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Geothermal Energy Development in the Philippines: Country Update

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ABSTRACT

The Philippines is the world's second largest producer of geothermal energy for power generation. As of end 2003, the total installed generating capacity from geothermal power plants was 1,931 MW, accounting for about 19% of the country's power generation mix.

The Government has set a renewable energy target, dubbed "100 in 10", that aims to double the current installed generating capacity from renewable energy sources in the next ten years. Geothermal energy will be a major contributor to the attainment of this target, as the country also aims to become the world's largest geothermal energy producer, having proven geothermal as a reliable and clean source of energy for the past 30 years.

1. INTRODUCTION

As of December 2003, the Philippine Government through the Department of Energy (DOE) continue to administer the operations of nine (9) geothermal service contract areas. Of these contract areas, six (6) are producing fields and three (3) are in advanced exploration stage (Figure 1). Two of the contracts are operated by Philippine Geothermal, Incorporated (PGI), a subsidiary of the Union Oil of California (UNOCAL), while the rest are managed by the government-owned and -controlled Philippine National Oil Company-Energy Development Corporation (PNOC-EDC).

The Philippines' total installed generating capacity from geothermal power plants stood at 1,931 MWe and is about 12.7% of the country's total capacity of 15,132 MWe (Table 1). The country has likewise maintained its position as the world's second largest producer of geothermal energy for power generation. The largest geothermal installation is located in Tongonan, Leyte with an aggregate capacity of 722.68 MWe or 37% of the total installed geothermal capacity. In terms of actual production, the contribution of geothermal energy to the country's total power generation mix has decreased from 21.52% in 1998 to 19.1% in 2003 (Figure 2) due to the commissioning between 2000-2001 of about 2,760 MWe natural gas power plants.

The onset of the 1997 Asian financial crisis slowed down the growth of the country's economy, thereby reducing electricity demand because the projected industrial activities, with its corresponding electricity requirement did not materialize (Perez, 2004). This economic slow down was aggravated further by the 9/11 incident in the U.S. in 2001 and dampened investors' interest in the country. Thus, only 22 MWe was added to the total installed capacity from geothermal power plants since 1998 and a total of 28 wells with total depth of 63.1 kms. drilled between 2000-2003 (Table 2).

To date, since production began in 1977, the cumulative electricity generation from geothermal energy totals 152,336 gigawatt-hour (GWh) from 100,602 GWh in 1998 or an increase of 51.4% (Table 1). The electricity generated is about 262.65 million barrels of fuel oil equivalent (MMBFOE), which translates to about US$5.57 Billion in terms of foreign exchange (forex) savings (Department of Energy, 2003).

2. GEOTHERMAL RESOURCES AND POTENTIAL

The geologic setting of the Philippine archipelago and individual Philippine geothermal systems was described and extensively discussed in Sussman et al. (1993). The service contract areas that are either currently producing, or likely to be developed in the next decade are discussed below which is essentially an update of the country paper presented by Karunungan et al. (2000) in the last World Geothermal Congress held in Japan in 2000.

2.1 Tiwi, Albay

The Tiwi field is located about 300 km southeast of Manila in the Albay Province of Luzon Island and operated by PGI (Figure 1). Throughout much of the past five years, production in the Tiwi field has been limited by the availability of aging power plant stations. The capacity of the field was also derated from 330 MW to 275 MW with the shutdown of Unit 4 as of December 2001 (Table 3).

Rehabilitation of Plants A (Units 1 and 2) and C (Units 5 and 6) commenced in 2003, and should be completed in 2005. As part of this rehabilitation, the rated capacities of the units will be increased to 59 MW for Units 1 and 2 and 57 MW for Units 5 and 6. By late 2005, it is therefore expected that Tiwi will be operating at 232 MW capacity. Unit 3 will continue operation without rehabilitation, in a standby mode. During the period of relatively low plant availability that has occurred from 1996 to 2005, reservoir pressures and fluid levels have recovered significantly, especially in the Naglagbong and Kapipihan areas (Protacio et al., 2001), and this also helped to stabilize the overall steam production capability of the field. However, since no new wells have been drilled in Tiwi since 1997, some steam development projects were required to meet the anticipated steam needs of the rehabilitated units (estimated at 4,400 kph at the wellhead).

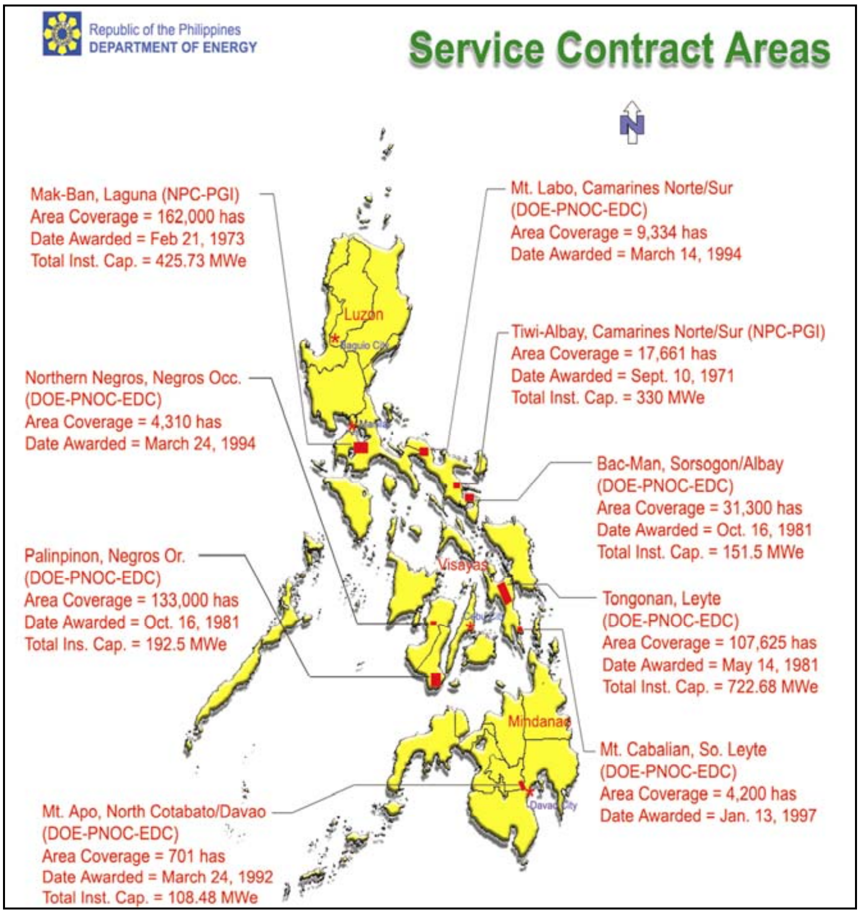

Figure 1: Philippine geothermal service contract areas

Table 1: Philippine geothermal industry performance

Year	Geothermal Power Plants Installed Capacity (MWe)	Philippine Power Plants (NPC+IPP) (MW)	% of Total Installed Generating Capacity	Geothermal Energy Generation (GWH)	% of Total Energy Generation	Fuel Oil Displaced (MMBFOE)	Overall Energy Bal. (MMBFOE)	% in Energy Mix	Average Oil Price in US$/ barrel	Foreign Savings in MM US$
1977	3	1,006.50	0.30	1	0.03	0.00	89.73	0.00	11.33	0.02
1978	3	2,188.60	0.14	3	0.06	0.01	92.05	0.01	12.32	0.06
1979	278	2,565.80	10.83	636.94	4.70	1.10	94.44	1.16	18.19	19.98
1980	446	3,820.80	11.67	2,044.85	13.80	3.53	92.51	3.81	29.79	105.03
1981	501	4,016.30	12.47	3,569.19	17.30	6.15	93.45	6.59	33.86	208.37
1982	559	4,459.20	12.54	3,563.86	20.60	6.14	95.57	6.43	32.80	201.54
1983	784	5,004.40	15.67	4,081.98	21.90	7.04	98.47	7.15	28.63	201.49
1984	894	5,195.40	17.21	4,531.46	24.30	7.81	93.70	8.34	27.89	217.90
1985	894	5,546.40	16.12	4,952.18	26.40	8.54	92.54	9.23	26.61	227.20
1986	894	5,787.90	15.45	4,577.30	23.80	7.89	93.28	8.46	13.06	103.07
1987	894	5,787.90	15.45	4,521.97	21.50	7.80	100.25	7.78	16.97	132.31
1988	888	5,782.40	15.36	4,845.91	21.10	8.36	108.14	7.73	13.53	113.04
1989	888	6,007.00	14.78	5,308.66	22.00	9.15	117.27	7.80	16.15	147.82
1990	888	6,035.80	14.71	5,464.76	22.06	9.42	120.59	7.81	25.00	235.55
1991	888	6,549.60	13.56	5,759.98	22.62	9.93	122.46	8.11	18.04	179.16
1992	888	6,549.60	13.56	5,696.80	22.19	9.82	124.59 #	7.88	18.08	177.58
1993	1018	8,796.10	11.57	5,667.25	23.92	9.77	136.81 #	7.14	16.00	156.34
1994	1074	9,175.00	11.71	6,319.69	20.28	10.90	146.51 #	7.44	15.82	172.37
1995	1194	9,630.00	12.40	6,134.52	18.47	10.58	209.75 #	5.04	16.60	175.57
1996	1448	10,944.00	13.23	6,538.73	17.67	11.27	221.31 #	5.09	18.65	210.25
1997	1819	11,635.40	15.63	7,430.88	18.70	12.81	241.73 #	5.30	18.27	234.07
1998	1861	12,067.02	15.42	8,951.61	21.52	15.43	240.01 #	6.43	12.24	188.91
1999	1909	12,335.56	15.48	10,367.95	25.53	17.88	246.16	7.00	17.45	311.93
2000	1909	13,196.30	14.47	11,317.11	25.33	19.51	243.37	8.00	27.36	533.86
2001	1931	13,459.00	14.35	10,381.03	22.14	17.90	254.36	7.00	23.48	420.25
2002	1931	14,702.06	13.13	10,248.04	21.10	17.67	255.54 #	6.91	25.00	441.73
2003	1931	15,132.37	12.76	9,419.02	19.10 *	16.24	261.86	6.20	28.00	454.71
TOTAL				152,335.67		262.65				5,570.12

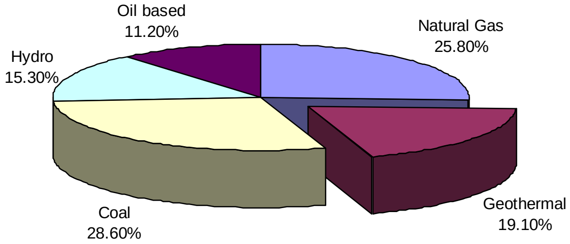

Figure 2. Power generation mix, 2003

These efforts included work-overs of a number of existing wells in 2003 and 2004, involving cleaning of silica scale from wellbores and, in some cases, perforation of identified production zones. Upgrades of the steam gathering system were also made to improve system efficiency, flexibility, and reliability. These upgrades included construction of new steam gathering and separation facilities employing "cascading brine scrubbing" and hot brine injection lines on the Matalibong Ridge, and upgrades of existing separators at wellsites 1, 3, 5, 6, and 7a (Kitz and Toreja, 2002). Injection capacity in the southeast portion of the field was also increased through construction of additional injection lines, commissioning of idle edgefield wells as injectors, and scale cleanouts of existing injection wells.

Since 1979 up to end 2002, Tiwi geothermal field has generated a total of 39,179 GWh of electricity (Table 4). In that time, the field has experienced many problems common to geothermal reservoirs (i.e., cold water influx, corrosion, scaling, HCl corrosion, etc.). PGI, in cooperation with the state-owed National Power Corporation (NAPOCOR), has responded to and largely overcome these problems (Sussman et al., 1993; Sugiaman et al., 2004). Despite these challenges, a financial study conducted by ELC-Electroconsult for the Asian Development Bank showed that the net cash flows including avoided oil cost had paid for the project investments by 1986. As of late 2003, 48 production wells and 16 injection wells were in service, with production coming mainly in the Kapipihan, Matalibong and Bariis areas. Since expansion possibilities are limited, PGI's resource strategy is focused on maximizing the existing generation potential of the field and ensuring its long-term sustainability. Pilot tests of infield injection into the superheated Matalibong steam zone, and downhole neutralization of acid-sulfate fluids in well Bariis-8 (Gardner et al., 2001) have indicated potential for augmenting steam production without drilling new wells.

2.2 Makiling-Banahaw (Mak-Ban), Laguna

The Mak-Ban field is located about 70 km south of Manila in the Laguna Province of Luzon Island and is also operated by PGI (Figure 1). It is a mature geothermal field having been in commercial production since 1979. Although currently second in the Philippines to the Greater Tongonan field in terms of installed capacity, Mak-Ban leads all Philippine fields in terms of total lifetime generation with more than 51,455 GWh (Table 4).

Recent resource summaries of this prolific resource stress its relatively small size (about 7 km^2); however, high porosity (average of more than 10%), and high resource temperatures (up to 640^{o}F) are factors that have allowed the field to be successfully produced at a high power density (Golla et al., 2001). A key factor in sustaining production is significant recharge from the relatively lower permeability regions surrounding the main production area (Nordquist et al., 2004). Geochemical studies have helped identify the major avenues of dilute (1400 ppm Cl) but relatively hot recharge to the main production zone, and attempted to quantify the relatively minor impact on field cooling (Abrigo et al., 2004). Mak-Ban has been comparatively free of resource problems, aside from injection breakthrough in the early years of operation (e.g., Sta. Maria et al., 1995). This problem was resolved by moving the large edgefield injection load of that area further to the west. Recent tracer tests using thermally stable naphthalene sulfonates (Rose et al., 2002) have shown that the present injection system now provides relatively little recharge to the production area.

As of late 2003, 71 production wells and 15 injection wells were in service. PGI's resource strategy is focused on upgrading steam supply to match the requirements of the power plants once the ongoing rehabilitation is completed toward the end of 2005. New steam wells are being targeted in the deeper portions of the resource to tap hotter, higher pressure conditions and to better ensure the field's long-term sustainability. Mak-Ban gross generation ranged from 2248 GWh in 2001 to 1657 GWh in 2003 (Table 4). The declining trend was due mainly to limited government investment in make-up drilling and declining plant availability. Further production declines in 2004 were due to ongoing plant rehabilitation efforts. Make-up drilling resumed in 2002 and 2003 with 6 new wells added to the field. All of these wells were drilled to >2800 meters vertical depth in order to tap the deep, high-pressure reservoir. In 2004 an additional 4 to 6 wells will be drilled to reach the steam supply requirement. Commissioning of several idle wells near the margin of the current production area as "trickle injectors" will be used as a low-cost method to meet the increased re-injection requirement of the field.

Rehabilitation of Plants A and B (Units 1 through 4) commenced in 2004 and should be complete by late 2005. As part of this rehabilitation, the rated capacities of Units 1 through 4 will be increased to 63 MW each. With Units 5 and 6 (55 MW each) and Units 9 and 10 (20 MW each), it is expected that Mak-Ban will then be operating at a full plant baseload of 402 MW.

Table 2. Geothermal wells drilled from 2000-2003

Purpose	Wellhead	Number of Wells Drilled				Total Depth	
	Temperature	Electric	Direct	Combined	Other	(km)	
		Power	Use		(specify)		
Exploration[1)]	(all)	3				4.3	
Production	>150° C	18				47.2	
	150-100° C						
	<100° C						
Injection	(all)	7				11.55	
Total		28				63.1	

2.3 Tongonan, Leyte

The total installed capacity of the Leyte geothermal field which is operated by PNOC-EDC stands at 722.68 MWe (Table 3). This is broken down as follows:

- 112.5 MWe Tongonan I power plants are operated by NAPOCOR;
- 219.48 MWe Tongonan II BOT power plants are composed of the 141.98-MWe Upper Mahiao Binary and the 77.5-MWe Malitbog power plants; and
- 390.70-MWe Tongonan III BOT power plants which come from the 3 x 6.5-MWe Tongonan I Topping Cycle, 2 x 6.50-MWe Mahanagdong A Topping Cycle, 1 x 6.50-MWe Mahanagdong B Topping Cycle, 1 x 16.70-MWe Malitbog Bottoming Cycle, 3 x 60-MWe Mahanagdong A&B and the 2 x 77.5-MWe Malitbog power plants.

Topping cycle plants are installed in Tongonan I, Mahanagdong A and Mahanagdong B Sectors, while bottoming cycle in the Malitbog Sector. Tongonan II power plants commissioned in 1996 export electricity from Leyte to Cebu via an AC submarine cable, while Tongonan III commissioned in 1997 transports power from Leyte to Luzon via DC submarine cable.

The power plants in Leyte have been in full operation since May 1998. Consequently, Tongonan's electricity gross generation of 3,111.98 GWh in 1998 escalated by as much as 200% as against the previous year's 998.36 GWh. As of December 2003, Tongonan power plants have generated a cumulative total of 35,223.3 GWh of electricity. Gross generation for 2003 of 4,745.6 GWh was slightly lower (by 300 GWh) than the year previous because of minor fluid and operational problems encountered, but these have been dealt with accordingly (Table 4). All ongoing activities in Leyte are geared towards sustaining the steam supply for the power plant requirements. These activities include drilling of make-up and replacement wells, working-over old wells with reduced outputs and injection capacities, and dealing with corrosion, erosion and mineral scaling problems.

2.4 Palinpinon, Southern Negros

The Palinpinon geothermal field, which is also operated by PNOC-EDC, is located in Southern Negros on the southern flanks of a young volcanic complex. A total of 43 production and 26 reinjection wells have been drilled in the field. Power plants with a combined capacity of 192.5 MWe are installed in Palinpinon. In Palinpinon-I (Puhagan), the installed capacity is 112.5MWe, and the plants have been in operation since 1983. Palinpinon-II is divided into three (3) modular power plants (Table 3): Balas-balas (20 MWe), Nasuji (20 MWe) and Sogongon (40 MWe). As of December 2003, all the above plants have generated a cumulative total 16,244.8 GWh of electricity (Table 4).

Power plant related problems have been encountered in the Palinpinon-I units, causing prolonged shutdowns and reduced loads. To date, however, all units are fully operational.

Plans are underway to expand the capacity of Palinpinon-II by adding another 20-MWe power plant. Idle and throttled production wells from the Nasuji sector will be utilized and optimized for the additional plant. PNOC-EDC is in the process of discharging stand-by wells and constructing new production and injection pads for the expansion project. Target commissioning year of this planned 20-MWe power plant is 2006.

2.5 Bacon-Manito (Bacman), Albay/ Sorsogon

The Bacon-Manito Geothermal Production Field (BGPF) is also operated by PNOC-EDC and is located in the provinces of Sorsogon and Albay in the Bicol Peninsula (Figure 1). A first stage geothermal power plant development of 110-MWe in the Palayang Bayan sector (Bacman I) was commissioned in 1993. In 1994, a 20-MWe extension in the Cawayan sector (Bacman II) was commissioned followed by the additional 20-MWe in the Botong sector, which was commissioned in May 1998. To date, a total of 24 production and 12 reinjection wells have been drilled in Bacman. As of December 2003, the power plants have delivered a cumulative total of 5,939.2 GWh of electricity (Table 4). A number of mechanical and other problems related to the power-generating turbines have plagued the Bacman-I power plant for several years now. Most of the time, Bacman-I was run with only one (1) unit operating, thus the low electricity output of the power plant. On the other hand, power plant operations in both Cawayan and Botong sectors have been relatively smooth, and steadily supply power to the Luzon grid.

Operation of the Manito Livelihood Geothermal Project inaugurated in 1998, has been suspended by PNOC-EDC. The Project is a joint undertaking by the DOE, National Power Corporation (NPC), National Electrification Administration (NEA), PNOC-EDC and the Local Government of Manito. It is located at Pawa, Manito, Albay within the Bacon-Manito Geothermal Power Project. The drop in market demand as well as major turbine problems have caused the shelving of the livelihood project.

2.6 Mindanao, North Cotabato/Davao

The country's sixth geothermal production field, the Mindanao field, is also operated by PNOC-EDC. It is located on the northwest slopes of Mt. Apo in the northern part of Cotabato and Davao provinces (Figure 1). It is made up of two power plants – Mindanao-I commissioned in 1996 with an installed capacity of 54.24 MWe, and Mindanao-II put on line in 1999 with the same installed capacity of 54.24-MWe. As of December 2003, total accumulated generation of both plants was 4,493.7 GWh of electricity (Table 4).

Existing idle production wells are planned to be used for an expansion project beyond the existing Mindanao-I and -II power plants. In the event that this project is realized, Mindanao will have more than enough steam to supply another 20-MWe plant.

2.7 Other Areas

2.7.1 Northern Negros, Negros Occidental (PNOC-EDC)

The Northern Negros Geothermal Project covers an area of 4,310.84 hectares situated in Mambucal, Negros Occidental Island in the Visayas Region. A projected 40 MWe of geothermal capacity is expected to be commissioned in 2006. To date, a total of ten (10) exploratory wells have been drilled in Northern Negros by PNOC-EDC. Current activities in this field are fluid collection and reinjection system (FCRS) and power plant construction.

2.7.2 Palinpinon-II Optimization (PNOC-EDC)

As mentioned earlier, construction activities for the 20-MWe Palinpinon-II optimization project will be underway by late 2004. The new plant will utilize excess steam from existing Nasuji wells, and separated brine will be piped to the current Nasuji RI sink. No new well drilling is programmed for the expansion. Like in Northern Negros, commissioning date is early 2006.

3. EXPLORATION AND DEVELOPMENT

The country's geothermal resource potential from 35 identified areas is estimated at 4,335 MW. Given this vast amount of potential reserves and the anticipated increase in energy demand, the Philippines has embarked on aggressive exploration activities to bring the total geothermal capacity to at least 3,131 MW and become the largest geothermal energy producer in the world in 2013.

As part of its Renewable Energy Policy Framework (REPF), the Philippine Department of Energy has undertaken in March to July 2004, the so-called Philippine "GEOTHERMAL-1", a contracting round aimed at attracting investments in 10 prospective geothermal areas (Figure 3). The technical details of the prospective areas and the contracting round activity are described in the Geothermal Contracting Round-1 Brochure published by the Department of Energy (2004). Short description of these prospective areas are as follows:

3.1 Manito-Kayabon, Albay/Sorsogon

The Manito-Kayabon is a sector of BGPF located in the Bicol Peninsula. BGPF is currently producing 110 MWe from its Palayang Bayan sector (Bacman-1) and 20 MWe each from its Cawayan and Botong sectors. The Manito-Kayabon sector is the northernmost cluster of resource blocks in BGPF. Stored heat calculations of this sector point to a total power potential of 51.2 MWe.

Table 3. Utilization of geothermal energy for electric power generation.

Locality	Power PlantName	Year Com-missioned	No. of Units (MWe)	Status1)	Type of Unit2)	Total Installed Capacity MWe	Annual Energy Produced 20033) GWh/yr	Total under Constr. or Planned MWe
1. Tiwi, Albay	Plant A	1979	2 x 55.00		1F	330	442	
	Plant B	1980	2 x 55.00	Unit 4 (N)	1F			
	Plant C	1982	2 x 55.00		1F			
2. Mak-Ban,	Plant A	1979	2 x 55.00		2F	425.73	1,538.00	
Laguna	Plant B	1980	2 x 55.00		2F			
	Plant C	1984	2 x 55.00		2F			
	Binary I	1994	2 x 3.00		B			
	Binary II	1994	2 x 3.00		B			
	Binary III	1994	1 x 3.00		B			
			1 x 0.73		B			
	Plant D	1996	2 x 20.00		1F			
	Plant E	1996	2 x 20.00		1F			
3. Tongonan,	Tongonan I	1983	3 x 37.50		2F	722.68	4,745.57	
Leyte	Upper Mahiao							
	GCCU	1996	4 x 34.12		Combined Cycle			
	OEC	1996	1 x 5.50		B			
	Malitbog	1997	3 x 77.50		1F			
	Mahanagdong A	1997	2 x 60.00		1F			
	Mahanagdong B	1997	1 x 60.00		1F			
	Tongonan I - Topping	1997	3 x 6.50		Combined Cycle			
	Mahanagdong A - Toppi	1997	2 x 6.50		Combined Cycle			
	Mahanagdong B - Toppi	1997	1 x 6.50		Combined Cycle			
	Malitbog - Bottoming	1998	1 x 16.70		Combined Cycle			
4. Palinpinon,	Palinpinon I	1983	3 x 37.50		1F	192.5	1,257.12	
Negros Oriental	Palinpinon II							
	Okoy	1993	1 x 20.00		1F			
	Nasuji	1994	1 x 20.00		1F			
	Sogongon	1995	2 x 20.00		1F			
5. Bacon-Manito,	Bacman I	1993	2 x 55.00		1F	151.5	456.68	
Sorsogon / Albay	Bacman II							
	Cawayan	1994	1 x 20.00		1F			
	Botong	1998	1 x 20.00		1F			
	Manito Lowland	1998	1 x 1.50		1F			
6. Mindanao,	Mindanao I	1995	1 x 54.24		1F	108.48	812.51	
North Cotabato	Mindanao II	1997	1 x 54.24		2F			
7. Northern								40
Negros Geothermal								
Project								
8. Palinpinon								20
Optimization								
Project								
Total						1,930.89	9,419.02	60

Table 4. Geothermal energy gross generation in GWh

YEAR	TIWI	MB	MB OR	MB MOD	TONG I	TONG II/III	PAL I	PAL II	BM I	BM II	MANITO	M1GPF	M2GPF	TOTAL
1977					1.00									1.00
1978					3.00									3.00
1979	441.20	191.74			4.00									636.94
1980	957.62	1,080.31			5.00		1.92							2,044.85
1981	1,892.89	1,645.71			11.00		19.59							3,569.19
1982	1,999.98	1,533.80			9.00		21.08							3,563.86
1983	2,318.10	1,547.60			164.00		52.28							4,081.98
1984	2,343.00	1,774.60			257.27		156.59							4,531.46
1985	2,045.00	2,247.67			419.53		239.98							4,952.18
1986	1,873.41	2,018.18			430.99		254.72							4,577.30
1987	1,470.72	2,247.10			485.09		319.06							4,521.97
1988	1,828.54	2,199.70			439.46		378.21							4,845.91
1989	2,006.35	2,431.17			453.00		418.14							5,308.66
1990	1,956.76	2,538.24			514.00		455.76							5,464.76
1991	2,039.11	2,451.83			512.07		756.97							5,759.98
1992	1,997.45	2,437.54			522.79		739.02							5,696.80
1993	2,116.89	2,143.89			562.65		790.64		53.18					5,667.25
1994	2,013.60	2,265.23	29.06		587.73		744.91	125.06	478.24	75.86				6,319.69
1995	1,722.83	1,815.56	33.12	78.94	637.13		639.67	492.10	619.48	95.69				6,134.52
1996	1,524.82	2,056.47	52.23	411.45	614.73	58.33	653.92	523.27	523.91	119.60		0.00		6,538.73
1997	1,661.76	2,022.73	44.36	500.45	498.56	499.82	613.13	598.83	545.78	163.43		282.03		7,430.88
1998	1,321.35	2,062.33	23.83	510.72	506.91	2,605.07	421.18	423.87	381.84	329.37	0.12	365.02		8,951.61
1999	960.06	1,961.00	21.97	576.62	739.80	3,861.84	663.24	547.17	372.51	273.58	0.06	390.10	208.74	10,367.95
2000	1,233.52	1,952.91	48.23	587.38	628.10	4,090.71	762.08	608.90	313.60	307.59	0.06	390.09	393.94	11,317.11
2001	454.32	1,673.66	40.87	573.82	686.73	4,392.05	669.70	636.12	235.83	234.59	0.00	396.01	387.33	10,381.03
2002	513.02	1,489.54	37.51	438.16	699.63	4,586.69	664.43	592.69	115.72	242.73	0.00	429.37	438.55	10,248.04
2003	486.21	1,302.70	21.80	333.01	730.87	4,014.70	600.76	659.78	267.79	188.89	0.00	394.68	417.83	9,419.02
TOTAL	39,178.51	47,091.21	352.98	4,010.55	11,124.04	24,109.21	11,036.98	5,207.79	3,907.88	2,031.33	0.24	2,647.30	1,846.39	152,335.67

D:\YEAR-END\TABLES\TOTALGEN 03.XLS\EDP

Notes:

MB	- MAKBAN	PAL	- PALINPINON
MB OR	- MAKBAN ORMAT (BINARY)	BM	- BACMAN
MB MOD	- MAKBAN MODULAR	M1GPF	- MIDANAO 1 GEOTH. PROD. FIELD
TONG I	- TONGONAN I	M1GPF	- MIDANAO 2 GEOTH. PROD. FIELD
TONG II/III	- TONGONAN BOT POWER PLANTS		

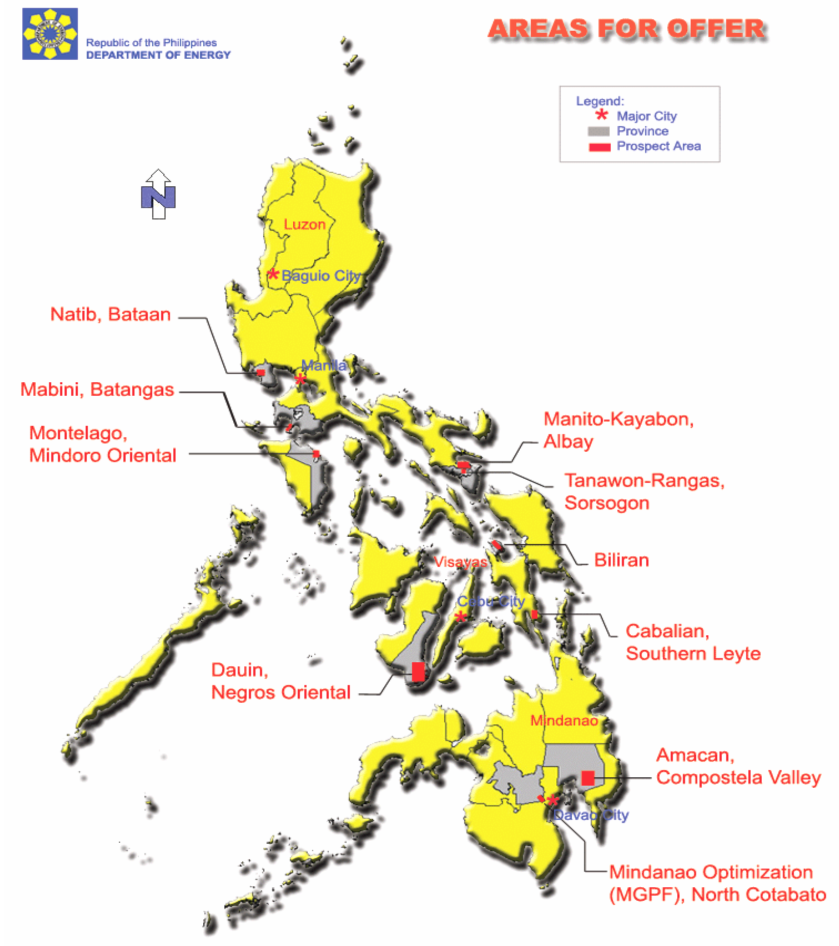

Figure 3. Prospective geothermal areas offered for private sector investment

3.2 Tanawon-Rangas, Albay/Sorsogon

The Tanawon-Rangas is another sector of the BGPF. Based on the reservoir model of the BGPF, Tanawon and Rangas sectors are considered well within the southern boundary of the BGPF's main upflow region. Two deviated wells drilled in Tanawon, TW-1D and TW-2D in year 2000 yielded power potentials of 8.9 MWe and 3.4 MWe, respectively, for a total of 12.3 MWe. Potential geothermal reserve estimates indicate a total power potential of about 22.4 MWe and 23.5 MWe for Tanawon and Rangas, respectively.

3.3 Mindanao Geothermal Production Field Optimization, North Cotabato

The Mindanao Geothermal Production Field (MGPF) which is found on the northwest flank of Mt. Apo, North Cotabato is divided into 3 sectors from southeast to northeast – Sandawa, Marbel and Matingao. In view of the current excess steam and brine in MGPF, an optimization plan was conceptualized and results of the study dictate that additional power generation facilities of at least 20 MWe could be realized.

3.4 Mt. Cabalian, Southern Leyte

Drilling of the second exploratory well in Mt. Cabalian, Southern Leyte was done in 2003. The well was spudded from a new pad and deviated to the NNE to test the resistivity anomaly defined by the magneto-telluric survey conducted earlier. Two (2) permeable zones were intersected by the well in the open hole section; the lower feed zone has an estimated temperature of about 280°C. During flow test, however, the hotter zone did not appear to contribute to the fluid discharge. Instead, fluid temperature was almost constant at 245-250°C reflective of the temperature in the upper horizon (Bayon and Sanchez, 2004).

The second exploratory well confirmed the presence of an exploitable geothermal system in Mt. Cabalian. Future plans for the area include acidizing and re-discharging well SL-2D, and drilling a third exploratory well to target the center of the geophysical anomaly.

3.5 Biliran Island

Geothermal exploration in Biliran started in 1979 up to 1981. Three prospective targets were delineated, namely, Vulcan, Kalambis and Panamao areas. In 1982, three exploration wells (BN-1, BN-2 and BN-3) were drilled to test the geothermal potential of Vulcan area. Results of exploration drilling indicated that the geothermal resource area in Biliran ranges from 14 to 16 km^2. The heat source is a magmatic body beneath the Vulcan-Libtong area where acid fluids with temperature of ≈ 332 ^{o}C are presently upflowing as intersected by well BN-3. Wells BN-1 and BN-2 established the presence of neutral-chloride brine at exploitable depths.

3.6 Amacan, Compostela

The Amacan prospect is characterized by impressive thermal features including fumaroles, solfatara and hot springs that are widely distributed. Significant data had been gathered in the Amacan geothermal prospect from 1975 to 1985. The deep exploratory well (AM-1) in Amacan encountered measured temperature of 265 ^{o}C at 2700 m depth but with low permeability. The areas with the largest potential for geothermal development are located around Ugos Dome, Amacan and Gopod North Solfataras.

3.7 Dauin, Southern Negros

The Dauin geothermal prospect is situated about 6 kms southeast of the Southern Negros Geothermal Production Field (SNGPF). Between 1973 and 1981, surface exploration surveys were conducted in Dauin. As a result of these surveys, two exploration wells (DN-1 and DN-2) were drilled in 1982-83. Based on available technical data, a geothermal convective system is postulated in Dauin area which is distinct from the brine system in Palinpinon. The upflow in Dauin probably lies beneath the center of the MT anomaly located between Mt. Talines and Cuernos de Negros.

3.8 Natib, Bataan

Surface geological, geochemical and geophysical surveys at the Natib geothermal prospect in Bataan were completed in 1987. Two deep exploratory wells NA-1D and NA-2D were drilled in 1989. Wells NA-1D and NA-2D encountered a reservoir temperature of 270 ^{o}C at depths of 2751 m and 2916 m, respectively, based on alteration mineralogy. While both wells have low permeability to sustain commercial discharge, the hottest portion of the geothermal system which is in between Natib dome and the Tigulangin and Mamot springs show great potentials.

3.9 Mabini, Batangas

The Commission on Volcanology (COMVOL) initiated the detailed geoscientific investigation of the Mabini geothermal prospect in the late 1970's. Succeeding surveys led by PNOC-EDC commenced in the 1980's. Based on PNOC-EDC's assessment, Mabini is an intermediate-temperature geothermal resource with reservoir temperature of at least 180 ^{o}C. It was postulated that the upflowing neutral-pH alkali chloride fluids are associated with the Pleistocene Mt. Binanderahan volcanics. It is envisaged that this prospect is suitable for direct utilization or binary system power generation.

Montelago, Oriental Mindoro

Reconnaissance survey at the Montelago eothermal prospect, in Oriental Mindoro started in 1982. This was followed by detailed geological, geochemical and geophysical studies in 1988 until 1989. An integrated geoscientific assessment revealed that the prospect hosts a hot, neutral-pH, alkali-chloride, water-dominated system associated with a cooling igneous body beneath Mt. Montelago. The potential resource area of 3-5 km^2 has been delineated with a reservoir temperature of 180-200 ^{o}C. It is envisioned that this prospect can be developed for either direct utilization or binary system of electricity generation.

4. INDUSTRY OPPORTUNITIES AND CHALLENGES

While the Philippines may be one of the pioneers and in the forefront of world geothermal energy production, the fact remains that only two entities, PGI and PNOC-EDC, are currently involved in steamfield exploration and development. Benito (1998) discussed the main reasons that hinder private sector investment in geothermal energy development such as the royalty tax imposed on the net proceeds from geothermal operations.

New laws have been passed that may have impacts or effects on geothermal energy development, investments as well as may prolong the gestation period of geothermal projects:

(1) Republic Act (RA) no. 8371 or the Indigenous Peoples Rights Act of 1997 promotes, protects and recognizes the rights of cultural communities and indigenous

peoples to their ancestral domains to ensure their economic, social and cultural well being. It also recognizes the applicability of customary laws governing property rights or relations in determining the ownership and extent of ancestral domains;

(2) RA No. 8749 or the Philippine Clean Air Act of 1999 has made environmental protection and sustainability a critical factor in geothermal energy development and investment; and

(3) RA No. 9136 or the Electric Power Industry Reform Act of 2001 that introduced reforms in the electric power industry and segregated power generation, transmission and distribution of electricity. A wholesale electricity spot market was also created that would facilitate competition in generation and supply of electricity.

The Government is also looking into the increased non-power uses of geothermal energy. Direct use of geothermal energy is limited to agricultural drying (Table 5). There are plans to utilize geothermal drying for spa and balneological aplications which are being coordinated with hot spring resort owners and developers. The Government through the DOE has entered into a Memorandum of Agreement for this purpose with the Department of Tourism and Department of Health.

The DOE has also formulated the country's Renewable Energy Policy Framework (REPF) in 2003 (Department of Energy, 2003). The REPF embodies the DOE's objectives, goals, policies and strategies as well as programs and Table projects to further develop the renewable energy (RE) sector within the perspective of the sector's supply and demand prospects and current stage of development given its critical role in the country's energy future. With the expected inflow of private sector investments as well as the adoption of modern and innovative technologies in exploration and development, the DOE is targeting the installation of an additional 1,200 MW of geothermal capacity within the next ten years, resulting to an increase of about 60 percent from the 2002 level of 1,931 MW. The attainment of this target is being pursued as a strategy to maintain, if not improve, the Philippines' ranking as the second largest geothermal producer in the world.

In support of the REPF, the Government has been advocating the passage of a new Renewable Energy Law that would institutionalize the policies, incentives and other government regulatory arrangements that would make renewable energy competitive with other alternative energy resources.

5. CONCLUSION

The Government is moving towards a policy environment that will facilitate the transition of the country's energy sector to a sustainable system by developing RE as a viable and competitive fuel option. The shift from fossil fuel sources to renewable forms of energy such as geothermal energy is the key element in ensuring the success of this transition. In fact, the global community strongly affirmed this concept based on its commitment towards implementing a sustainable production and consumption framework in the recently held World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa.

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Table 5. Geothermal direct heat uses

Use	Installed Capacity[1] (MWt)	Annual Energy Use[2] (TJ/yr = 10^{12} J/yr)	Capacity Factor[3]
Individual Space Heating[4]			
District Heating [4]			
Air Conditioning (Cooling)			
Greenhouse Heating			
Fish Farming			
Animal Farming			
Agricultural Drying[5]	1.63	26.93	0.52
Industrial Process Heat[6]			
Snow Melting			
Bathing and Swimming[7]	1.67	12.65	0.24
Other Uses (specify)			
Subtotal	3.3	39.58	0.39
Geothermal Heat Pumps			
TOTAL	3.3	39.58	0.39

[4] Other than heat pumps
[5] Includes drying or dehydration of grains, fruits and vegetables
[6] Excludes agricultural drying and dehydration
[7] Includes balneology