Proceedings World Geothermal Congress 2010
Bali, Indonesia, 25-29 April 2010

Resource Assessment of Philippine Geothermal Areas

Michael S. Pastor, Ariel D. Fronda, Vanessa S. Lazaro and Noel B. Velasquez

Geothermal and Coal Resources Development Division, Energy Resource Development Bureau

Department of Energy, Energy Center, Merritt Road, Fort Bonifacio, Taguig City, Philippines

mikepastor68@yahoo.com / mpastor@doe.gov.ph

Keywords: assessment, resource

ABSTRACT

A geothermal resource estimate of Philippine geothermal areas potential for power generation was made using the volumetric reserve estimation. The method involves the calculation of the thermal energy contained in a given volume of rock and water and then the estimation of how much this energy might be recoverable. Following a general definition on geothermal resource classification, the identified geothermal resources in this paper were classified as proven, probable and possible.

With a present installed capacity of 1,902.32 MWe, we have only reached around 50% of our identified resources. The estimate shows that there are still considerable geothermal resources available for development. Indicative geothermal capacity addition will come from development and expansion of new and existing fields and power plant optimization.

1. INTRODUCTION

The Philippines being located in the Pacific "ring of fire" is abundant of geothermal resource potential. Geothermal exploration was started in 1962, and the first large commercial power plants came on line in 1979. Geothermal energy supplied about 18.4% of the country's total power requirement during the year 2006 as shown in Figure 1.

The installed capacity shown in Table 1 as of end March 2009 stands at 1,902.32 MWe.

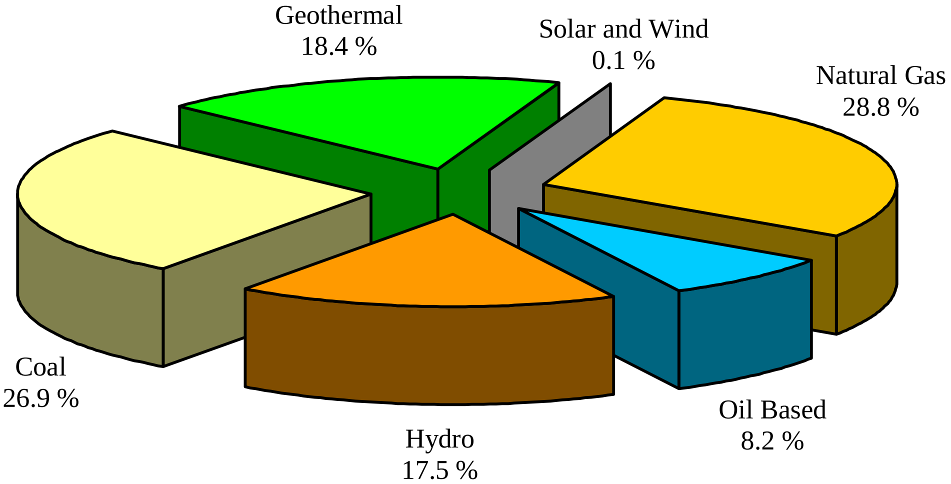

Figure 1: 2006 Power Generation Mix

Table 1: Installed Capacity

PROVINCE	LOCATION	INSTALLED CAPACITY (MWe)
Laguna	Mak-Ban	457.70
Albay	Tiwi	234.00
Albay/Sorsogon	Bac-Man	150.00
Negros Occidental	Northern Negros	49.00
Negros Oriental	Palinpinon	192.50
Leyte	Tongonan	715.89
Cotabato	Mt. Apo	103.23
Total		1,902.32

The Philippine Government through the Department of Energy administers the operations of thirteen (13) geothermal service contract areas as of December 2008 shown in Figure 2. Three (3) Geothermal Service Contracts in 1) Biliran, 2) Mabini, Batangas, and 3) Amacan, Compostela Valley were awarded last 2008 under the Philippine Energy Contracting Round (PECR).

The country's geothermal resource potential was estimated at around 4,000 MWe. Given this vast amount of potential reserves, continuous exploration and development are being undertaken where several prospect areas have been surveyed and re-evaluated.

This paper aims to give an estimate of the potential of Philippine geothermal fields and prospects using volumetric method that can be used as guide for further exploration works. It must be noted that several assumptions are used in the estimate and should be accordingly modified and improved as more data are evolved.

2. PRINCIPLE

Geothermal resource assessment as defined by Muffler, 1981, is the estimation of the thermal energy in the ground, referenced to mean annual temperature, coupled with an estimation of the amount of this energy that can be extracted economically and legally at some reasonable future time.

Several methods are used for geothermal resource assessment. These include 1) surface thermal flux, 2) volume, 3) planar fracture, and 4) magmatic heat budget. Muffler and Cataldi, 1977; 1978 concluded that the volume method appears to be the most useful because of the following:

1. It was applicable to virtually any geologic environment;
2. The required parameters could in principle be measured or estimated;
3. The inevitable errors were in part complensating; and
4. The major uncertainties were amenable to resolution in the foreseeable future.

The volume method involves the calculation of the thermal energy contained in a given volume of rock and water and then the estimation of how much of this energy might be recoverable. It is calculated by the following equation:"

$$E = E_r + E_f \qquad (1)$$

$$= V \cdot \rho_r (1-\Phi) \cdot C_r \cdot (T - T_r) + V \cdot \rho_f \cdot \Phi \cdot C_f \cdot (T - T_r)$$

where E, E_r, E_f, C_r, C_f , ρ_r, ρ_f, Φ, T, T_r, V are total energy available for utilization, energy contained in the rock, energy contained in the fluid, rock specific heat in kJ/kg °C), fluid specific heat in kJ/kg °C, density of rock in kg/m^3, density of fluid in kg/m^3, porosity, rock and fluid temperature in °C, reference (abandonment) temperature in °C, reservoir volume in m^3.

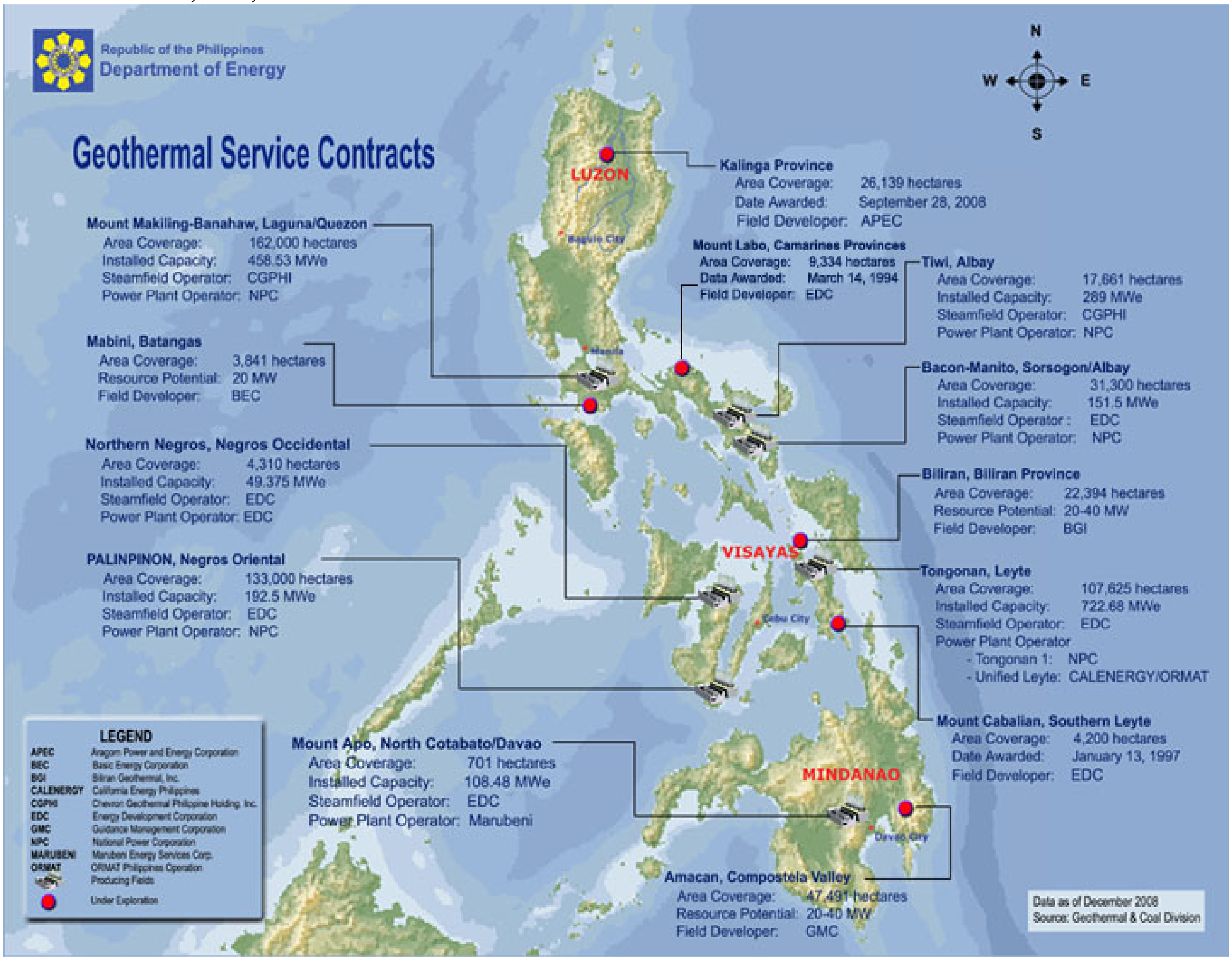

Figure 2: Geothermal Service Contract Map

The reserve potential is estimated by:

Reserve (MWe)= (2)

$$\frac{\text{Energy Available} \cdot \text{Recovery Factor} \cdot \text{Conversion Efficiency}}{\text{Plant Life} \cdot \text{Load Factor}}$$

Volumetric method essentially estimates the amount of heat contained in a given reservoir (rock+fluid) volume and determines the power capacity over a fixed period by assuming recoverability and conversion efficiency factors. The nature of the technique calls for many assumptions, which can result in overestimation of the reservoir capacity. Some of the variables that can contribute to reserve overestimation include thickness of reservoir, extent or size of the resource and rock porosity.

3. SELECTION OF PARAMETERS

To determine the potential of a geothermal resource, several parameters such as reservoir size, reservoir temperature, rock and fluid properties are obtained from different prospect areas. Moreover, recovery factor, conversion efficiency, load factor and plant life are assumed to come up with the estimated reserve potential. Below are the assumptions used for the above parameters.

3.1 Reservoir Geometry

The reservoir geometry is defined by boundaries delineated by geophysics, geology and distribution of surface thermal manifestation. The reservoir volume is computed by multiplying the estimated area by the assumed reservoir thickness.

For prospects where geophysical surveys have been conducted, the area was approximated based on interpreted geophysical resource boundary. For prospects with no geophysical survey, the area of assumed of reservoir was based on extent of distribution of thermal manifestation.

A reservoir thickness of 1,500 meters was assumed this being the mean thickness in most of the geothermal fields in the world.

3.2 Reservoir Temperature

A simple average of the minimum and maximum temperature is used in the estimates. In cases where drilling have been conducted, measured temperatures from the well is used. In cases where there is no drilling, reservoir temperature is estimated using available conventional geothermometers.

Experience has shown that in some Philippine geothermal fields, measured temperature from wells exceeded the values obtained from conventional geothermometry calculations.

The reference temperature is somewhat arbitrary. A value of 180 ^{o}C for the reference (abandonment) temperature is normally used. This is reckoned to be the minimum temperature, which will support a steam column with sufficient wellhead pressure.

3.3 Rock Properties

Porosity of rock is defined as the volume of pore space measured in percentage of rock volume while rock density is defined as the sum of the volume fraction of each mineral times its density. Rock porosity ranges from practically nothing in hard crystalline rocks to a maximum of 80% in loose unlithified shales or mudstones. These properties may be measured from drill cores. In the calculation, assuming a a homogenous porous medium, a fixed value of 0.05% for rock porosity and 2,700 for rock density is used.

Rock specific heat, on the other hand, can be taken from laboratory measurements of core samples. A number of values for various rock types and conditions are available from tables. A specific heat value of 0.9 kJ/kg ^{o}C is assumed in the calculation.

3.4 Fluid Properties

The specific heat and density of water were taken from the steam table at the average reservoir temperature.

3.5 Recovery Factor

Since not all the heat stored in the reservoir is thermally recoverable, recovery factor is usually assumed. The recovery factor is the fraction of heat that can be commercially extracted. Muffler and Williams, 1976, proposed a theoretical recovery factor, which is linearly dependent on the field porosity. Using a 5% rock porosity, assumed recovery factor is 15%.

3.6 Conversion Efficiency, Load Factor and Plant Life

Conversion efficiency is dependent on the reservoir temperature and the plant design. In practice, this ranges from 0.1 to 0.2 for single flash plants. In the calculation, a value of 0.1 is used for conversion efficiency.

The plant load factor is inherent in the design and utilization plan for the power plant. For a single flash plants, a long term load factor of 0.8 to 0.9 is typical, McNitt, et. al., 1982. In the calculation, a conservative value of 0.75 is used for load factor. A plant life of 25 years was assumed.

The various parameters and assumptions are summarized in Table 2. These parameters and assumptions are used to calculate an initial estimate of the potential reserve of Philippine geothermal fields and prospects using the volumetric method.

Table 2: Reservoir Parameters use in Resource Estimate

Parameters	Assumption
Area (km^2)	Variable
Thickness (km)	1.5
Reservoir Temperature (^{o}C)	Variable
Reference Temperature (^{o}C)	180
Rock Density (kg/m^3)	2,700
Rock Specific Heat (kJ/kg ^{o}C)	0.90
Rock Porosity	0.05
Fluid Density (kg/m^3)	792
Fluid Specific Heat (kJ/kg ^{o}C)	Variable
Recovery Factor (%)	15
Conversion Efficiency (%)	0.1
Load Factor (%)	0.75
Plant Life (years)	25

4. GEOTHERMAL RESOURCE CLASSIFICATION

Following a general definition on geothermal resource classification, the geothermal resources were classified as proven, probable and possible.

4.1 Proven Resource

Proven resource refers to the calculated economically recoverable geothermal energy contained in the geothermal reservoir identified by delineation/development drilling, geological, geochemical and geophysical evidences. A proven resource should have been adequately defined in three dimensions by surface exploration and the drilling and testing of wells.

Proven resources are those found in producing fields and areas of advance exploration. The estimated potential is taken from wellhead potential.

4.2 Probable Resource

Probable resource refers to the estimated geothermal energy available based on exploration drilling, geophysical, geochemical and geological evidences that may be extracted economically at some reasonable time. Probable resources are in prospect areas of advance exploration.

4.3 Possible Resource

Possible resource refers to the estimated geothermal energy that may be available based on geophysical, geological and geochemical evidences. Possible resources are mostly in prospect areas that have impressive thermal manifestations and intermediate to high estimated reservoir temperature.

5. RESULTS

A geothermal resource estimate for power generation of Philippine fields and prospects using the volumetric method was prepared. A total of 3,377 MWe was estimated with positive resource at 1,796.99 MWe, probable resource at 530 MWe and possible resource at 1,050 MWe. A summary of the geothermal resource estimate is shown in Table 3.

Table 3: Geothermal Resource Estimate, in MWe

PROVINCE	PROSPECT	PROVEN	PROBABLE	POSSIBLE
Cagayan	Cagua		25.00	40.00
Benguet	Acupan		10.00	10.00
	Daklan		30.00	30.00
Benguet-Ifugao	Buguais-Tinoc			80.00
Kalinga	Batong-Buhay			120.00
Mt. Province	Mainit			80.00
Bataan	Natib		15.00	185.00
Batangas	Mabini			20.00
Laguna	Mak-Ban	429.10		
	Maibarara	30.00		
Oriental Mindoro	Montelago			20.00
Albay	Tiwi	198.80		
	Manito		20.00	
Albay/ Sorsogon	Bac-Man	134.10		
Sorsogon	Rangas-Tanawon		40.00	
Camarines Sur	Mt. Labo	10.90	65.00	
Negros Occidental	Mambucal	45.30	50.00	
	Mandalagan-Silay			120.00
Negros Oriental	Palinpinon	217.70		
	Dauin		30.00	
	Lagunao		60.00	
Leyte	Tongonan	639.60		
	Mahagnao		30.00	40.00
	Bato-Lunas			60.00
Southern Leyte	Cabalian		20.00	30.00
Biliran	Biliran		25.00	15.00
Zamboanga del Sur	Lakewood			80.00
Misamis Occidental	Ampiro			30.00
Compostela Valley	Amacan		60.00	30.00
Cotabato	Mt. Apo	91.49	50.00	
Surigao del Norte	Mainit			60.00
Total		1.796.99	530.00	1.050

Most of the clearly identifiable geothermal fields in the Philippine are now developed and/or coming into commercial operation. Javellana, S. P., 1995, suggests that there is reasonable basis to place the over-all geothermal reserve in the Philippines, which is viable for electric power generation in the range of 3,000 MWe to 4,000 MWe. This is similar to the estimate made by Vasquez, et. al. in 1999 on the basis of identified resources and data on regional heat flow. They have estimated that the potential for geothermal power of undeveloped field ranges from a firm 500 MWe to a possible 1,000 MWe.

The result of the present estimate shows a total geothermal resource potential of around 3,000 MWe. Probable resource was estimated at 500 MWe which approximates the minimum estimate of Vasquez, et. al., 1999 while possible resource is 1,050 MWe. It must be noted that several assumptions were used in the estimate and should be accordingly modified and improved in the subsequent assessments as more data are evolved in the process of continued exploration and development.

6. CONCLUSION

The results show that there is still a substantial geothermal resource available for development. Vasquez, et. al., 1999, expect additional geothermal generation in the future to come from a mix of new field developments, expansion of existing production steam fields, increased utilization efficiencies and application of technology advances.

Geothermal capacity addition for the planning period 2007-2014 is around 700 MWe. This will come from development and expansion of new and existing fields and power plant optimization.

To realize this, the Philippine Department of Energy in its bid to becoming the world leader in geothermal energy will carry out the following strategies to advance its exploration, development and utilization:

- Conduct further assessment of geothermal prospective fields to identify sites that can be offered in the Philippine Energy Contracting Round (PECR)
- Monitor closely the exploration and development of awarded geothermal areas
- Conduct reservoir and production studies for optimized utilization of geothermal resource in existing power plants
- Pursue optimization of low temperature geothermal energy
- Enhance policy framework in the development of geothermal energy through policy initiatives.

According to Vasquez, et. al., 1999, the future is bright for geothermal energy in the Philippines.

REFERENCES

Balmes, C. P.: Reservoir Temperature Estimates for Geothermal Prospect Areas covered in the National Inventory of Geothermal Resource Project: A Summary, Internal Memorandum. Geothermal Division, Energy Resource Development Bureau, Department of Energy, Fort Bonifacio, Taguig, Metro Manila (2000).

Buning, B. C.: Geothermal Resource Assessment and Reservoir Simulation: an Overview, *The Philippine Geologist*, Volume 33, No. 4, (1984).

Del Rosario, R. A.: Philippine Geothermal Areas, Geothrmal Division, Energy Resource Development Bureau, Department of Energy, Fort Bonifacio, Taguig, Metro Manila (1999).

Delfin, F. G.: Exploration Methods for High-Enthalpy Geothermal Resources, in: IAEA Regional Group Training on Isotope Geochemistry for Exploitation of Geothermal Energy Resources, Philippines (1997).

Javellana, S. P.: Country Update on Philippine Geothermal Development and Operations, 1991-1995, Proceedings: World Geothermal Congress, 1995, Italy (1995).

Muffler, L. J. P.: Geothermal Resource Assessment, in: Geothermal Systems: Principles and Case Histories, edited by L. Rybach and L. J. P. Muffler, (1981).

Pastor, M. S.: Philippine Geothermal Energy Resource Estimate, Internal Memorandum, Geothermal Division, Energy Resource Development Bureau, Department of Energy, Fort Bonifacio, Taguig, Metro Manila (1997).

Philippine Energy Plan, 2007-2014, Department of Energy, Republic of the Philippines, Energy Complex, Merritt Road, Fort Bonifacio, Taguig City (2007).

Sussman, D., Javellana, S. P. and Benavidez, P. J.: Geothermal Energy Development in the Philippines: An Overview, Geothermics, 22, (1993), 353.

Ulgado, A. F.: Update on Inventory of Philippine Geothermal Wells, Internal Memorandum, Geothermal Division, Energy Resource Development Bureau, Department of Energy, Fort Bonifacio, Taguig, Metro Manila (2002)

Vasquez, N. C., Javellana, S. P. and Ferrer, H. P.: Present and Future Geothermal Development in the Philippiness-Part 1, IGA News No. 37, July-September 1999, (1999)

Vasquez, N. C., Javellana, S. P. and Ferrer, H. P.: Present and Future Geothermal Development in the Philippiness-Part 2, IGA News No. 38, October-December 1999, (1999)