/h	14	28	100%	14.00
5. AZ-64 2005	3759	6 t/h	6	0	0%	-
6. AZ-9AD 2005	1326	22 t/h	22	68	209%	46.00
7. LV-3 2006	calcite	25 t/h	0	0	0%	-
8. AZ-9A 2006	505	15 t/h	25	67	168%	42.00
9. AZ-56R 2006	10921	15 t/h	15	70	367%	55.00
10. LV-4A 2007	2700	0	0	20	100%	20.00
11. LV-13D 2007	1326	0	0	20	100%	20.00
12. AZ-25 2008	amorphous silica	40	16	30	88%	14.00
13. AZ-68D 2008	8238	10	10	64	540%	54.00
14. LV-6 2010	1630 LODO BENTONITICO	0	0	25	100%	25.00
15. H-01D 2010	CALCITE	42	6	45	650%	39.00
16. AZ-57 2010	amorphous silica	25	15	0	0%	(15.00)
17. AZ-36 2010	amorphous silica	44	15	35	133%	20.00
18. AZ-51 2010	amorphous silica	37	17	42	147%	25.00
Well	**Mud Losses**	**Injection Capacity**			**Improvement**	
Name	**during drilling (m3)**	**Original (t/h)**	**Pre-acid (t/h)**	**Post-acid (t/h)**	**%**	**t/h**
1. AZ-7 injector 2000	silice	600	750 post limmecanica	850	13%	100.00
2. AZ-15 injector 2000	silice	350	340 post limmecanica	450	32%	110.00
3. AZ-8 injector 2005	silice	290 t/h	180	410	127%	230.00
4. AZ-52 injector 2005	silice	350	70	130	86%	60.00

5. NEW GEOTHERMAL DEVELOPMENTS

The National Development Plan 2007-2012 states that environmental sustainability is a central public policy of Mexico. This implies the country should take into consideration the environment as one of the elements of competitiveness and economic and social development. Using renewable sources of energy can simultaneously reduce the dependence on fossil fuels, reduce the emissions of greenhouse gases and increase the added value of economic activities. Mexico has great potential in renewable energy, especially geothermal and provides ample opportunities to be exploited, and meet the challenges of global warming. According to this public policy, geothermal projects for the near term are shown in Table 8.

TABLE 8: Mexican geothermal projects in the near term

	2011	**2012**	**2013**	**2014**	**2015**
Los Humeros II Phase A	25				
Los Humeros II Phase B		25			
Los Azufres III				50	
Los Humeros III					50
Total					150

The project Los Humeros II phases A and B is composed of two condensing units of 25 MW each to be commissioned in 2011 (phase A) and 2012 (phase B). Phase B includes the replacement of 3 x 5 MW backpressure units, using the same amount of steam to generate 10 MW of additional power. Thus, the net additional capacity of the Los Humeros II project will be 35 MW.

Los Azufres III project is scheduled for 2014. This project consists of one 50 MW unit, which considers dismantling four 5 MW backpressure units currently in operation. Therefore, the net additional capacity in this field will be 30 MWe.

There are plans for the project Los Humeros III, with another 2 units of 25 MW each (Table 8), dismantling the last five 5-MWe back pressure units that will be operating there by 2015. Thus, this project will bring a net additional capacity of 25 MW.

By 2015 the new geothermal projects would amount 150 MW, with 90 MW of net additional capacity (Table 8).

6. EXPLORATION

Exploratory studies of geology, geochemistry and geophysics have made it possible to identify areas of high, medium and low enthalpy geothermal potential interest of approximately 500 MW. The most likely areas are shown in Figure 4 and Table 9.

6.1 El Chichonal Volcano

Studies to evaluate the geothermal potential of the Chichonal Volcano area started since the 80's with geological surveys, identification of thermal manifestations and geochemical evaluation, concluding that this area presents the best conditions for the existence of high enthalpy resource in the state of Chiapas. In 1982 Chichonal Volcano erupted causing a disaster in the region. After the eruption, the volcano has been studied by numerous scholars and academic institutions, from the point of view of volcanic hazards; recently CFE has started exploration studies to locate exploration wells. Geothermometry estimates temperatures around 220 °C.

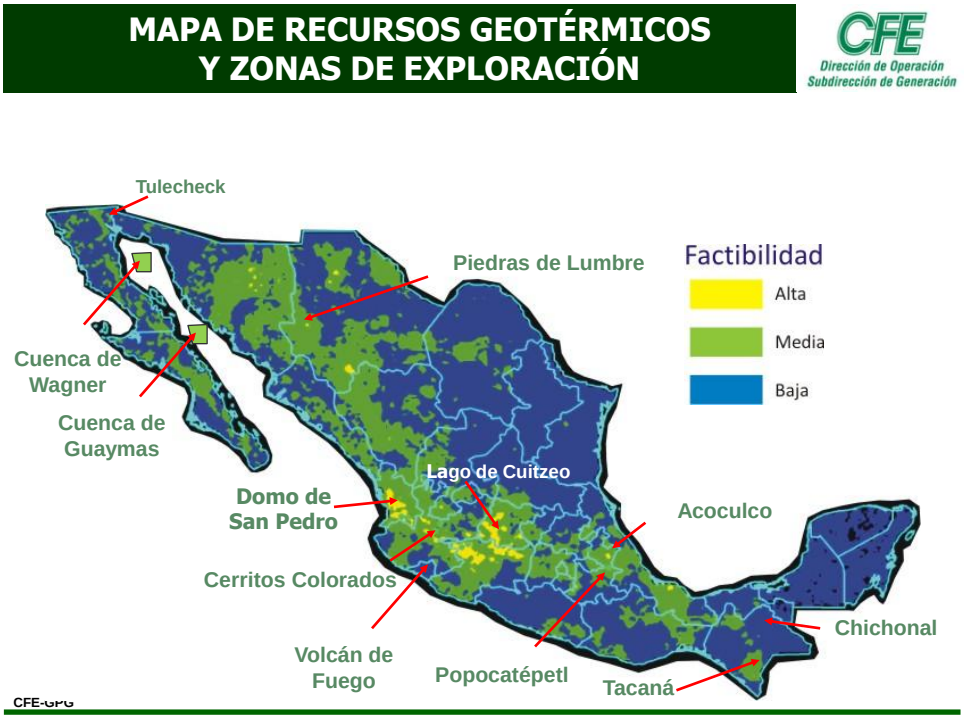

FIGURE 4: Main geothermal areas in exploration stage

TABLE 9: Geothermal exploration projects

Project	Objective	Current Status
Cerritos Colorados, Jal.	Install 25 MW, condensing type unit	EIA approved, but social issues still in progress
Acoculco, Puebla.	Assessment as an EGS project.	2 depth wells drilled with high temperature but negligible permeability.
Tulecheck, BC.	Binary Cycle project	2 exploration wells drilled in 2010.
El Chichonal, Chis.	Exploration for high temperature resources	Exploration studies in progress
Tacaná, Chis.	Exploration for high temperature resources	Exploration studies in progress
Cuitzeo Lake	Binary Cycle project	Exploration studies in progress

6.2 Piedras de Lumbre, Chich.

The geothermal area of Piedras de Lumbre is located 220 km in a straight line southwest of Chihuahua City and 60 km southwest of San Juanito, Chihuahua railroad station-Pacific, within the municipality of Maguarichi.

In the past, this geothermal area had a 300-kW binary cycle power plant, fed by a shallow low-enthalpy reservoir. This unit supplied energy to a nearby, small village then isolated from the grid. The unit was dismantled when the grid reached the village, but recently the CFE reassumed exploration surveys looking for a high temperature, deeper reservoir.

6.3 Tulecheck

This geothermal area is located in the Mexicali Valley around 15 km south of the city of Mexicali, about 20 km northwest of Cerro Prieto, and between 6 and 8 km east of the Sierra Cucapa. A low enthalpy resource is expected to be developed there, since geothermometry studies indicate temperatures of 180-200 °C.

6.4 Acoculco

The Acoculco geothermal zone, Pue., is a volcanic complex located in the eastern Mexican Volcanic Belt and the Sierra Madre Oriental provinces. Currently two exploratory wells have been drilled by the CFE in the area, with temperatures above 300 °C and low permeability. With the known information is not still possible determine the feasibility of a geothermal-electric project, and further studies are required. However, given the most recent results this project is a candidate to be developed as an enhanced (or engineered) geothermal system in the future.

6.6. Cuitzeo Lake

Some geothermal manifestations occur at the shores of this lake, located in the state of Michoacán, presenting geothermometry temperatures of around 200 °C. A low enthalpy resource is expected to be developed here. Geophysical, geological and geochemical exploration surveys were finished in 2010, and exploration wells are to be sited in order to continue with the assessment of the project.

7. CONCLUSIONS

Mexico is a very rich country in renewable sources of energy, and then it is possible reduce simultaneously the dependence on fossil fuels, reduce GHG emissions and increase the added value of economic activities. Mexico has great potential in renewable energy, especially geothermal, and provides ample opportunities to be exploited, to meet the challenges of global warming.

There are four geothermal fields in commercial operation. Cerro Prieto has been in operation for more than 37 years and currently presents a large production decline requiring changes in the exploitation and injection strategy.

Mexico occupies the fourth geothermal installed capacity place worldwide. However its growing has been slow compared with other countries such as the US and Indonesia. For 2015 it is expected the installed capacity to grow to ~1050 MW, with projects Los Humeros II and III and Los Azufres III

Besides that, large exploration campaigns are running in order to find new geothermal areas that can be commercially exploited using both high and medium enthalpy systems. The most important places are El Chichonal volcano, Cuitzeo Lake, Acoculco and Cerritos Colorados.

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